



FLUE GAS ANALYSER GA-21 *plus*

Operating manual

Version: 2.1
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1. INTRODUCTION

Congratulations on your purchase of the microprocessor-controlled flue gas analyser



It is a high quality instrument produced using the latest technical discoveries. The **GA-21 plus** is easy to use. You also have the possibility of using the extra capabilities of this analyser, of examining measurement results, checking service intervals and many others. Please read the operating manual carefully. It contains valuable tips and information for problem-free operation. Regular maintenance will help to keep your analyser ready for use at all times.

1.1. Use of this operating manual

Keep this manual with the analyser **GA-21 plus**, and take it with you when carrying out measurements. Here is a short description of the sections of this manual.

2. Maintenance

This section contains important information designed to keep your analyser working and to save you time and trouble.

3. General information

This describes the most important characteristics of your new analyser.

4. Construction

A knowledge of the hardware of the analyser will help you to use the instrument correctly and to avoid unnecessary down-time.

5. Operation

This section explains the use of the analyser with detailed descriptions of the various functions. It is important to read the sections **5.1** and **5.2** first. The other sections can be read when required.

2. MAINTENANCE

2.1. Gas sensors

The following points are important for maximising the operational life of the cells and achieving measurements without errors:

- do not exceed the rated concentration;
- all the gas cells may react unpredictably to the presence of substances which are not usually found in flue gases. For this reason, the analyser may not be cleaned with chemical solvents. If organic solvents enter the gas chamber, the cells may become unstable or even suffer permanent damage;
- some cells require the presence of a bias voltage when not in use. Do not allow the battery to become fully discharged;
- do not switch the analyser off before the system is purged of remaining flue gas;
- store the analyser in a cool place to reduce the ageing of the cells.

2.2. Gas system

The gas system of the analyser is protected by a double in-line filter. The elements should be changed when necessary. Check the condensate traps regularly and empty them when needed.

2.3. Battery

The rechargeable battery used in the analyser is maintenance-free. An acoustic warning signal is given when the voltage drops below 11 V. The **GA-21 plus** will switch off automatically if the voltage should drop below 10.5 V. The analyser will operate for about 5 hours from the battery.

Warning:

Some parts of the analyser draw current even when the device is switched off. If the analyser is not being used then the battery should be charged fully at least once a month.

2.4. Service intervals

The parameters of the electrochemical cells change with time, and therefore it is necessary to carry out a service periodically. This service should include re-calibration of the gas sensors using test gases. The recommended service interval is 800 operating hours or 6 months, whichever comes first. The analyser is fitted with an operating hour counter and automatically shows when a service is necessary.

The operating time and the number of hours until the next service are shown in [MENU->OPTIONS->madur SERVICE->DEVICE INFO](#).

2.5. Errors during operation

The analyser checks all circuitry continuously. Should an error become evident, then this is signalled acoustically and by the message "ERROR" on the screen. The error can be found shown on the screen [MENU->OPTIONS->madur SERVICE->CONTROL LIST](#).

2.6. Switching off after use

The operating life of the electrochemical cells is dependent on the usage of the instrument. The wear and tear on the cells is greater when the cell is exposed to the gas for longer or the concentration is higher. The gas cell is hence "used up" during measurements.

Info:

For this reason, the analyser should not be switched off until all the gas tubing has been completely cleared of flue gases and the gas cells have been purged with fresh air for several minutes.

The **GA-21 plus** will not normally allow the instrument to be switched off if there are still traces of flue gas in the system. The analyser will continue to operate until the signals from the gas cells are nearly zero. This activity is shown by the message "VENTILATION REMOVE PROBE FROM FLUE".

The [OFF] key must be pressed twice to switch the instrument off completely. Pressing the key once will put the analyser in the standby mode and the instrument will remain in this mode until it is activated again by pressing "C" or switched off completely.

Warning:

Certain conditions, such as strong electro-magnetic fields can cause the analyser to become "hung-up". The only solution to this problem is to switch the instrument off. It is, however, possible that the analyser will no longer react to the keyboard and can not be switched off.

Info:

Pressing the [OFF] key for a period of about three seconds will always switch the analyser off.

3. GENERAL INFORMATION

The **GA-21 plus** is a multi-functional flue gas analyser. Electrochemical sensors are used for the measurement of gas concentration. The instrument can be fitted with between 2 and 4 of these sensors. All analysers are fitted with O₂ and CO sensors, further gas cells must be chosen when the instrument is ordered.

The following description is based on an analyser containing 3 cells, the third one being an NO sensor.

- Oxygen, O₂
- Carbon monoxide CO
- Nitric oxide NO
- Carbon dioxide CO₂
- Nitrogen oxides NO_x

The first three gases (O₂, CO, NO) are measured directly using the electrochemical cells. The remaining components are calculated. The concentrations of oxygen and carbon dioxide are shown in percent. The concentrations of the remaining gases are shown as follows:

- volume concentration in [ppm]
- absolute mass concentration in [mg/m³]
- mass concentration relative to the oxygen content in [mg/m³]

In addition, the air inlet or ambient temperature and flue gas temperature are measured. Using the measured temperatures, gas concentrations and the known fuel

parameters the analyser calculates a variety of combustion parameters such as Stack Loss – SL, Efficiency - η , Excess Air - λ , Loss through Incomplete Combustion – IL.

The **GA-21 plus** also measures differential pressure.. This can be used to measure the draught or pressure in the flue gas channel. The instrument is also equipped for the soot test according to Bacharach method.

The analyser is also fitted as a 3 channel data logger, capable of measuring voltage or current together with temperature using thermocouples or thermistors.

The instrument can be used at a broad range of ambient temperatures (0 - 50°C). It is fitted with a rechargeable battery making it independent of the mains power supply.

Hence, the **GA-21 plus** is ideally suited for all those involved in the construction, maintenance and adjusting of heating systems.

The keyboard of the instrument can be wiped clean if necessary.

The **GA-21 plus** is controlled by a microprocessor. The easy-to-read LCD display, the comprehensive keyboard and the built-in printer allow the operator to communicate with the instrument easily and to document the measurements on the spot. The EEPROM memory used in the **GA-21 plus** allows large quantities of data to be stored without fear of data loss should the instrument be switched off or should the battery be accidentally run down. The **GA-21 plus** comes complete with programmed data for the 18 most common fuels. A further 10 fuels can be programmed by the operator to cover all eventualities.

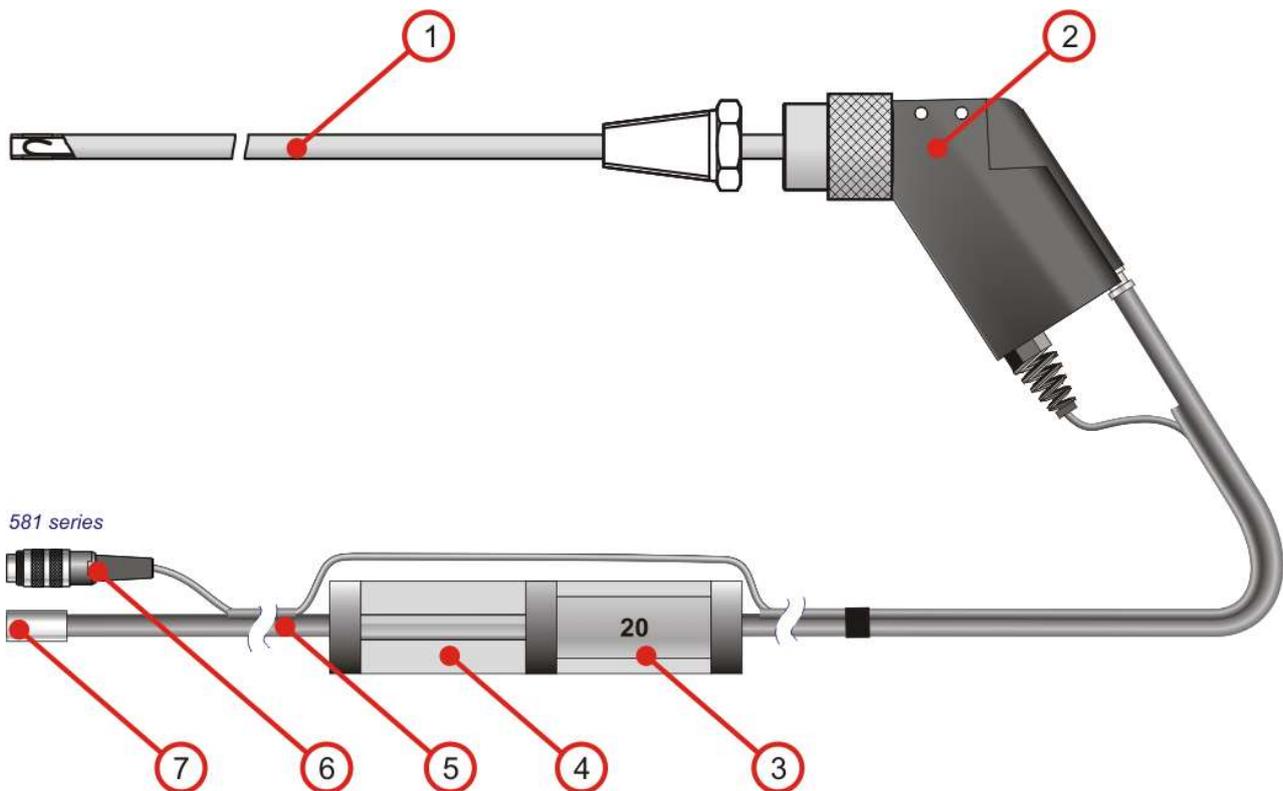
The RS232C interface fitted to the **GA-21 plus** allows all stored data to be read for later treatment or the instrument can be used on-line with the computer.

4. CONSTRUCTION

4.1. Elements of gas circuit

4.1.1. Gas probe with in-line filter

The gas probe is used to extract the gas under investigation and to measure its temperature. The gas probe consists of two parts, the probe pipe with thermocouple (1) and the probe holder (2).



