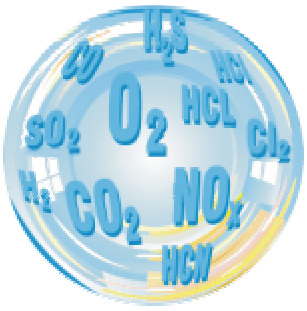


FLUE GAS ANALYSER
GA-12 *plus*

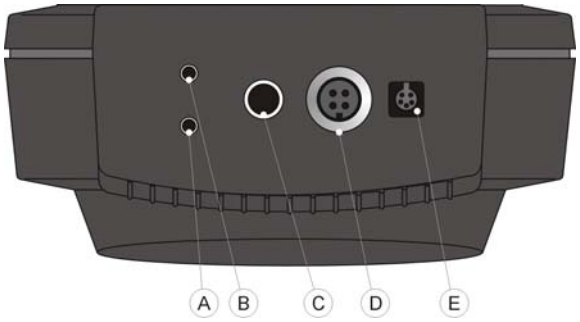
Operating manual

02/ 2006
V 0.05

1 DESCRIPTION OF GA-12PLUS ANALYSER.

GA-12*plus* is a portable flue gas analyser extending the series of our well-known **GA-12** analysers. There can be up to four gas sensors installed in the device. The basic version of the device is designed for measuring the concentration of the following gases: O_2, CO, NO. Optionally NO_2, SO_2 or H_2S sensor can be installed as the last, fourth sensor.
To guarantee the accuracy of measurement the velocity of the gas flow through the analyser is stabilized. The efficient pump additionally makes it possible to measure the content of soot in the flue gases.
The analyser can be equipped with either one or two pressure sensors. In the first case it is unavoidable to switch the pump off in order to measure the pressure. In the second case, measurement of the pressure can be done simultaneously to gas measurements and does not interrupt them.

Description of the connections



GA-12*plus* analyser – bottom view:

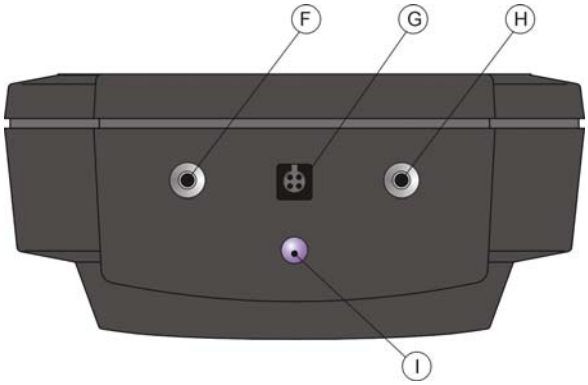
A – basic pressure sensor inlet (+

B – gas inlet

C – gas outlet

D – gas probe socket

E – HT (humidity + temperature) probe socket



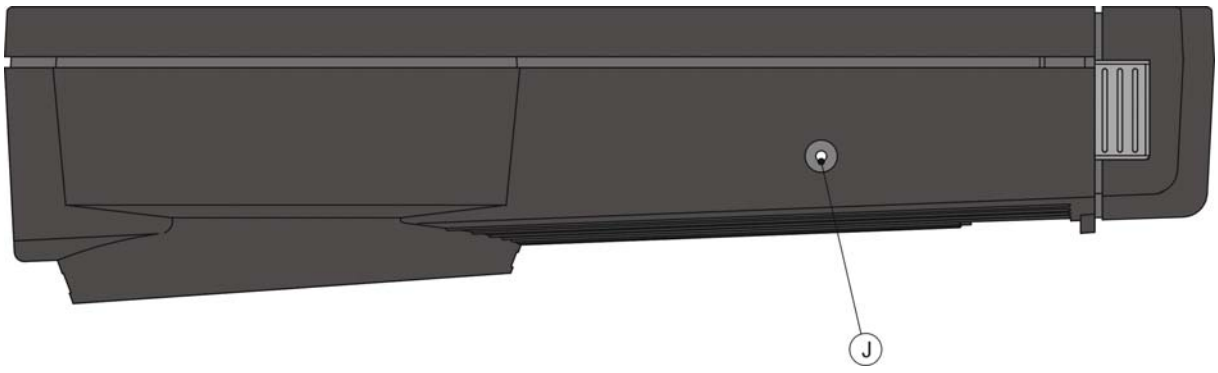
GA-12 *plus* analyser – top view

F – differential pressure sensor inlet (-) – only in the version with two pressure sensors

G –RS-232C interface socket

H – differential pressure sensor inlet (+) – only in the version with two pressure sensors

J – IR emitter for communication with printer



GA-12 *plus* analyser – side view

J – mains adapter socket

2 MAINTANANCE

Electrochemical cells

To extend the lifetime of the cells and guarantee the accuracy of the measurements the points listed below should be followed.

- The cells should not be exposed to the influence of concentrations exceeding the measurement range.
- All the cells can react unpredictably to chemicals whose components are not typically found in flue gases. For this reason the equipment should not be cleaned with chemical solvents. The vapour produced by such solvents can lead to destabilisation and even permanent damage to the cells should it penetrate into the gas chamber.
- The cells have a voltage applied to them even when the analyser is switched off. It is therefore advised to make sure that there are always charged batteries in the analyser.
- It is advised not to switch the analyser off before the gas system is free of flue gases.
- The analyser which is not to be used for some time should be kept in a cool place. This will reduce the wear on the cells.

Gas channel

An in-line filter with the condensate separator protects the gas channel of the analyser from condensed water contained in fumes. The filter element will become dirty with use and should be changed when necessary. The water that condenses in the condensate separator should be emptied as required.

Battery

The device uses Li-Ion 3.6V battery.

If the instrument is not in use for some time, then the battery will nevertheless be consumed since certain circuits are permanently in use. For this reason the state of charge of the batteries should be checked monthly at least.