Picture 1. Gas probe with hose and in-line filter

The probe pipe is typically supplied in one of four standard lengths: 150 mm, 300 mm, 450mm, 750 mm, 1000mm and 1500 mm. As standard a Ni-CrNi thermocouple is used. The probe pipe is fitted with an anchor cone to simplify fixation in the flue gas channel.

The probe pipe is attached to the probe holder with a threaded connector.

The gas tubing in the **GA-21 plus** is protected from the dust and moisture present in the flue gases by a filter (4). The filter elements (3) should be changed when dirty to ensure a free flow of gas. The condensate should be removed from the condensate traps when necessary.

The plug (6) and hose quick coupler (7) are connected to the front plate of the analyser.

4.1.2. Gas pump

The internal gas pump draws the gas into the **GA-21 plus** and passes it through the gas chambers. The self-cleaning pump is a high quality item and is known to be extremely reliable.

The gas cells operate best with a flow rate of 90 l/h, which is set at the factory and is compensated automatically for flow restrictions or changes in battery voltage.

4.1.3. Gas chamber

The gas chamber can be fitted with minimum two and maximum six gas sensors. Oxygen and carbon monoxide cells are standard equipment. The other sensors are chosen when the instrument is ordered. The gas chamber of the **GA-21 plus** system is characterised by minimal dead capacity, which leads to low inertia of the analyser indications. In addition to the gas sensors, there is a temperature sensor placed in the chamber for temperature compensation of the sensors.

4.2. Measurement system

4.2.1. Gas sensors

The oxygen concentration is measured using an electrochemical cell. The sensor signal is directly proportional to the oxygen volume concentration. The oxygen sensor needs no calibration with standard gases – it is fully calibrated during the initial calibration when a point corresponding with the contents of oxygen in clean air (20.95%) is determined.

The toxic gases are also measured using electrochemical cells.

Table 1 presents all standard gas sensors available in **GA-21 plus** system.

Gas	Cell type	Range
O ₂	5FO	0-20.95 %
O ₂	MOX-1	0-100 %
CO	5F	0-20000 ppm
CO	5MF	0-10 %
CO	A5F	2000 ppm
NO	5NF	0-5000 ppm
NO ₂	5ND	0-1000 ppm
SO ₂	5SF/F	0-5000 ppm
H ₂ S	3HL/M	0-1000 ppm
H ₂	3HYT	0-2000 ppm
CL ₂	3CLH	0-250 ppm
HCl	3HL(s)	0-100 ppm

Table 1 Available gas cells and ranges

To guarantee long-lasting, trouble-free function of electrochemical sensors the following points are important:

- the stated maximum measuring range of the sensor should not be exceeded.
- all of the gas sensors can react unpredictably to certain chemicals which are not typical for combustion gas composition. For this reason, it is absolutely forbidden to wash the parts of the gas line with chemical solvents. The vapours from such solvents can get inside the gas chamber and result in destabilisation or even permanent damage of the gas sensors.
- the gas sensors are working even when the analyser is switched off - so the battery should never be disconnected or completely discharged.
- the analyser should not be switched off before all the flue gases have been removed from the analyser's gas circuit.
- the sensor chamber must be kept dry.
- the switched off analyser should be kept in a cool place, which increases the lifetime of the gas sensors.

4.2.2. Ambient temperature sensor

The ambient temperature is measured by the analyser for use in some of the calculations carried out, such as Stack Loss. This can be carried out either by the temperature compensation sensor built into the plug of the probe holder (INT) or the external connector T3 (EXT). The temperature sensor is chosen under the suboption:

OPTIONS → SENSORS → ANALOGUE INPUTS.

4.2.3. Flue gas temperature sensor

The flue gas temperature sensor is situated in the gas probe pipe and plugged into the *PROBE* socket on the front panel of the analyser. This sensor is a NiCr-Ni thermocouple in the standard probe version. The range of such a thermocouple is 50-800°C in the standard version (1100°C available optionally). A special gas probe with PtRh-Pt thermocouple can also be used, with a range up to 1600°C. Proper flue gas temperature measurement is the most important factor for correct calculation of the chimney loss and other heat engineering results.

4.2.4. Gas chamber temperature sensor

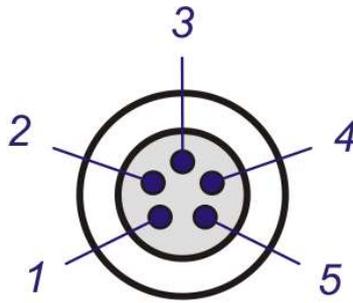
To compensate for temperature drift of the gas cells, the temperature of the gas chamber is constantly monitored.

4.2.5. Differential pressure sensor

The **GA-21 plus** is fitted with a precise semiconductor differential pressure sensor. Stubs marked +/- PRESSURE situated on the left side of the front panel are used to measure pressure. Negative pressure in flue gas channel (chimney draught) can be measured with the one stub only; differential pressure measurement is possible using both stubs. The measuring range of the pressure sensor is +/- 25 hPa.

4.2.6. Analogue inputs

The three analogue inputs installed can be used to measure voltage or current on two channels (U and I), temperature using a thermocouple (T1 EXT) and temperature using a thermistor (T3 EXT). The values measured can be viewed on the screen or stored in the EEPROM memory.

Current and voltage inputs – top view (outputs - optional)***U/I1***

1 – GND

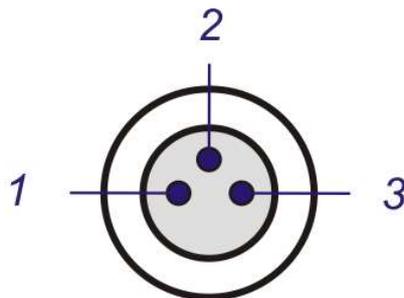
2 – I1 in

3 – U1 in

4 – I1 out GND (optional)

5 – I1 out (0/4-20mA, optional)

Parameter	U	I
Range	-10V to +10V	-10mA to +10mA
Input resistance	100k Ω	100 Ω
Resolution	10mV	10 μ A

Temperature input – top view***Temp1***

1 – PT3 (Thermistor 1 +)

2 – TH1 (Thermocouple 1 +)

3 – GND (-)

Parameter	Thermocouple	Thermistor
Range	Ni-CrNi: 1 – 1300°C Pt-RhPt: 0 – 1600°C Fe-CuNi: 0 – 700°C	Pt100: 0 – 200°C Pt500: 0 – 500°C
Resolution	1°C	1°C

4.3. Data input/output system

4.3.1. Keyboard

A film keyboard is used in the **GA-21 plus** analyser which is durable, washable and highly resistant to external agents. The keys are modern membrane keys with perceptible stroke.

Each press of a key is accompanied by an acoustic signal. The keyboard is shown in picture B (page [14](#)) and consists of the following elements:

PROBE - Socket for the electrical connection of the probe holder

GAS -Connector for the gas hose

PRESSURE +,- -Connectors for the differential pressure sensor

RS 232 C -Socket for the RS232C cable

TEMP. 1 -Socket for the temperature channels 1 & 2

U/I 1 -Socket for the current/voltage channels

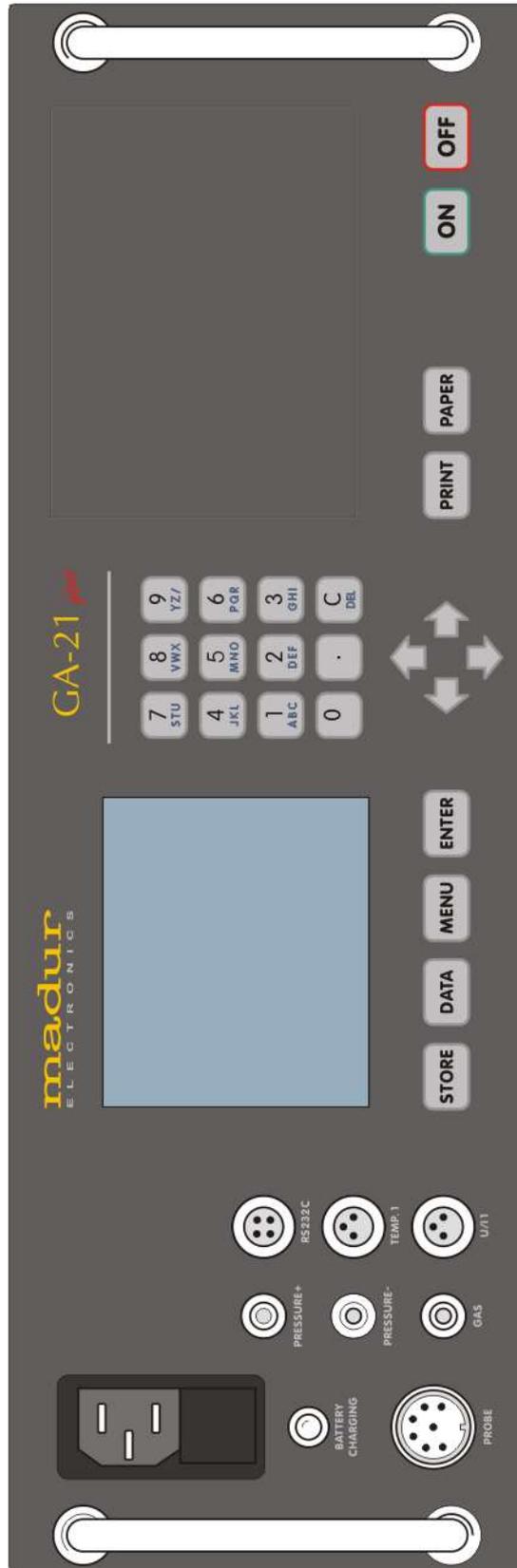
Function keys - 

Arrow keys - 

Printer keys - 

ON/OFF keys - 

Numerals - 



Picture 2. Front elevation picture

4.3.2. Display

The **GA-21 plus** has an LCD display with graphic capabilities. To improve the read-out quality, contrast regulation for the display and backlighting are used. Measurement results, calculation results, diagrams, text information, menu options and others appears on the display.

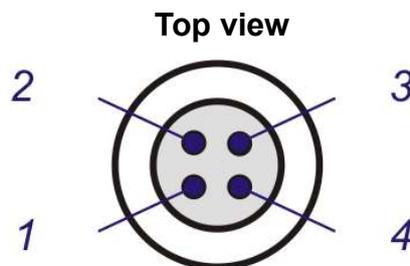
4.3.3. Printer

The **GA-21 plus** is fitted with an EPSON dot matrix printer capable of printing the data as graphic or in the form of tables. All the screens seen on the analyser may be printed.

Printing speed is about 2.5 lines per second. The printer uses normal paper, 57 mm wide.

4.3.4. Interface RS232C

The **GA-21 plus** is fitted with a serial RS232C interface. The socket is mounted on the front of the instrument and marked RS232C. The interface allows the **GA-21 plus** to communicate with a PC and the software **madCom** is available for carrying out extensive analysis of the stored results.



1 – +15V out

2 – RxD

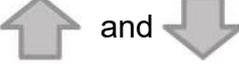
3 – GND

4 – TxD

5. OPERATION

5.1. Use of the keyboard

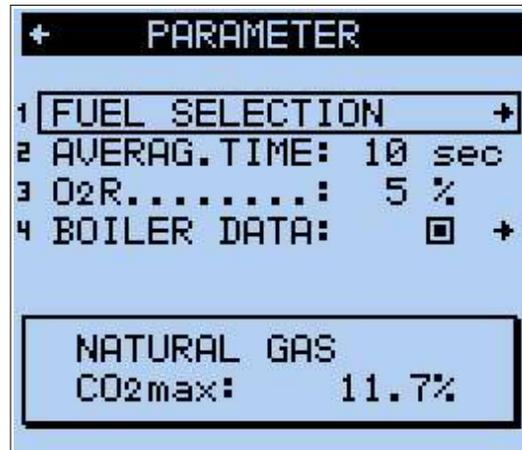
5.1.1. Description of the keys

	-	Switches to the STORE menu
	-	Switches to the first results screen. From the current results, the use of this key switches between MEASURE and HOLD.
	-	Switches to the MAIN MENU
	-	Confirms entries and switches options
	-	Alphanumeric keyboard for entering data and for fast movement between MENU options
	-	Decimal point when entering data. If used when the screen is showing RESULTS, this key switches the zoom function on or off.
	-	starts a print-out
	-	moves the paper forward one line
	-	switches the analyser on
	-	switches the analyser to stand-by or off
	-	moves one step backwards in the menu
	-	moves one step forward in the menu or, during editing, moves the cursor one space to the right
	-	move the cursor vertically in the menu

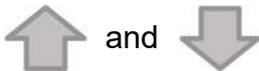
5.1.2. Selecting menu options

The menu structure is shown at the end of the manual. The various displayed menus are leading the user through the structure.

The following picture shows an screen, which explains the different types of existing lines.



Here is an explanation of the movement between the various menu options:



and

- move the cursor vertically in the menu



- if the cursor is on the left side of the **Title line**, the key moves one step backwards in the menu



- if the cursor is on the right side of the **Option line** or the **Title line**, the key leads to the displayed **Option**.



- executes the displayed function (starts data storage for example), in the Command line starts or ends the respective edit function (setting the average time for example) in the Data line switches (i.e. YES/NO) in the Switch line



- for fast movement between MENU options

If a displayed line carries a function, then there will be a number (1 to 9) on the left side of the line. Press the number of the option you want to select, and the cursor will "jump" to the selected line. If number 4 is pressed in the above demo screen the beam would move to *BOILER DATA*.

5.1.3. Entering numbers

Numbers are edited as follows:

-  to   - digital keys enter corresponding numbers
-  and  - move the cursor within the line
-  - erases whole number (zero on each position)
-  - confirms and ends the entry

5.1.4. Editing text

Text is edited as follows:

-  - switches the keyboard into either digital or alphabetical mode. When in digital mode the cursor has a block form on the screen, in the alphabetical mode it has the shape of an underlining
-  and  - move the cursor within the line
-  - erases the whole text line
-  to   - the alphanumeric keys enter numbers in digital mode or letters in alphabetical mode. Each key has a three letter designation. The first press enters the first letter, the next presses the second and the third letter. Key presses in alphabetical mode does not move the cursor.
-  - (SPACE) prints 0 number in digital and the space character in alphabetical mode. The space moves all the next characters one position to the right.
-  - (DEL) erases the character above cursor position. This moves all the following characters one position to the left.

ENTER

- ends the entering of a text (if only one line is edited - e.g. the name of a fuel) or moves the cursor down to the next line (if there are several lines in the edited text - e.g. the report header)

STORE

- end the editing of a header or footer - it enables the storage of edited text. If you do not need to store the contents of header or footer you should leave the screen by pressing the MENU key.

5.2. Basic operating instructions

5.2.1. Setting-up the analyser

Connect the components of the analyser system:

- Attach the hose to the connector GAS. The plug from the probe holder connects to the socket PROBE.
- Attach the outlet hose from the filter to the connector INLET
- Ensure that the gas flow from the base of the analyser is free of obstructions.

5.2.2. Switching on

Before use, the condition of the analyser should be checked:

- Check the filter elements. Clean or replace as necessary.
- Check the state of charge of the battery if the analyser is to be operated from the internal battery. This is carried out by switching on and reading the battery voltage or charge from the initial screen, or from the screen MENU/OPTIONS/DEVICE INFO.

5.2.3. Switching off / standby

Pressing the key [**OFF**] once will switch the analyser to the **STANDBY** mode.

In **STANDBY** mode the power consumption is drastically reduced. Amongst others the pump and the backlight are switched off. Only the sensors remain supplied to be ready to operate immediately after the instrument is switched on again.

The analyser does not switch to **STANDBY** mode if [**OFF**] is pressed in case:

- the key is being pressed during Initial Calibration. In that case the instrument realises the action, but will switch to **STANDBY** only after the calibration is finished.
- the key is being pressed while there is still a high gas concentration detected in the gas chamber. In this case the instrument will automatically switch to **FLOODING WITH AMBIENT AIR** mode and switch to **STANDBY** mode later on.

The following screen is shown in the **STANDBY** mode.



By pressing [**OFF**] the instrument can be switched off completely. If [**C**] is pressed the instrument switches ON again. If the instrument is in **STANDBY** mode for more than 8.5 hours it switches off automatically. It is highly recommended to carry out a [calibration of the oxygen](#) sensor when re-activating the instrument.

5.2.4. Initial calibration

After the instrument is switched on it carries out an initial calibration for 2 minutes.

Warning: Make sure the probe is not in the stack during the initial calibration

Initial calibration is of basic importance for measurement correctness and it must not be interrupted before it is finished automatically.

During this time the Oxygen sensor is calibrated to 20,95% in ambient air, and the other sensors (CO, NO,...) will be zeroed.

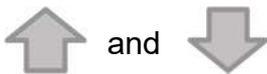
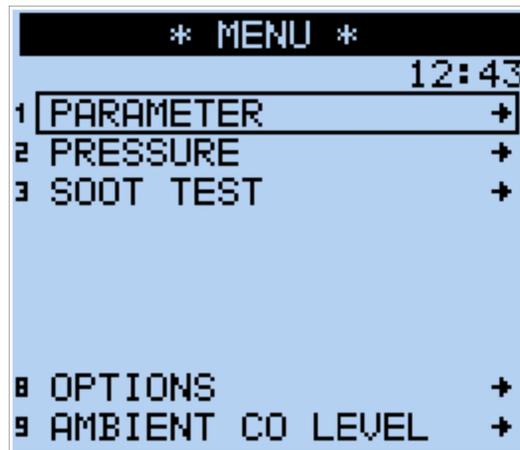


5.2.5. Measurement parameters

Directly after the calibration is finished the option **PARAMETER** is displayed for control reasons or in case changes need to be done. Usually the option is selected as follows:



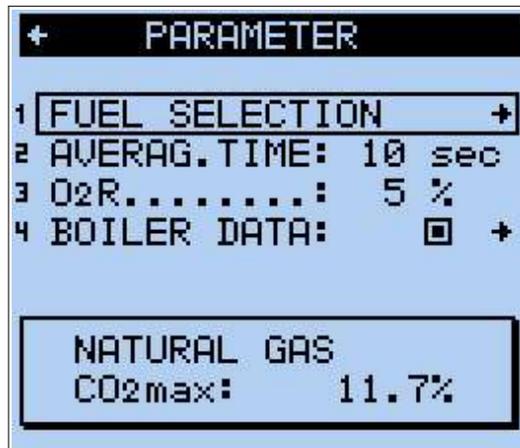
- selects the **MENU** screen



- move the cursor to the **PARAMETER** option



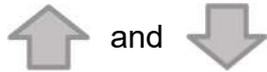
- select the option. The following screen will appear:



5.2.5.1. Fuel selection

This option enables the selection of a fuel (if necessary), or the programming of a customised fuel.