Service

Due to the fact that electrochemical cell parameters change with time it is necessary to carry out a periodical service connected with either the calibration of the electrochemical cells or their replacement. We recommend that service be carried out every 12 months or after the device have worked for 200 hours.

Errors

The instrument has a self-check function. Should an error occur it will be shown on the screen ***Control list***.

Switching off after use

The lifetime of the electrochemical cells depends on the use of the instrument. Wear on the cell is greater at higher gas concentrations and during longer measurements. This leads to a slow deterioration of the cell.

For this reason the instrument should not be switched off until all the flue gases have been purged from the system with clean air and the instrument has been allowed to run in air for a few minutes.

3 OPERATION

3.1 Use of the keyboard

The analyser's appearance.

Description of the keys

- Left function key. Carries out the function shown on the display whilst the instrument is switched on.
- Right function key. Carries out the function shown on the display whilst the instrument is switched on.
- Centre function key. Switches the instrument on. Carries out the function shown on the display when the instrument is switched on.
- Calls the printing options.
- Switches the instrument off.

On a results screen calls the ***Chart*** menu, in text mode shifts the cursor to the left

- On a results screen calls the option ***Menu***, in text mode shifts the cursor to the right.
- Moves the cursor upwards in a menu. In text mode increases the value. On a results screen chooses the next screen.

Moves the cursor downwards in a menu. In text mode decreases the value. On a results screen chooses the next screen.

Entering numbers

Numbers are entered as follows:

and move the cursor backwards or forwards to the digit to be changed.

and - increases/decreases the value of the marked digit.

3.2 Basic operation

Getting started

Connect the individual parts of the instrument:

- connect the probe.
- ensure that the gas outlet is not blocked.

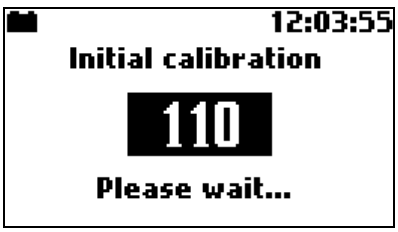
Switching on

Check the filter before switching on. Clean or replace as necessary.

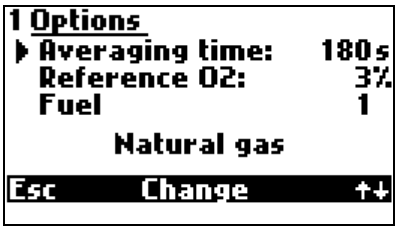
Zero calibration

The instrument performs a zero calibration immediately after being switched on.

During zero calibration the probe must be outside the flue gas channel.

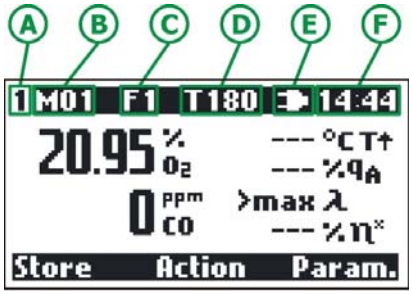


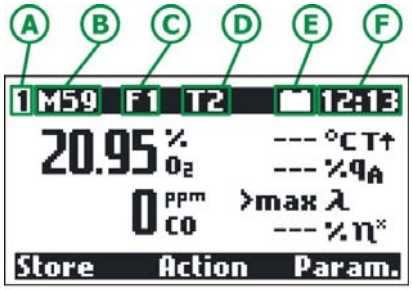
After the zero calibration has been completed the ***Options*** open automatically. Here the measuring parameters can be checked or changed. See also point Measurement parameters.



3.3 Results screens

The function keys ***Data*** or ***Esc*** will automatically call up the results screen from any point. Below there are two examples of results screens





Explanation:

The Info bar

The Info bar is at the top of the screen. The fields have the following meanings:

- **A.** The number **1** stands for the first results screen. Four results screens can be defined. These can be called up using the up and down keys.
- **B.** **M01/M59** shows how many memory spaces are still available. In the screen on the left-hand side one report is still empty. In the second window 59 reports are still empty.
- **C.** **F1** shows the chosen fuel. The instrument contains 6 fixed and 4 programmable fuels. These are numbered 0...9.
- **D.** **T180/T2** shows the set averaging time. This can be programmed in fixed steps between 2 and 180 seconds. If the period of time measured since the starting of the instrument is shorter then the chosen averaging time, this field will refer to the current averaging time.
- **E.** **Plug/battery** The symbol of the plug means that the instrument is being supplied with the energy from the outside, the symbol flashes until the charging of the battery is completed; battery stands for the inner battery of the instrument and also shows the state of charge of the battery.
- **F.** **14:44/12:13** shows the current time as set in the analyser.

The menu bar

The menu bar at the base of the display shows the use of the function keys. The possibilities are explained under the point Menu.

Results

All the results of measurements and calculations are shown as averaged values. Averaging time is chosen by the user under ***Options*** from 2 – 6 – 10 – 20 – 30 – 60 – 120 – 180 seconds.

The user can define the content of the individual results screens. The necessary software, PCGA12plus.exe, is to be found on the utility disk.

Here is a list of all measured or calculated variables that can be shown on the results screens:

- Volumetric concentration of the gases: O_2, CO, NO_x, CO_2 and SO_2 or NO_2 (depending on the analyser's configuration)
- Undiluted volumetric concentration of the gases CO_u, NO_{xu}, NO_u and or NO_{2u}
- Mass concentration of the gases:
  A. absolute: CO_m, NO_{xm}, NO_m and SO_{2m} or NO_{2m}
  B. relative, related to a defined level of rest oxygen: CO_{rel}, NO_{xrel}, NO_{rel} and SO_{2rel} or NO_{2rel}
- Emission of the gases related to the energy value: ECO, ENO_x
- Combustion parameters: qA, Sco, ETA, ETA*, Lambda, TI, EA
- Temperatures of the combustion gas (T↑), the air (T↓) and inside of the analyser.
- Draught/differential pressure and flow rate
- Relative humidity of the gas in the analyser.
- Battery voltage

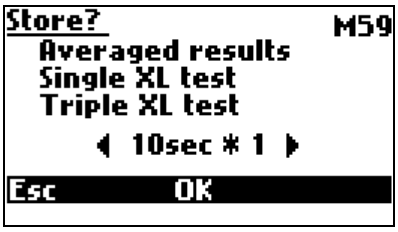
4 MENU

From the results screens the following options can be activated with the keyboard:

- ***Store*** – Left function key.
- ***Action*** – Centre function key.
- ***Options*** – Right function key.
- ***Chart*** – Arrow left.
- ***Menu*** - Arrow right.
- ***Print*** – Key with a printer shown on it.
- ***Switch off*** – Pressing the round, red key will switch the instrument off completely.