From **PARAMETER** you move to the option as follows:

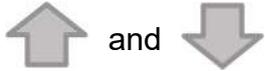


and

- move the cursor to **FUEL**



- choose **SELECT FUEL**

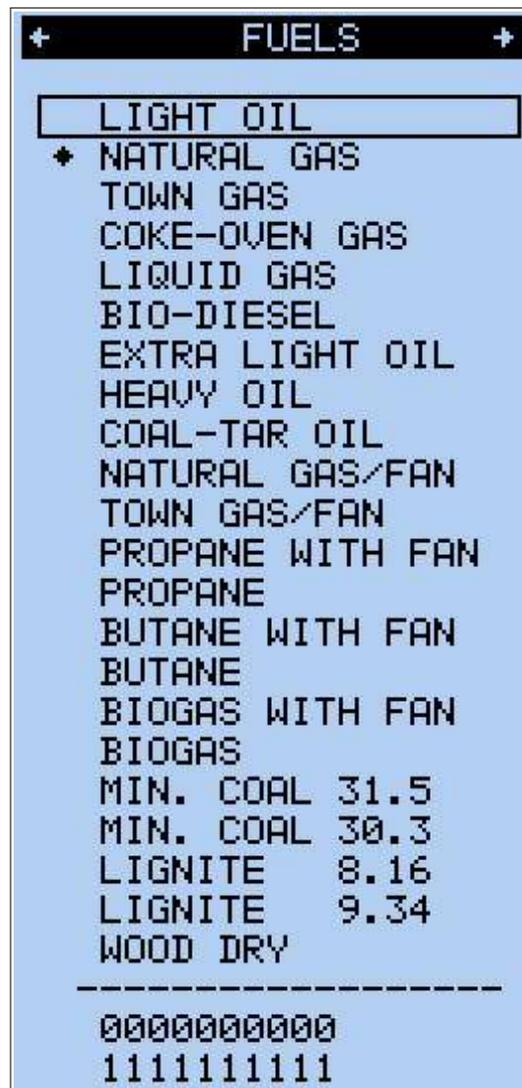


and

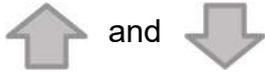
- move the cursor to the desired fuel



- confirm the selection - an asterix (*) will appear on the left side



Each fuel of this screen is defined through various parameters. To view them proceed as follows:



and

- move the cursor to the desired fuel



- displays the fuel parameters , or gives the opportunity to enter fuel data for the programmable fuels.



- back to option **FUEL**

The following screen appears.

+ FUEL DEFINITION			
1	0000000000		
2	DP	[K]	0.0
3	CO2max	[%]	0.0
4	A1	[]	0.000
5	B	[]	0.000
6	ALPHA	[]	0
7	O2R	[%]	0
8	Vgd	[m ³ /m ³]	0.00
9	HV	[MJ/m ³]	0.0
-	UNITS		m ³

The already defined fuels can only be viewed. For the user definable fuels all parameters can be programmed.

The variables are as follows:

- **0000000000**- Name of the fuel
- **DP**-
- **CO2max** - the maximum concentration of CO2 (for complete combustion, O2=0 %)
- **A1, B** - factors for Sievert's formula
- **ALPHA** - fuel specific parameter
- **O2R** - reference oxygen
- **Vgd** - volume of the flue gas at perfect combustion of the fuel
- **HV** - Heating value of the fuel
- **UNITS** - unit in which the fuel is measured

5.2.5.2. Averaging time

To select the average time proceed as follows:

-  and  - move the cursor to **AVERAG. TIME**
-  - select Average Time edition
-  to  - select the time (1 to 60)
-  - confirm the number
-  and  - select **min** or **sec**
-  - confirm the selection

5.2.5.3. Reference oxygen parameters (O2R)

To select the reference oxygen proceed as follows:

-  and  - move the cursor to **O2R**
-  - switches between a pre-programmed standard value **<NORM>** and a free programmable one, called manual value.
-  to  - if "manual" was selected, a number from 1 to 20 can be entered
-  - confirms and ends editing

5.2.5.4. Boiler parameters

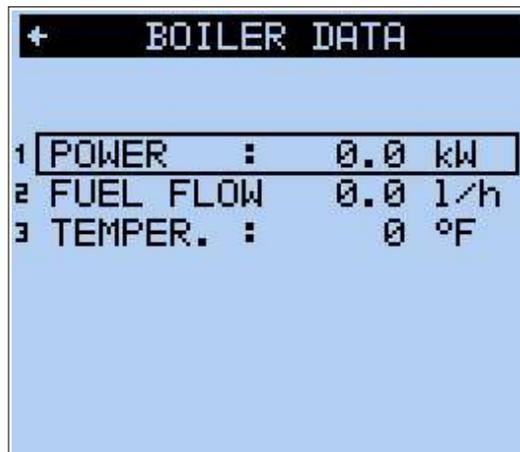
This option enables the user to have relevant boiler parameters printed on the Protocol printout for exact documentation.



and



- move the cursor to *BOILER-PARAMETER*
- select with YES/NO whether or not the Boiler Parameters shall appear on the printout, respectively being stored in a Protocol
- if YES was selected, this key moves to the Boiler Parameter menu. The boiler parameters can be entered in the screen shown below:



- Boiler power
- Boiler consumption
- Boiler temperature

5.3. Displaying the measurement results

Select the measurement screen by pressing **DATA**. The measurement results are displayed on three screens, either as current values or as averaged values.

5.3.1. Current values

DATA

- select the first screen

* CURRENT VALUES * →		
LIGHT OIL		
TEMP. GAS	357	°C
TEMP. AMB.	23	°C
O ₂	5.31	%
CO ₂ IR	11.24	%
CO Lo	438	PPM
STACK LOSS	24	%
R-EFFIC*	76	%
DEW POINT		°C
λ-LAMBDA	1.73	



and

- move backward or forward to select a screen

* CURRENT VALUES * →		
Gas	Vol. [PPM]	Rel. m% ↓ 5% O ₂
CO	438	
NO	128	
SO ₂	120	
NO ₂	430	

NO _x	430	

* CURRENT VALUES * [E]		
TEMP1 EXT.	---	°C
TEMP3 EXT.	30	°C
U/I1 EXT.	10.03	mA

ENTER

- switches between **AVERAGED VALUES** and **CURRENT VALUES**

DATA

- switches **On/Off** the **HOLD** function ("freezing" the current values)

5.3.2. Averaged values

Select desired averaging time as described in section [5.2.5.2](#).

DATA

- select the screen. The title line has to read **AVERAGED VALUES**



- backward or forward to select one of four screens

ENTER

- switches between **AVERAGED VALUES** and **CURRENT VALUES**

C
DEL

- the display on the **AVERAGED VALUE** screen gets "synchronised" (a row of strokes appears instead of the values) and a new averaging session starts. The measured results are displayed after the whole cycle is finished.

DATA

- switches **On/Off** the **HOLD** function ("freezing" the current values)

Warning:

If a continuous storage recording is taking place the analyser won't synchronise the averaging process (not to interfere with the continuity of storage)

5.3.3. The averaging process

The analyser is capable to display all results, measured or calculated, either as current value or as averaged value. The averaging time can be selected in a range of 10 seconds to 60 minutes. If a time of 1 min was set, the averaged results over that time would be shown on the display. During the start of the averaging process a row of strokes appears on the screen, since there are no results to display.

If measurement parameters are changed during the averaging process, the averaging cycle has to be re-started.

In case the data storage is activated it is stopped as well.

The following incidents cause an interruption of the averaging cycle.

- change of the [averaging time](#)
- change of the [reference oxygen](#)
- change of the [fuel](#)
- switching the instrument to the [STANDBY](#) mode

5.4. Pressure/Draft measurements

It is possible to measure differential pressure with the **GA-21 plus**. To do so the stubs **PRESSURE (-)** and **(+)** on the front plate are used. The measurement is performed as follows:



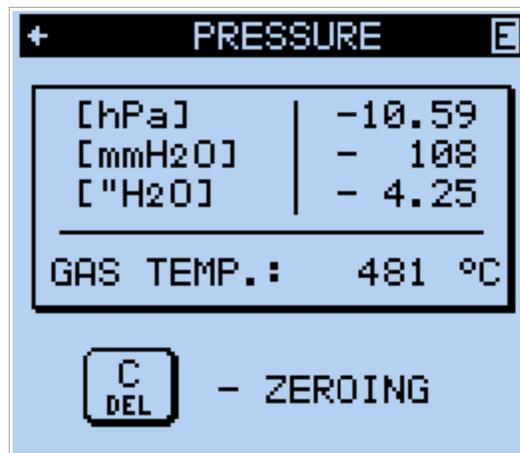
- select the main MENU



- move the cursor to **PRESSURE**



- select the option. The following screen appears



The current pressure and gas temperature are displayed on the screen. The last line shows the command **ZEROING**. By pressing this key the sensor is set to zero, e.g. the current value will be taken as zero value..

Please be aware that the sensor has to be zeroed before the measurement.



- ZEROING the sensor

Connect end of the sample hose to the **PRESSURE(+)** stub. The screen will display the measured pressure and the measured gas temperature.



- leaves the option. The displayed value will be stored until a new one is stored or either a printout of the measured values is performed or they are stored as a report.

5.5. Soot (smoke) Measurement

To perform a soot test it is essential to prevent the flue gas from condensing on the filter. Therefore it is necessary to use a heated probe holder. It is only possible to perform a soot test if the instrument is connected to the mains.

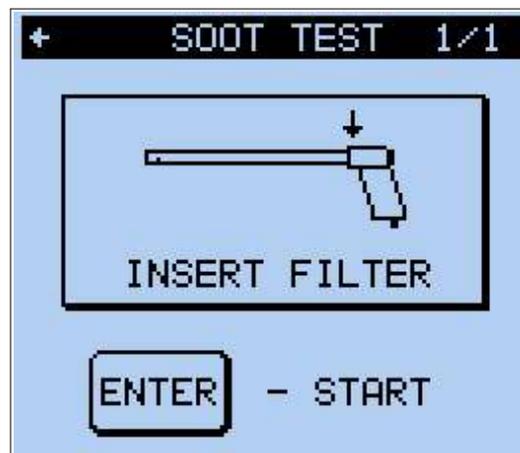
The soot test is done by means of the Bacharach comparison method.

MENU

↑ and ↓

→

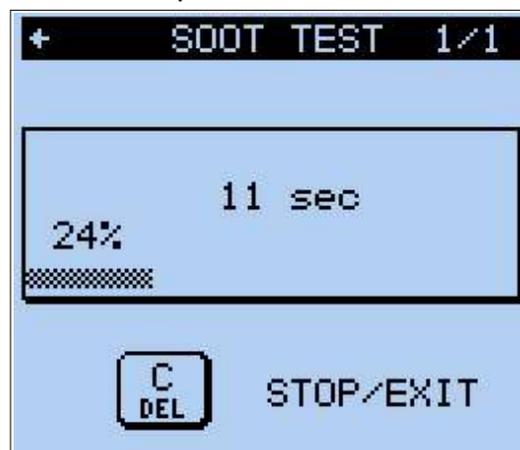
- select the main MENU
- move the cursor to **SOOT TEST**
- select the option, the pump is switched off and the following screen appears:



Insert the soot filter in the slit of the heated probe holder, and place the probe in the stack.

ENTER

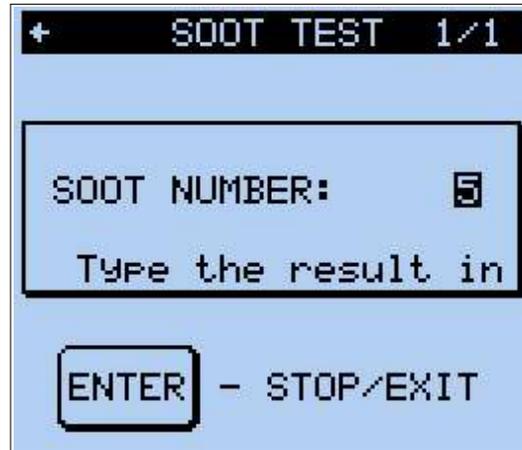
- starts the soot measurement. The pump is switched on and sucks in 60 s (according to TÜV) the required volume of 1.63 +/- 0.07 l





- stops the soot test

After the soot test the filter is compared with a scale, and the evaluated soot number is entered.



- enter the detected soot number

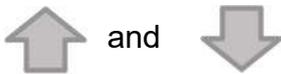


- confirm the soot number

The stored soot number remains stored until a new one is entered, or either a printout of the measured values is performed, or they are stored in a report.

5.6. Options

The **OPTIONS** can be reached from the **MENU** as follows:



and

- move the cursor to **OPTIONS**



- select option. The following screen appears



5.6.1. Device info



and

- move the cursor to **DEVICE INFO**

- select option



The **DEVICE INFO** screen shows the serial no. of the instrument, the date of the last service, the operating time, the time until the next service, the speed of the sucked flue gas , the battery charge, the battery capacity and whether or not the communication with the **madCom** PC software is locked.

5.6.2. Sensors

Select the option **SENSORS** from the screen **OPTIONS** as follows:



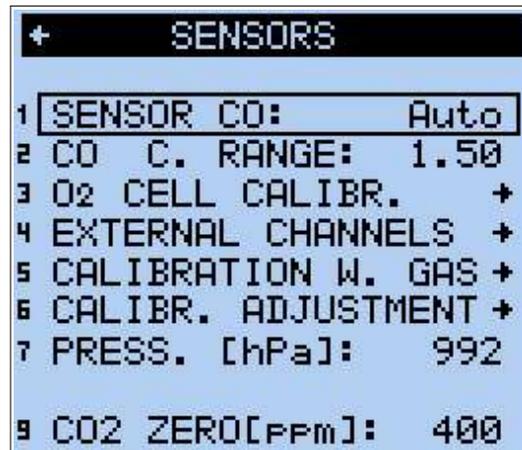
and



- move the cursor to **SENSORS**



- select the option. The following screen appears



5.6.2.1. Sensor CO (only in dual CO sensor configuration)

In dual CO sensor configuration there is possibility to select working mode:

- Auto** – This mode is designed to protect low range CO sensor. Measurement results collected using low concentration CO sensor. When the measured gas concentration exceeds value inserted in **CO C. range** then the purging pump starts flushing the low concentration CO sensor with ambient air for its protection. Result are from this point collected using high concentration CO sensor. When the gas concentration drops below value inserted in **CO C. range** then the pugging pump stops and the measurements are again collected using low concentration CO sensor.
- Hi** – In this mode purging pump is always on and results are always collected using high concentration CO sensor.

5.6.2.2. CO range

If the concentration of CO in the gas stream exceeds the limit set here, then the cell is automatically purged with fresh air. This limit can be altered as follows:

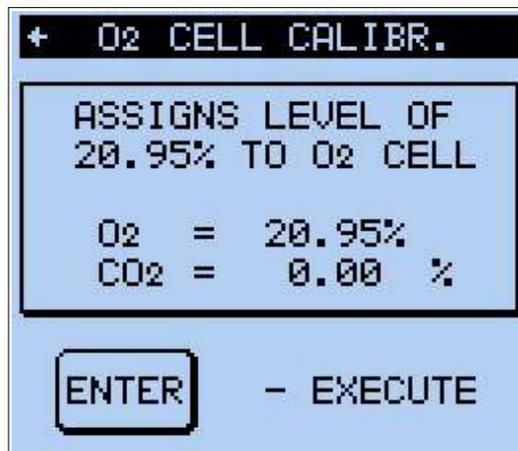
-  and  - move cursor to the line **CO RANGE**
-  - start editing of the value
-  to  - enter a number between 0 and 20000 ppm
-  - close the option

5.6.2.3. O2 cell calibration

To increase the accuracy of the O₂ sensor during measurements over a longer period of time the **GA-21 plus** has the capability of calibrating the sensor with ambient air.

Take the probe out of the stack !

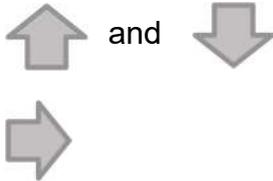
-  and  - move the cursor to **O₂ cell calibration**
-  - select the option. The following screen appears



-  - confirms the calibration

5.6.2.4. External channels

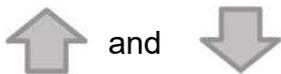
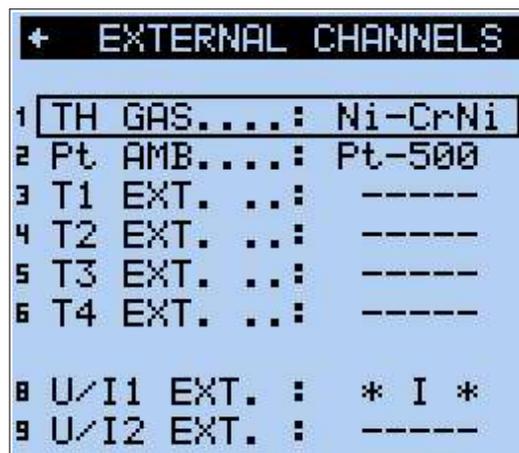
Get from the screen **SENSORS** to the option **EXTERNAL CHANNELS** as follows:



and

- move the cursor to **EXTERNAL CHANNELS**

- select option



and

- move the cursor to the line to be changed



- change the setting:

- TH GAS** - **Gas temperature sensor** – default setting: **NiCr-Ni**. For special applications (temperatures up to +1600°C) the setting can be changed to **PtRh-Pt** thermocouple. Of course that would need the use of the respective thermocouple as well.
- Pt AMB** - **Ambient temperature sensor** - default setting: **Pt 500**. The ambient temperature can either be measured with an internal sensor placed in the probe plug (Pt500), or with an external sensor (Pt500), connected to the TEMP (T3 EXT.) socket.
- T1/T2 EXT** - **External thermocouple** - Select the desired temperature sensor. The **T1 EXT** input can be defined as a **Ni-CrNi**, **Pt-RhPt** or **Fe-CuNi** thermocouple.

- T3/T4 EXT** - **External resistance thermometer** - Select the desired temperature sensor. The input **T3 EXT** can be defined as a **Pt100, Pt500 or KTY-2k** thermistor.
- U/I1 EXT** - **External Voltage/Current input** - Select the desired input signal . The socket **U/I1** can be used to measure either current (0-10 mA) or voltage (-10V - +10V).
- U/I2 EXT** - **External Voltage/Current input** – second current or voltage input

5.6.2.5. Sensor calibration

Except for O₂ every electrochemical sensor needs to be calibrated with calibration gas. To calibrate the sensors they are fed one by one with calibration gas of a known concentration. After a few minutes the sensor supplies a stabilised signal which can be stored as calibration value. The order of calibration does not effect the calibration.

Warning:

Any calibration screen value change is followed by loss of the original calibration settings. Thus the CALIBRATION option should be selected only when it is to be carried out.

The standard gas concentration should be similar to that usually met during measurement and it should not be less than 10% of the required measuring range of a given sensor

The time the sensor is fed with standard gas should not be less than 4 min. After each calibration the sensors should be flooded with ambient air for at least 15 minutes.

Calibration procedure:



and



- move the cursor to **CALIBRATION W. GAS**



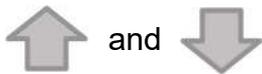
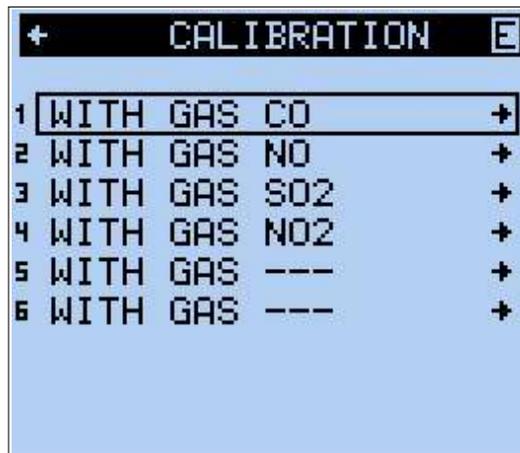
- select the option



- carry on with the calibration



- abort the calibration, move back to **SENSORS**



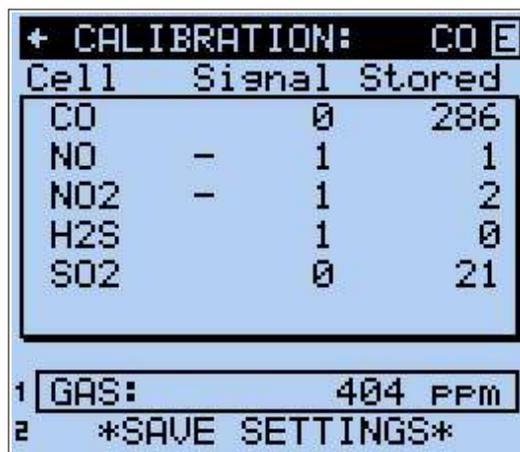
and

- move the cursor to the sensor to be calibrated



- select the gas type

Calibration screen will appear:



All currently installed electrochemical sensors are visible in this screen

The individual rows have the following meanings:

Cell – Sensor type

Signal – Current value of sensor's signal

Stored – Value of stored signal



- in the **GAS [ppm]** line, starts editing of the standard gas concentration



- enter the concentration of the standard gas [ppm] in the line **GAS**

ENTER

- in the **GAS** line. Confirm standard gas editing. Supply the instrument with standard gas for about 4 min.