4.1 Storing results

The option ***Store*** can be reached from any results screen by pressing the left function key. The results on the screen are stored in a buffer and remain there until stored permanently.
The results are stored in the form of reports. This is a collection of all the results.
If the report should also include the chimney draught, or the soot content then this measurement must be carried out before storing the results.
Opening the option calls up the following screen:



Results can be stored in three different ways:

Averaged results

The averaged results will be stored. The averaging times that can be chosen from 2, 10, 20, 30, 60, 120 and 180 seconds.

Single XL test

The averaged results will be stored. The term XL (extra long) is used for the formation of especially long averages. XL test time can be set via ***Options 2*** screen or on current screen by the use of the keys:

and .

Available times: 10sec, 20sec, 30sec, 1min, 2min, 5min, 10min, 15min, 20min, 30min.

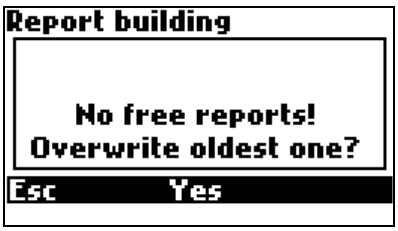
Triple XL test

This will automatically store three consecutive single XL Tests.

During storage of XL test, battery charge icon is replaced with the number of current test (X1, X2, X3) and the clock counts down the time, till the end of test. During the XL test the analyser beeps every two seconds.

In the top-right corner the number of available reports is shown.

If the memory of analyser is full, and no more reports can be stored, the following screen is shown when storing is attempted.



ESC

The storing of results will be stopped and the instrument returns automatically to the results screen.

YES

The oldest report(s) will be deleted and the new one(s) stored instead.
If the results are to be stored, then the instrument will request a customer number (identification number of the report). This number will appear on the report.

When the number has been entered and confirmed with ***OK***, the following screen will appear momentarily.

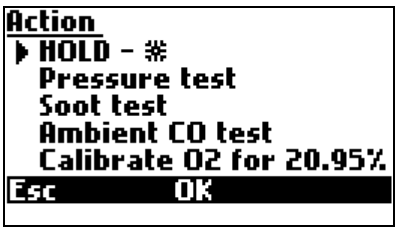
This completes the storing of the results and the instrument will return automatically to the results screen. The number that appears on the confirmation screen **#00063** is the serial number of the report registered by the analyser. The reports counter can be restarted by the use of the GA12plus.exe software.
There is a possibility of stopping and shortening the XL test.

If the function key  is pressed durinng the single XL test or during the X1 test (the first test of triple XL test) then the measurement is stopped and result is not stored. If the function key  is pressed during the X2 or X3 test, the measurement is disrupted but its result will be stored.

During the XL test, its result can be viewed. Pressing the  key during displaying the results screen, for a few seconds, the XL test results will be shown (averaged for the period of time since the beginning of the test).

4.2 Action

Pressing the centre function key on the results screen will open ***Action*** screen.



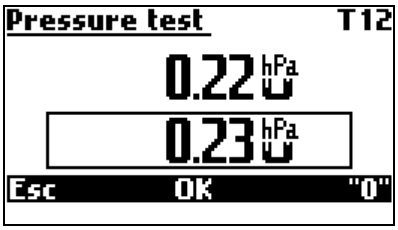
HOLD - ❄

The present measurement values are frozen and the screen will spring automatically to the frozen values. Pressing the centre function key again will end the freezing of the values. Hold mode is signalised by flashing ❄ sign over the central function key.

Note: Holding the measurement can hold the pump. Settings are made by the use of the option *„Pump stop when hold*" from PCGA12plus.exe programme. If this option is ticked, every time the test is held the pump is turned off until it's restarted.

Pressure test

The following screen will appear:



The upper displayed value is the currently measured pressure value. The value in the frame is the value stored for a printout or a report.

T12 in the right upper corner is the set averaging time. If the period of the time since the beginning of the measurement is shorter than the chosen averaging time, the current averaging time of the test will be displayed.

0 key is used for the zeroing of the sensor. It is important that during this process there is no pressure applied to the sensor.

OK key stores the measured pressure value (it will appear in the frame at the bottom of the display).

The value is stored until the next print of the results is done or the next report is stored, after which it is erased.

The pressure test is carried out differently for the instruments equipped with optional differential pressure sensor and the instruments without one.

The analyser without the optional pressure sensor.

Only the single-inlet pressure measurement is available. This is carried out via the inlet situated at the bottom of the instrument's case. During the pressure test the pump must be switched off (it is automatically switched off when the screen shown above appears on the display). The pressure test can be carried out only when the ***Pressure test*** screen is displayed. The flow velocity test carried out with the use of Pitot tube is not available.

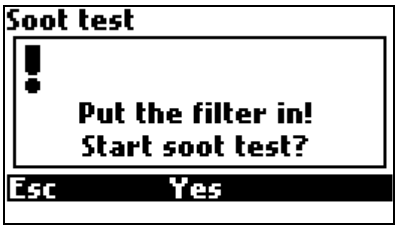
The analyser with the optional differential pressure sensor

If the analyser is equipped with the optional differential pressure measurement sensor (the inlets at the top of the analyser case) the differential pressure measurement is available. The pressure measurement is carried out simultaneously to all the other measurements. It is not necessary to hold the pump and the flow velocity test can be carried out with the use of Pitot tube.

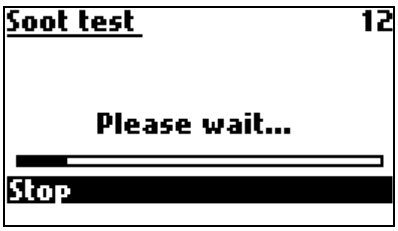
Soot test

The soot test can be carried out provided that the analyser is being supplied with power from the mains. The power of the pump powered by the inner battery is not enough to carry out the test. Also the warming up of the pump (unavoidable when carrying out the soot test) requires that the instrument be powered by the mains adapter. If the instrument is not powered by the mains adapter the following screen will appear:

The user should plug the mains adapter to the instrument. After choosing the option ***Soot test*** the user will be asked to put the filter in.



After confirmation the measurement will begin.

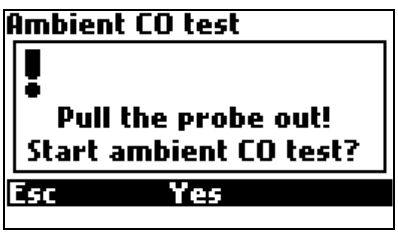


The measurement can be disrupted with function ***Stop***.
Once the measurement is finished the following screen will appear.

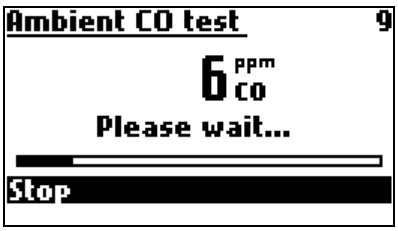
With the use of arrow keys the value taken from the comparative scale should be filled in and confirmed with ***OK*** key. The instrument will go back to regular measurement.

Ambient CO test

This option is used to measure the ambient CO level. After this option is chosen the user will be asked to remove the probe from the stack.



After confirmation the measurement will begin.



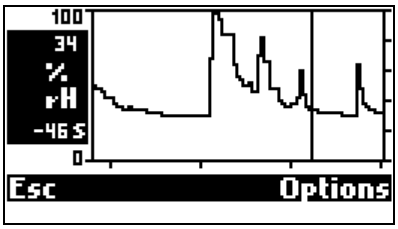
The measured value of ambient CO will be stored and will appear in the next report.

Calibrate O2 for 20.95 %

In order to increase the accuracy of long-period measurements **GA-12** *plus* has the possibility of calibrating the O_2 sensor on demand. Before choosing the command ***Calibrate O2 for 20.95 %*** the probe should be removed from the stack and the readings should be stabilised. Calibration of the O_2 sensor can be combined with the zeroing of all the other gas sensors. Suitable settings can be made via PCGA12plus.exe programme.

4.3 Chart

The instrument can display the measurement results for the last 190 seconds. The most recent value is on the right-hand side of the chart. The arrow left/right keys are used to scroll the marker enabling one to read the exact value at each point of the chart.



the values on the left have the following meanings:

- Maximum value of the Y axis (here 100).
- Current value or, when the marker is activated, the marker value (here 34).
- The unit (here %). This appears automatically with the variable.
- The variable (here rH). The arrow up/down keys can be used to scroll through the variables.
- Marker time (here –46s). This means the marker stands on the value that was recorded 46 seconds earlier.
- Minimum value of the Y axis (here 0)

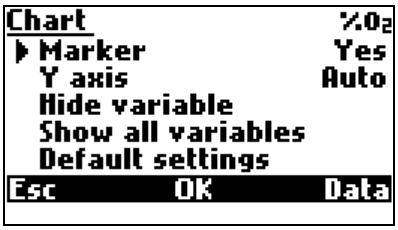
The menu bar:

ESC

Leaves the ***Chart*** and returns to the results screen.

Option

This opens the window for the ***Chart settings***. The following screen appears:



Marker

Switches the marker on or off.

Y Axis

The scale system for the Y-axis can be set. These are the options:

- Auto (automatic scale) – the instrument chooses according to the measured values.
- Manual – can be set by the user with the PCGA12plus.exe programme.
- Full – done according to the measurement range of the variable

Hide variable

After confirmation with ***OK*** the variable will no longer be shown on the chart. Can be re-activated using ***Show all variables*** or with the PCGA12plus.exe programme.

Show all variables

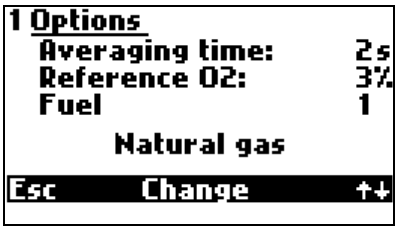
After confirmation with ***OK*** the instrument will show all measured and calculated variables on the chart.

Default settings

After confirmation with ***OK*** the instrument will show some important measured and calculated results: O2, CO, ETA, Lambda, Tgas.

4.4 Measurement parameters

The right function key will access ***Options*** from the results screens.
The following screen appears:



Averaging time

The averaging times ranging from 2 to 180 seconds can be set using the arrow left/right key.

Reference oxygen

Using arrow left/right keys or the function key ***Change*** averaging oxygen can be set choosing from the range 0-13% O_2.

Note: If option "ÖNORM" or "Use O_{2ref} from fuel data" was ticked in service programme PCGA12plus.exe there is no possibility to change the reference oxygen in the instrument, this value is adopted from defined fuel parameters.