ENTER

- in the **STORE** line, as soon as the value has stabilised, stores the measured value as calibration value. Disconnect the standard gas and flood the instrument for at least 15 min with ambient air.



- return to select the next gas, or end the calibration

5.6.2.6. Calibration adjustment

+ CALIBR. ADJUSTMENT			
	[PPM]	Read	Gas
1	CO	2031	2031 <input checked="" type="checkbox"/>
2	NO	503	503 <input checked="" type="checkbox"/>
3	NO ₂	0	0 <input type="checkbox"/>
4	SO ₂	500	500 <input checked="" type="checkbox"/>
* ADJUST *			
REMOVE ADJUSTMENT			

Calibration adjustment is a new feature (introduced in firmware version 2.07). Allows to perform a quick correction to a factory calibration using one calibration mixture (mixture of gases in N₂ balance).

Calibration adjustment does not substitute factory calibration with a single gas in N₂ balance. I.e. calibration adjustment cannot create matrix of cross-sensitivity signals – this is created only during standard calibration.

- means that correction for a selected gas is applied.

If all sensor are unmarked: , it means no adjustment to factory calibration is applied.

To perform calibration adjustment:

Enter the concentration for each gas present in mixture. If any of listed gas is not present in mixture set its concentration to 0 → analyser will not include this sensor in adjustment.

Apply reference mixture for few minutes and allow the signals to stabilise.

Finish the adjustment by pressing * **ADJUST** * button.

Adjustment is remembered, even after powering ON/OFF the analyser! To remove this calibration adjustment, one need to manually perform **REMOVE ADJUSTMENT**.

5.6.3. Settings

This option allows the user to adjust some of the standard settings.



and



- move the cursor to the option **SETTINGS**



- select the option



5.6.3.1. Backlighting



- pressing the key switches the **BACKLIGHTING** on and off

5.6.3.2. Contrast



and

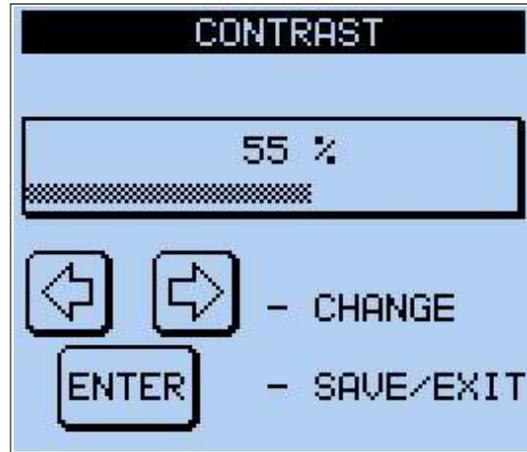


- move the cursor to **CONTRAST**



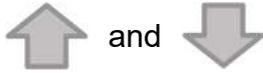
- select option

Follow the explanations on the screen to adjust the contrast



5.6.3.3. Clock

This option allows the internal clock to be adjusted.

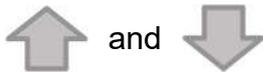
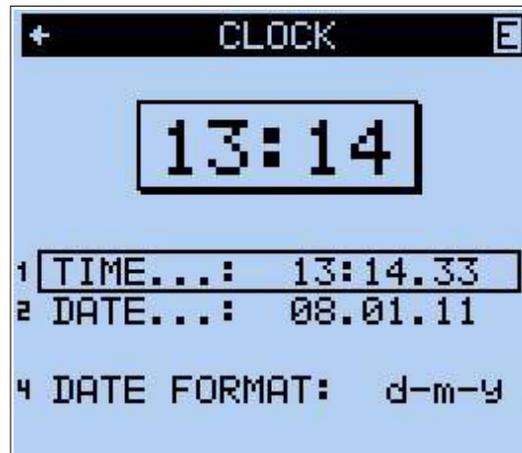


and

- move the cursor to **CLOCK**



- select option



and

- move the cursor to desired line



- opens editing



to

- set date and time. They are entered in the sequence TIME - HH:MM.SS and DATE as given by the format line below.



- confirms settings

5.6.3.4. Printer

This option allows the printer (printout) settings to be defined.



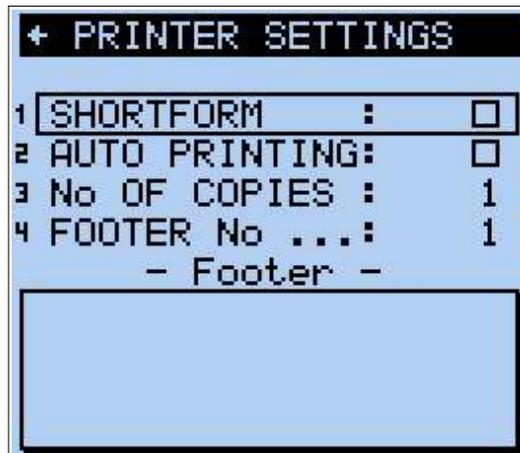
and



- move the cursor to **PRINTER SETTINGS**



- select option



SHORTFORM

- switches between **YES/NO**. If the option is activated, then a print-out of the current values will show only the volume concentrations of the gases, not the mass concentrations in mg/m³. A stored report will still have all the information as usual.

AUTO PRINTING

- switches between **YES/NO**. If the option is activated, automatic printouts will be carried out according to the programmed average time, provided the time is not less than 2 min. If the average time is shorter than 2 min. only one printout will be performed.

No OF COPIES

- switches between 1/2/3.

FOOTER No

- the instrument can store up to 50 footers. Number one is already stored and can not be changed. If address 0 is selected, no footer will be on the printout. The footers 2 to 50 are freely programmable.

5.6.3.5. Language/Country

The instrument enables the user to select between languages.

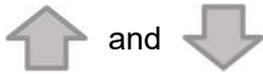


and

- move the cursor to **LANGUAGE**



- confirms the selection



and

- select language



- confirms the language



5.6.3.6. Acoustic warning



- enables/deisables acoustic warning

5.6.3.7. Soot (1/3)

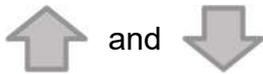
5.6.3.8. Standard



- sets the instrument to default settings

5.6.4. Control list

The option **CONTROL LIST** displays a similar list to the one above. The list shows which subassembly functions correctly (OK), or which is defective (*E*).



and

- move the cursor to **CONTROL LIST**

- select option

+ CONTROL LIST				
CO I	-	1		OK
CO II	-	1		
NO		29		OK
SO2		14		OK
NO2		8		OK
---		32767	---	
---		32767	---	
O2		3811		OK
PRESS.		72		OK
Th GAS.		32767		*E*
Pt AMB.		32767		*E*
T1 EXT.		32767		---
T2 EXT.		32767		---
T3 EXT.		32767		---
T4 EXT.		32767		---
NTC		6339		OK
BATTERY		8237		OK
U/I1		3		OK
U/I2		2		---
PRESS2		306		
T INT		29		OK
FLOW		92		OK
PUMP 1		52		
PUMP 2		□		
IR CO2		14406	▣	11
IR CO		11933	▣	11

5.6.5. madur Service

This option is for service engineers only. A code is needed to enter the menu - exit with [MENU] key.

5.7. Storing of results

Since the measured results can be stored in the EEPROM memory, it is possible to read them out later for treatment using the **madCom** software. Data can be stored in two separate forms. Up to 30 measurement reports and up to 10 banks from continuous measurements containing a total of 1024 sets of results. Using an averaging time of 30 minutes, this would allow the results of over 21 days of measurements to be stored (please be aware that for measuring sessions of that length a proper gas conditioning system is absolutely necessary)

A rectangular button with rounded corners and a grey gradient, containing the word "STORE" in bold, black, uppercase letters.

- selects the menu **STORE**

A screenshot of a monochrome LCD display showing a menu titled "STORE DATA". The menu has four options: "1 REPORTS", "2 BANKS", "3 DELETE ALL REPORTS", and "4 DELETE ALL BANKS", each with a right-pointing arrow. Below the menu is a table with three columns: the first column lists "REPORTS", "BANKS", and "BLOCKS"; the second column, labeled "free", shows values 29, 7, and 1012; the third column, labeled "busy", shows values 1, 3, and 12.

	free	busy
REPORTS	29	1
BANKS	7	3
BLOCKS	1012	12

5.7.1. Storing measurement reports

The measurement report contains all the results obtained in a single measurement. It contains either current or averaged values and other user-defined factors such as fuel, footer, header etc. If the report should contain soot measurement results or pressure data, then these measurements must be carried out before storing the report. The report will contain either the current or the averaged results depending on which screen was visible when the storing process was started.

Store REPORTS as follows

DATA

- the measured values are displayed. Do you want to print the displayed values proceed as follows

STORE

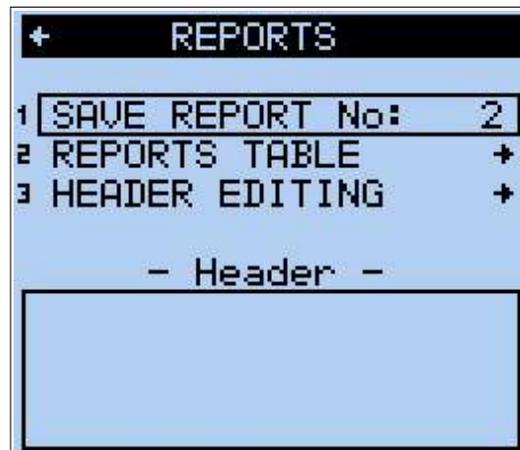
- select option. The measured values are stored in a buffer memory

↑ and ↓

- move the cursor to **REPORTS**

→

- select option **REPORTS**



↑ and ↓

- move the cursor to **SAVE REPORT No. XX**
- the "buffered" data are stored in a Report with the displayed number.

ENTER

5.7.1.1. Report table

This option allows one to view, print and erase Report contents.



and



- move the cursor to **REPORTS TABLE**



- select option

+ REPORTS TABLE E				
♦01	02	03	04	05
06	07	08	09	10
11	12	13	14	15
16	17	18	19	20
21	22	23	24	25
26	27	28	29	30

Reports without [♦] are empty.



- erases the selected Reports



- shows the selected Reports, the following screen **REPORT NO.: XX** is opened

```

+ REPORT No: 1 E
14:40 07.03.13
-----

NATURAL GAS
O2R.....: 5 %
AVERAG. TIME: 2 sec
-----

POWER      : 0.0 kW
FUEL FLOW: 0.0 l/h
TEMPERAT.: 0 °F
-----

T AMB.    : 76.1 °F
T GAS.    : --- °F
O2.....: 20.95 %
CO2.....: 0.00 %
CO .....: 0 PPM
NO .....: 0 PPM
SO2.....: 0 PPM
NO2.....: 0 PPM
---.....: --- PPM
NOx.....: 0 PPM
-----

EXCESS AIR: ---
STACK LOSS: --- %
EFFICIENCY: --- %
-----

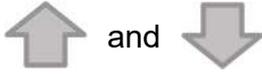
D -DRAUGHT      "
B -SOOT...:

```

5.7.1.2. Header (Notice) editing

This option allows to edit a notice which can be stored and printed with a Report. The HEADER may have 4 lines of 20 characters.

Measurement site and/or short description of the site are commonly stored in such notes.



and

- move the cursor to **HEADER EDITING**



- select option

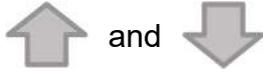


The pictures show screens without text. The screen appears as it was when the report was stored. How the text should be edited is described in section [5.1.4](#).

This screen can be left at any time using **[MENU]** and **[DATA]**.

5.7.1.3. Erasing reports

All protocols can be erased in that option.



and

- move the cursor to **DELETE ALL REPORTS**



- select option



- leaves the screen without erasing the Reports



- erases all reports

5.7.2. Continuous storing of results

This type of storing involves the continuous storing of a set of up to 10 measurement results (ONE BLOCK) during a measurement session. The EEPROM can store up to a total of 1024 blocks freely dividable between 10 measuring sessions. These 10 sets of results are known as BANKS. The size of a single bank is only limited by the free memory available. Each bank also contains all necessary information about the measurement (fuel, time, O2R, averaging time etc.). All the results stored are average results for the time set. If the analyser is switched off, and under certain circumstances, the storing of averaged results will stop automatically.

This is signalled by a single long warning tone.

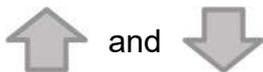


Starting the continuous storing of results (in Banks)

STORE

- call the STORE menu

check whether enough free memory is available for the measurement. If not, one or more banks must be erased. The option [DELETE ALL BANKS](#) can be used.

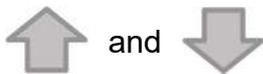


and

- move the cursor to the option **BANKS**



- open the option **BANKS**



and

- move the cursor to the line **STORAGE**

Set or check the [averaging time](#).

ENTER

- start the storing, the word **ACTIVE** appears

DATA

- the measured/calculated values are shown, storage is active

Stopping the continuous storing of results

STORE

- call the STORE menu



and

- move the cursor to the option **BANKS**



- open the option **BANKS**



and

- move the cursor to the line **STORE**



- storage is stopped, the word **ACTIVE** disappears

5.7.2.1. Banks table

The option **BANKS TABLE** provides information about the stored Banks.



and



- move the cursor to the option **BANKS TABLE**



- select the option **BANKS TABLE**.

The last bank can be erased in the **BANKS TABLE** screen (the Bank must not be active)



and



- move the cursor to the last stored Bank



- erase bank

5.7.2.2. Erasing banks

The option **DELETE ALL BANKS** allows to erase all Banks.



and



- move the cursor to **DELETE ALL BANKS**



- select the option



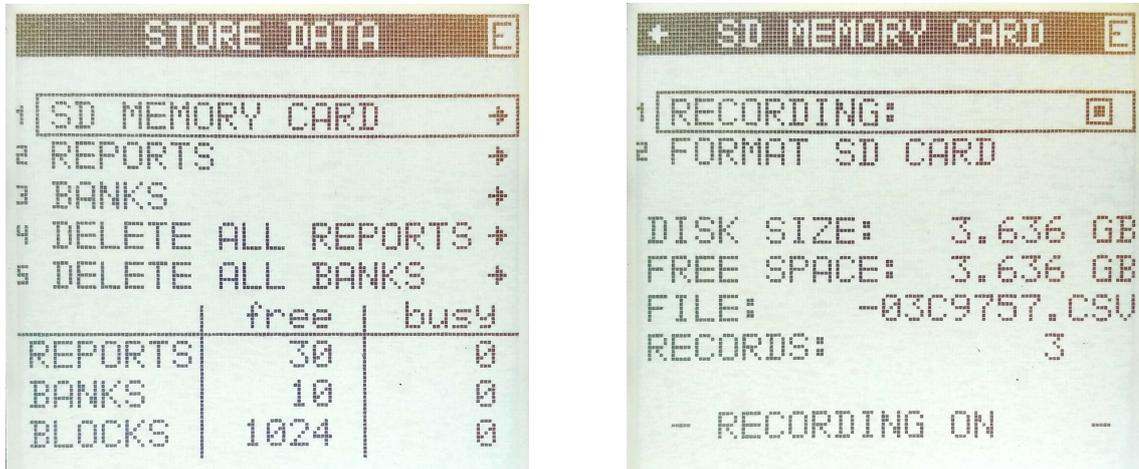
- leaves the screen without erasing **BANKS**



- erases all **BANKS**

5.7.3. Data-logger

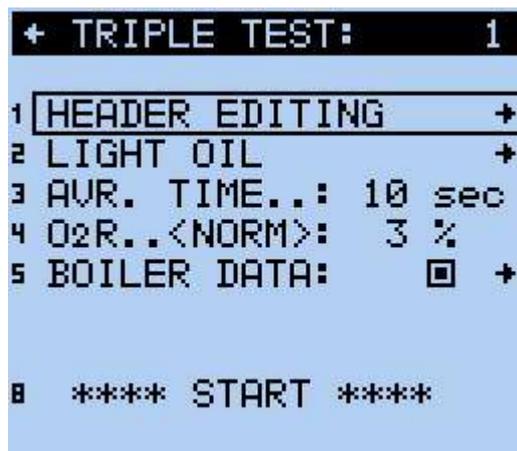
GA-21plus analyser can be optionally equipped with data-logger. Such device has additional microSD card slot, located beneath the printer cover. Data-logger options are available from *Store* menu:



To use data-logger, insert SD card to the slot and, if necessary, format it from analyser's menu. Then thick *Recording* option to start collecting measurements to csv file (comma separated) on SD card.

5.8. Triple XL test

To enter triple XL test menu: on any of the results screen, press and hold  for 2 seconds.



Before executing the test, set necessary parameters:

1. Header (Notice) editing
2. Fuel selection
3. Averaging time
4. Reference oxygen parameters (O2R)

5. Boiler parameters

When all is set, execute 3-XL by pressing ***** START ***** - analyser will perform test according to the set averaging time. Each test will start immediately after previous one has ended. Currently performed test is indicated with its number in top left corner. Results presented on screen are for the previous period, i.e. during the first test, instead of results '----' are presented. During the second test, results from the first period are presented. During the third test, results from the second test are presented:

1 AVERAGED FOR: 10s +			2 AVERAGED FOR: 10s +			3 AVERAGED FOR: 10s +		
LIGHT OIL			LIGHT OIL			LIGHT OIL		
Tgas	---	°C	Tgas	30.6	°C	Tgas	26.6	°C
Tamb	---	°C	Tamb	30.8	°C	Tamb	26.7	°C
O2	---	%	O2	20.95	%	O2	20.95	%
CO2	---	%	CO2	0.00	%	CO2	0.00	%
CO	---	PPM	CO	1	PPM	CO	0	PPM
SL	---	%	SL	---	%	SL	---	%
Pdiff	---	hPa	Pdiff	0.07	hPa	Pdiff	0.05	hPa
Lambda	---		Lambda	---		Lambda	---	

3-XL test is stored along with reports. 3-XL test occupy memory of 2 reports, and are marked in Report table with +:

+ REPORTS TABLE				
01	02	03	04	05
06	07	08	09	10
11	12	13	14	15
16	+17	+18	19	20
21	22	23	24	25
26	27	28	29	30

Reports from 3XL test contains 4 pages:

REPORT No: 173	REPORT No: 17-1	REPORT No: 17-2	REPORT No: 17-3
POWER : 0.0 kW	13:58 09.06.17	13:58 09.06.17	13:58 09.06.17
FUEL FLOW: 0.0 l/h	EXAMPLE	EXAMPLE	EXAMPLE
TEMPERAT.: 0 °C	HEADER	HEADER	HEADER
T AMB. : --- °C	FOR	FOR	FOR
T GAS. : --- °C	3XL TEST	3XL TEST	3XL TEST
O2.....: 0.64 %	LIGHT OIL	LIGHT OIL	LIGHT OIL
CO2.....: --- %	O2R.....: 3 %	O2R.....: 3 %	O2R.....: 3 %
THC ..: --- %	↓ AVERAG. TIME: 10 sec	↓ AVERAG. TIME: 10 sec	↓ AVERAG. TIME: 10 sec

Average from all 3 tests

Average from the 1st test

Average from the 2nd test

Average from the 3rd test

5.9. Printer

5.9.1. Printing the contents of a screen

This is not possible for the screen **(D1)**. A screen may not be printed whilst data is being entered using the alphanumeric keyboard until this activity has been ended.