Fuel

The following 6 fuels can be set using the function key ***Change*** or the arrow left/right:

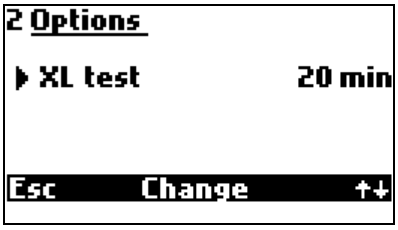
0- Light oil
1- Natural gas
2- Town gas
3- Coke-oven gas
4- Liquid gas
5- Extra light oil

There are also 4 memory locations (6-9) for 4 fuels specific to the user which can be freely programmed by the user. This is carried out using the PCGA12plus.exe programme.
There is a possibility to replace the first six standard fuels with the set of fuels recommended by ÖNORM. To use the Austrian set of fuels tick option ***ÖNORM*** in PCGA12plus.exe programme.
Using of the Austrian set of fuels will automatically switch the mode of the manual reference oxygen O_{2ref} choice off (the value will always be taken from fuel's parameters).

The Austrian fuels:

0- Erdgas
1- Flüssiggas
2- Heizöl HEL
3- Heizöl EL
4- Holz
5- Kohle

Using the ↑↓ function key displays the following screen:



XL test

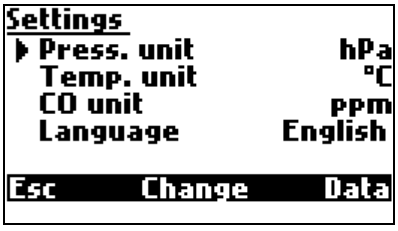
Using the key ***Change*** or arrow left/right key allows setting the XL test time. The following values are available:

10sec - 20sec - 30sec - 1min - 2min - 5min - 10min - 15min - 20min - 30min

4.5 Menu

From the screen results the ***Menu*** option is available after the use of the key: ▷.

4.5.1 Settings



The ***Settings*** Menu can be used to change following parameters:

Pressure unit

There are four pressure units available: hPa, Pa, mmH_2O and inH_2O.

Temperature unit

Two units are available: °C and °F.

CO unit

There are two units available: % and ppm. % is available only if the sensor with a widened CO range (10%) has been installed.

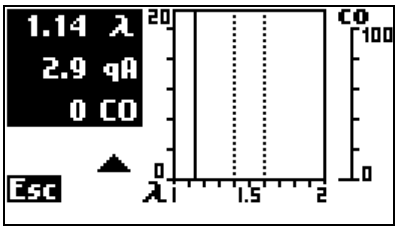
Language

The instrument is pre-programmed with a number of languages. There is also a possibility of downloading an additional language through PCGA12plus.exe programme. In case of an accidental language change (when having problems with finding the proper setting in the analyser's menu) it is possible to restore the default language by keeping the key pressed when starting the analyser. The choice of the default language is made in PCGA12plus.exe programme.

4.5.2 Burner regulation

This option allows the combustion process in a burner to be visualised. Three variables that define the combustion process are shown graphically.
These are:

CO – carbon monoxide concentration
qA – stack loss
Lambda – Excess air



All three appear on the screen at the same time. This means that the dynamic connection between all the variables is easily seen and the air inlet can be adjusted for optimal combustion.

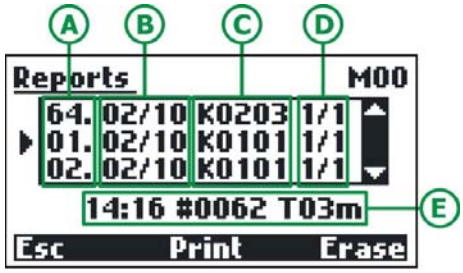
- qA is shown as a diagonal straight line that will move up or down when adjustments are made. This is shown in the range 0…20 %.
- Lambda is a vertical straight line, which will move left/right during adjustment. This is shown in the range 1…2.

The user can also set two markers to define the desired range for Lambda. If the Lambda becomes larger then the value defined by the right marker, an arrow on the left-hand side points downwards meaning that the air flow must be reduced. If the λ value becomes smaller then the value defined by the left marker the arrow points upwards meaning that the air flow should be increased.

On the right-hand side of the display the CO concentration indicator is shown (used range: 0 – 100ppm)

4.5.3 Reports

This option is used to administrate the stored reports.



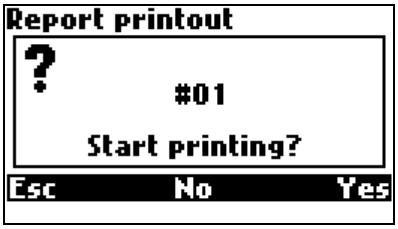
The fields have the following meanings:

A. The report number given to the report within the reports table (1..64).
B. The creation date of the report. Displayed in the format defined in the menu ***Clock***.
C. The customer's number.
D. These numbers inform the user of whether the report is a single one; or the first/second or the third of the three reports of a triple XL test – 1/3, 2/3, 3/3
E. In this field the additional information on the marked report will be displayed. This includes the exact creation time of the report – 14:16, the serial number of the report registered by the analyser #0062 and the averaging time – in this case three minutes.

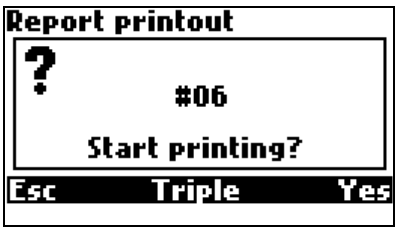
In the right-hand upper corner the information on how many memory spaces are still available is displayed.
Esc returns to the ***Menu***. To erase the report use the ***Erase*** button; the confirmation screen will be displayed.

Pressing ***Esc*** returns to previous menu. Pressing ***Yes*** will erase the chosen report, pressing ***All*** will delete all stored reports.