A grey rounded rectangular button with the word "PRINT" in black capital letters.

- prints the contents of a screen

5.9.2. Printing of all results

A grey rounded rectangular button with the word "DATA" in black capital letters.

- open the first results screen **(D1)**

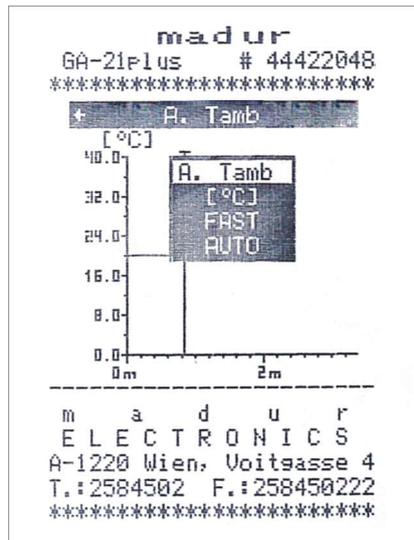
A grey rounded rectangular button with the word "PRINT" in black capital letters.

- start a print-out containing all measured results

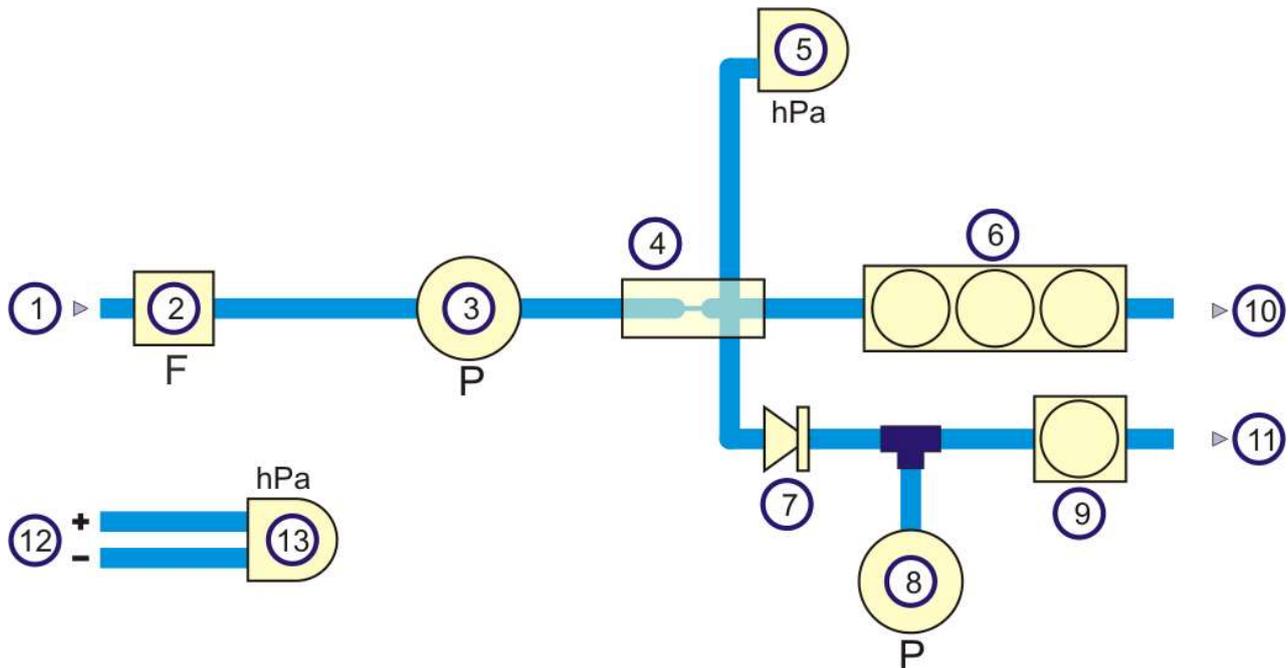
If the current values are displayed they will be printed; if the averaged values are displayed then these will be printed.

```

madur
GA-21plus # 44422048
*****
00:00.39 01.01.23
-----
FUEL: LIGHT OIL
Ozrel 3 %
AVERAG. TIME: 2 sec
-----
BOILER POWER: 0.0 kW
FUEL FLOW : 0.0 l/h
TEMPERATURE : 0 °C
-----
TA 20.0°C TG **E**°C
Oz **E**% CO2 --- %
-----
CO 0PPM
NO 0PPM
NO2 1PPM
--- --- PPM
--- --- PPM
NOx 1PPM
NOxrel --- mg/m³
-----
EXCESS AIR...: ---
STACK LOSS...: --- %
EFFICIENCY...: --- %
EFFICIENCY*..: --- %
-----
m a d u r
E L E C T R O N I C S
A-1220 Wien, Voitsasse 4
T.:2584502 F.:258450222
*****
    
```



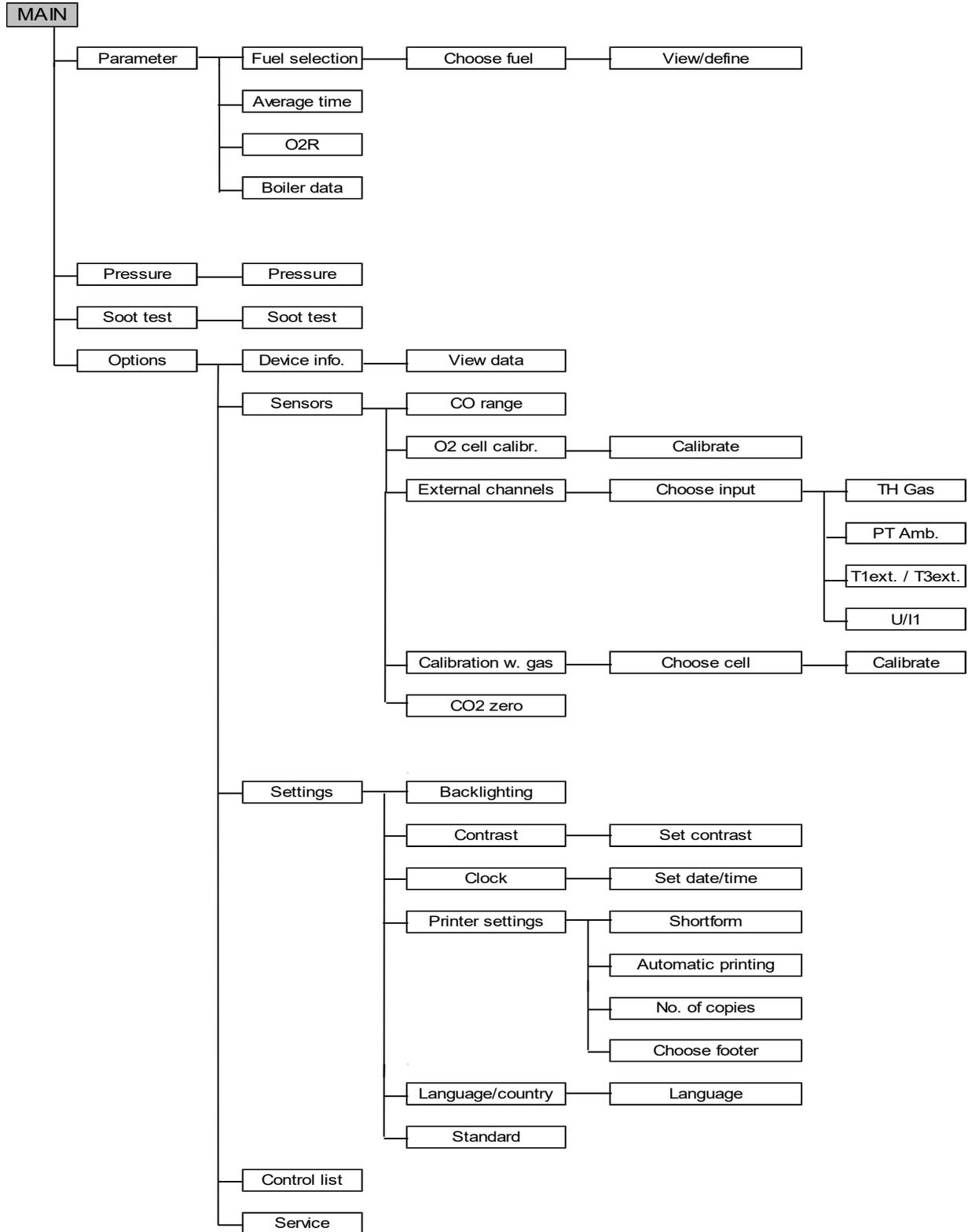
6. GAS BLOCK DIAGRAM



1. Gas inlet
2. Filter
3. Main gas pump
4. Flow control sensor
5. Pressure sensor
6. Electrochemical cells in the main gas channel
7. Check valve
8. Purging pump
9. Electrochemical cell in the secondary gas channel
10. Gas outlet 1
11. Gas outlet 2
12. Differential pressure inlets for the duct's flow velocity measurement
13. Second pressure sensor

7. MENU STRUCTURE

7.1. Structure of the main menu



7.2. Structure of the menu STORE