After pressing the ***Print*** key the following screen will appear:



Using ***Esc*** or ***No*** returns to the previous screen, choosing ***Yes*** starts painting. If the chosen report is a one from the triple XL test report, the following screen is displayed:



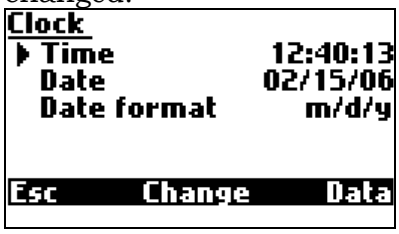
Choosing ***Triple*** causes averaging and printing all three parts of triple report as a whole.

Attention! Check if the printer is on and its receiver is near the upper edge of the analyser.

It is also possible to define the printing format. This can be done only in the window *Print* see point Print**.**

Clock

In the ***Clock*** Menu options the following settings (as shown in the picture) can be changed:



Time

The time displayed by the internal clock can be set.

Date

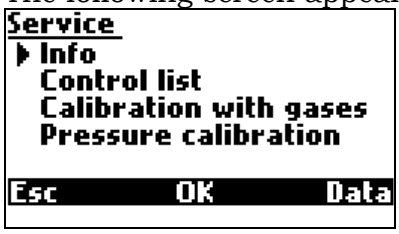
The date indicated by the internal calendar can be set.

Date format

Two date representation formats are available. The user can choose between: **Day – Month – Year** and **Month – Day – Year date** format

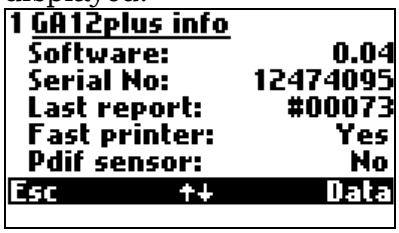
Service

The following screen appears when the option is opened:

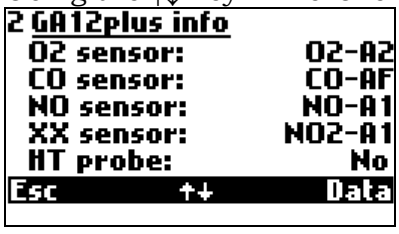


Info

On the ***Info*** screen the information concerning the configuration of the instrument are displayed.

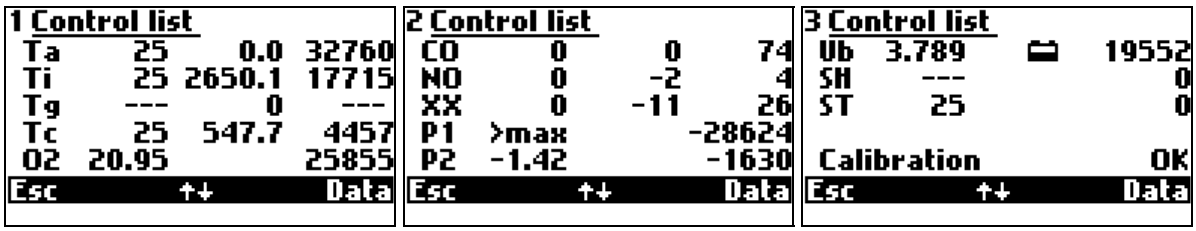


Using the ↑↓ key will evoke the next ***Info*** screen.



4.5.3.1 Control list

The option ***Control list*** shows all measured signals. This is of great use when searching for possible defects. The content of the ***Control list*** is displayed on the three screens numbered 1, 2 and 3.



The ↑↓ key is used to change between the consecutive screens of the ***Control List***.

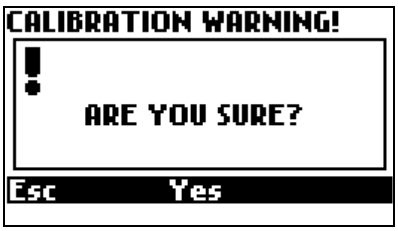
4.5.3.2 Calibration with gases

Calibration with gases is about observing the sensors' reaction to the familiar to the user gas concentration. The access to the calibration is originally blocked at the factory. If so after choosing the option the following screen will appear:

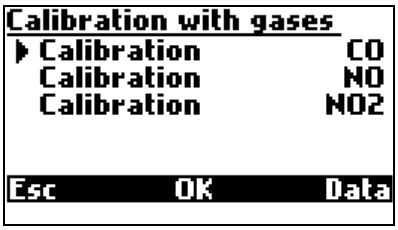
Unblocking the calibration process is possible via the PCGA12plus.exe program.

Each incorrect change of the calibration value will cause an irreversible loss of the previous values thereby the instrument will become of no use for further measurement. The calibration should be therefore carried out only by qualified staff of the service.

Choosing the option ***Calibration with gases*** displays the following screen:

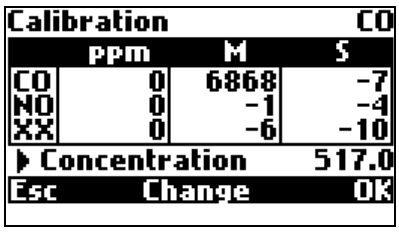


After confirmation the following screen will appear:

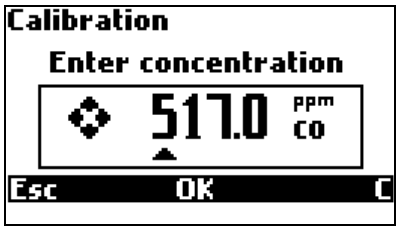


The screen makes it possible to choose between the calibration gases.

The process of calibrating will be presented for CO.



The ***Change*** key evokes the screen used for entering the reference gas concentration value.



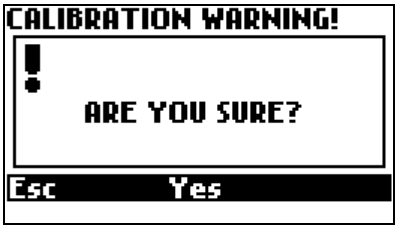
After applying the gas to the instrument it is advisable to wait until stable values appear in the S (signal) column and then to press the OK key. The values from the S column will be saved and stored in the column M (memorized).

4.5.3.3 Pressure calibration

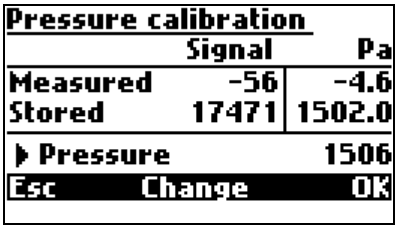
Pressure calibration like gas calibration is available only to service staff. To carry out the calibration process it is necessary to have a precise pressure source.

Each incorrect change of the calibration value will cause an irreversible loss of the previous values thereby the instrument will become of no use for further pressure measurement. The calibration should be therefore carried out only by qualified staff of the service.

After choosing the pressure calibration option the following screen will appear:



After confirmation the following screen will be displayed.



The fields on the screen have the following meaning:

Measured

The signal currently supplied by the pressure sensor and the pressure measured by the instrument.

Stored

The previously stored signal and calibration pressure.

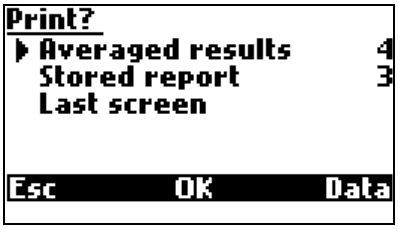
Pressure

Calibration pressure in [Pa].

The calibration process

Apply the calibration pressure to the instrument. With the ***Change*** key fill in the value of the calibration pressure. Press ***OK*** to store the value of the calibration pressure.

4.6 Print



Using the arrow left/right keys for given line will cause the change of the printing format. There are four defaults, set at the factory formats, the other four can be defined by the user with the help of the PCGA12plus.exe program.

Averaged results

The last measured temporary values will be printed.

Stored report

Report printout. After choosing this command the window of administrating the reports will be displayed.

Last screen

The content of the last screen displayed will be printed.

5 BASIC PRINCIPLES OF CALCULATING RESULTS

5.1 Quantities obtained from direct measurements (O_2, CO, NO, NO_2 or SO_2)

The values mentioned above are measured directly by means of independent electrochemical cells. The electrochemical cell indications are proportional to the gas concentration and given in ppm (parts per million) or percents.

5.2 Calculating the concentration of carbon dioxide

The volume concentration of carbon dioxide (expressed in [% vol]) is not obtained by direct measurement, but is calculated on the basis of measured oxygen concentration and the CO_{2max} parameter, characteristic for the given fuel.

$$CO_2 = CO_{2max} \bullet \left(1 - \frac{O_{2meas}[\%]}{20.95\%}\right)$$

5.3 Calculating the concentration of nitrogen oxides NO_X

In addition to nitric oxide NO, combustion gases contain also higher oxides of nitrogen - mainly NO_2.The concentration of nitrogen oxides expressed in [ppm] can be (with a high accuracy) defined as a sum of NO and NO_2 concentrations. It is generally assumed that nitric oxide NO contained in combustion gases makes up about 95% of the total amount of nitrogen oxides NO_X. **GA-12**plus calculates the total concentration of nitrogen oxides NO_X according to the following formula:

$$NO_X[ppm] = \frac{NO[ppm]}{0.95}$$

If the analyser is equipped with NO_2 sensor the NO_x concentration is the sum of NO and NO_2 concentrations taken from the direct measurements.

5.4 Concentration of "undiluted" carbon monoxide CO_u

To make the calculation of the carbon monoxide concentration in combustion gases independent of excess air with which the combustion process is conducted, the idea of "undiluted" carbon monoxide CO_u was introduced. The value of CO_u is calculated according to the formula below:

$$CO_u = CO \cdot \lambda$$

where:

CO - volume concentration CO[ppm]

λ - excess air number

5.5 Absolute mass concentration of gas components

Absolute mass concentration is calculated from the concentration expressed in [ppm] using the factor A according to the following formula (here CO concentration):

$$CO\left[\frac{mg}{m^3}\right] = CO[ppm] \cdot A_{CO}$$

where:

$CO[mg/m^3]$ - absolute CO mass concentration in combustion gas (at standard conditions).

CO[ppm] - absolute CO volume concentration in combustion gas (from measurement).

A_{CO} - correction factor from table below:

Gas	$A\left[\frac{mg}{m^3 * ppm}\right]$
CO	1.250
NO	1.340
NO_x	2.056
SO_2	2.860
H_2S	1.520
Cl_2	3.220

Factors to correct concentration in [ppm] into mass concentration in [mg/m³] (at standard conditions 1013 hPa, 0°C).

Note: mass concentration of nitrogen oxides (NO_x) is calculated by the analyser (according to the standards) using the nitrogen dioxide (NO_2) factor.

5.5.1 Mass concentrations relative to the concentration of oxygen in combustion gases

As well as absolute mass concentration, the mass concentration relative to oxygen concentration in the combustion gases is calculated. The concentration of a given component in relation to oxygen concentration is expressed by the following formula (as an example for CO value):

$$CO_{rel}\left[\frac{mg}{m^3}\right] = \frac{20.95\% - O_{2ref}}{20.95\% - O_{2meas}} \cdot CO\left[\frac{mg}{m^3}\right]$$

where:

CO_{rel} - CO concentration in relation to oxygen expressed in [mg/m3]

O_{2ref} - reference oxygen, conventional parameter (chosen by selecting fuel or entered independently from keyboard) expressed in [% vol]

O_{2meas} - the measured concentration of O_2 in combustion gases expressed in [% vol]

20.95% - oxygen concentration in pure air

CO - the measured concentration of CO in combustion gases expressed in [mg/m3] (absolute mass concentration)

Note: If the measured concentration is less then the reference oxygen then the relative concentration calculated according to the formula would be less than the value of the absolute concentration. Not to lessen the value artificially in such a case - when $O_{2meas} < O_{2ref}$ - relative concentration values are replaced by the analyser with absolute concentration values.

5.6 Calculating combustion parameters

Beside calculating gas component concentrations the analyser calculates some parameters describing the combustion process. The formulas for calculating combustion parameters are empirical formulas. **GA-12**plus analyser calculates the parameters of the combustion process according to the principles predicted by DIN standards.

The most important parameter is the amount of heat convected by combustion gases to the environment - the so-called stack loss $_{qA}$. Stack loss in calculated on the basic of empirical formula known as Siegert's formula:

$$qA = \left(T_{gas} - T_{amb} \right) \bullet \left(\frac{A1}{CO_2} + B \right)$$

where:

qA	- stack loss - the percentage of heat produced in combustion process, which is convected with the combustion gases.
T_{gas}	- flue gas temperature
T_{amb}	- the temperature of the boiler inlet air (it is assumed by the analyser to be the ambient temperature)
CO_2	- the calculated (on the basis of oxygen concentration and CO_{2max}) amount of CO_2 in combustion gases, expressed in [% vol]
A1, B	-Siegert factors characteristic for a given fuel type (see fuels table)

On the basis of the calculated stack loss the analyser estimates the efficiency of the combustion process η (notice the difference between η and boiler efficiency).

$$\eta[\%] = 100[\%] - qA[\%]$$

where:

η	- combustion efficiency

The above formula assumes that the only quantity decreasing combustion efficiency is stack loss. Thus it omits incomplete combustion losses, radiation losses etc. Because of this gross simplification in the formula above it should be remembered that the efficiency calculated in this way can not be treated as precise.
However, efficiency calculated like this is very convenient as a comparable parameter when regulating the furnace. The formula, though simplified, reflects precisely the tendencies of efficiency change, thus it is possible to observe whether the efficiency increases or decreases. It is sufficient information for the regulation process.

It is possible to take into account the efficiency reduction caused by incomplete combustion. This loss is represented by a quantity called the loss by incomplete combustion IL. It determines the percentage of energy loss caused by the presence of flammable gases (in this case mainly CO) in the combustion gases.

$$IL = \frac{\alpha \bullet CO[\%]}{CO[\%] + CO_2[\%]}$$

where:

CO, CO_2 - volume concentrations of CO and CO_2 in the combustion gases

α - the factor specific for a given fuel

Calculating IL enables correction of the previously calculated combustion efficiency. Then the so-called corrected efficiency η* is calculated (the difference between the combustion efficiency η and the loss by incomplete combustion IL) :

$$\eta^*[\%] = \eta[\%] - \mathrm{IL}[\%]$$

The last combustion parameter calculated by **GA-12***plus* is the excess air factor λ. This factor expresses how many times the amount of air supplied to the boiler is larger than the minimum amount which is necessary to burn the fuel completely. The system calculates λ on the basis of the known CO_{2max} value for the given fuel and the measured concentration of CO_2 in the combustion gases using the formula:

$$\lambda = \frac{CO_{2max}}{CO_{2meas}}$$

The above formula may be transformed into the following form:

$$\lambda = \frac{20.95\%}{20.95\% - O_{2meas}[\%]}$$

5.7 Fuel parameters

The basis for determining the quantities describing the combustion process correctly is the knowledge of fuel parameters. **GA-12***plus* analyser stores parameters for a set of fuels. These are called standard fuels. The table below presents parameters for all the standard fuels stored in the analyser's memory.

No	Fuel type	CO_{2max} [%]	A1	B	α	O_{2ref} [%]	Hu [MJ/UNIT]	Unit
1.	Light oil	15.4	0.5000	0.007	52	3	42.70	kg
2.	Natural gas	11.7	0.3700	0.009	32	3	35.90	m^3
3.	Town gas	13.1	0.3500	0.011	32	3	16.10	m^3
4.	Coke-oven gas	10.2	0.2900	0.011	32	3	17.40	m^3
5.	Liquid gas	14.0	0.4200	0.008	32	3	93.20	m^3
6.	BIO-Diesel	15.7	0.4567	0.005	52	3	41.80	kg

Parameters of fuels stored in the memory of GA-12plus analyser.

Table shows the following parameters:

CO_{2max} - the maximum concentration of carbon dioxide in the combustion gas, a quantity specific for a given type of fuel. The parameter determines the amount of carbon dioxide in the combustion gases if the combustion process is carried out with excess air factor equalling 1.

A_1, B - factors which appear in Siegert's empirical formula

α - the factor used to calculate loss caused by incomplete combustion.
It should be assumed
α = 69 for solid fuels
α = 52 for liquid fuels
α = 32 for gaseous fuels

O_{2ref} -reference oxygen - the parameter used to calculate relative concentrations of components

Hu - fuel quality - the amount of energy emitted during complete combustion of 1 kilogram (or $1m^3$ in case of gas) of fuel.

5.8 The influence of fuel parameters on the accuracy of result calculations

As has already been mentioned, **GA-12**plus does not measure the concentration of carbon dioxide, but calculates it from the measured oxygen concentration and the CO_{2max} parameter. On the basis of CO_2 concentration calculated in this way, the stack loss, combustion efficiency and loss by incomplete combustion are calculated. Obviously, the fuel parameters (especially CO_{2max}), have a fundamental influence on calculations of combustion processes. The following results calculated by **GA-12**plus are affected by fuel parameters:

CO_2 contents - depends on CO_{2max}
qA stack loss - depends on CO_{2max}, A1 and B
η and η^* - depends on CO_{2max} , A1 and B
IL loss by incomplete combustion - depends on CO_{2max} and α.

$$\lambda = \frac{20.95\%}{20.95\% - O_{2meas}[\%]}$$

As formula above shows, the value of the excess air factor is independent of fuel parameters. The calculated results of gas quantities (except CO_2) and the results of temperature measurements and power quantities do not depend on fuel parameters either.

Please note that fuel quality HV does not appear in any formula. This parameter does not influence any measurement result shown by **GA-12***plus*.

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