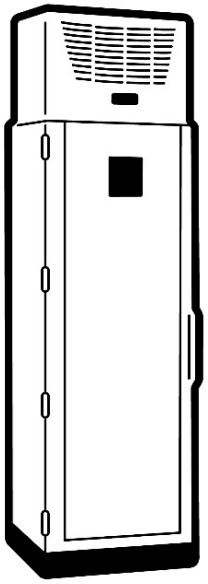
gasmet

A Nederman Company

# Continuous Mercury Monitoring System (CMM & CMM AutoQAL)



## Instruction and Operating Manual

Version E.4.2

# Warranty Statement

This warranty applies to the Gasmet brand name products sold with this warranty statement. This warranty is applicable in all countries and may be enforced in any country where Gasmet Technologies Oy or its subsidiaries or its authorized service providers offer warranty service subject to the terms and conditions set forth in this warranty statement. The warranty period varies by product, check the warranty period, if necessary.

Gasmet Technologies Oy and its subsidiaries guarantee that all products manufactured and sold by it are free of defects in materials and workmanship under normal use during the warranty period.

The products of Gasmet Technologies Oy and its subsidiaries are manufactured using new materials or new and used materials equivalent to new in performance and reliability. Spare parts may be new or equivalent to new.

Gasmet Technologies Oy and its subsidiaries agree to either replace or repair free of charge (Ex Works Vantaa, Incoterms 2020) any such defective product or part that is returned to its repair facility within one (1) year of the delivery date. All parts or products removed under this warranty become the property of Gasmet Technologies Oy or its subsidiaries. The replacement product or part takes on the warranty status of the removed product or part.

The warranty does not extend to any product from which the serial number has been removed or that has been damaged or rendered defective (a) as a result of accident, misuse, abuse, normal wear of components or other external causes; (b) by operation outside the usage parameters stated in the user documentation that is provided with the product; (c) by the use of parts not manufactured by Gasmet Technologies Oy and its subsidiaries; or (d) by modification or service by anyone other than Gasmet Technologies Oy and its subsidiaries.

Gasmet Technologies Oy and its subsidiaries are not liable for any damages caused by the product or the failure of the product to perform, including any loss of profits or savings, incidental damages, or consequential damages.

# Recycling Information

At the end of the product's life cycle, we encourage you to recycle the product in accordance with best local recycling practices. Contact your local authorities for more information on recycling of your old product. You can also contact Gasmet Technologies Oy for advice (contact@gasmet.fi). Please note, that the Test gas Generator contains liquid mercury and possibly liquid mercury chloride. Contact your local authorities for proper recycling of mercury.

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# Introduction

This instructions manual provides information of the Gasmet Continuous Mercury Monitoring System CMM. Please read this manual carefully prior to using the system. Improper use of the system may damage the equipment.

# 1. Gasmet CMM Overview

## 1.1. Basic structure

The Gasmet CMM is designed for continuous total mercury (atomic mercury $Hg^0$ and oxidized $Hg^{2+}$, $HgCl_2$) monitoring and the measurement is based on Cold Vapor Atomic Fluorescence (CVAF). Integrated high temperature dry thermal converter converts all Hg compounds to atomic mercury.

The Gasmet CMM is designed for on-line measurements. It measures hot, wet and corrosive gas streams. All sample wetted parts of the Gasmet CMM are heated up to 180 °C.

The Gasmet CMM consists of the Gasmet CVAF mercury analyzer, the Gasmet test gas generator for atomic mercury and mercury chloride, and the Gasmet Hg dilution probe (Figure 1). All parts of the system are 19” rack mounted and are installed on pullout shelves. The Gasmet CMM includes all power connections and temperature controllers for heated line and heated sample probe. The operation of the system is fully automatic and controlled by the Gasmet MAUI application software. Additionally, all functions of the Gasmet CMM can also be performed manually.

The built-in control panel PC and the Gasmet MAUI software control the CMM fully automatically. The measuring data can be transferred from the CMM to control room with analog output 4-20 mA. The alarms are transferred with relay contacts. The Gasmet CMM provides alarm functions such as System alarm, Service request, Maintenance, Concentration alarm and Result valid.

The Gasmet CMM is air conditioned by a compressor-cooling unit.

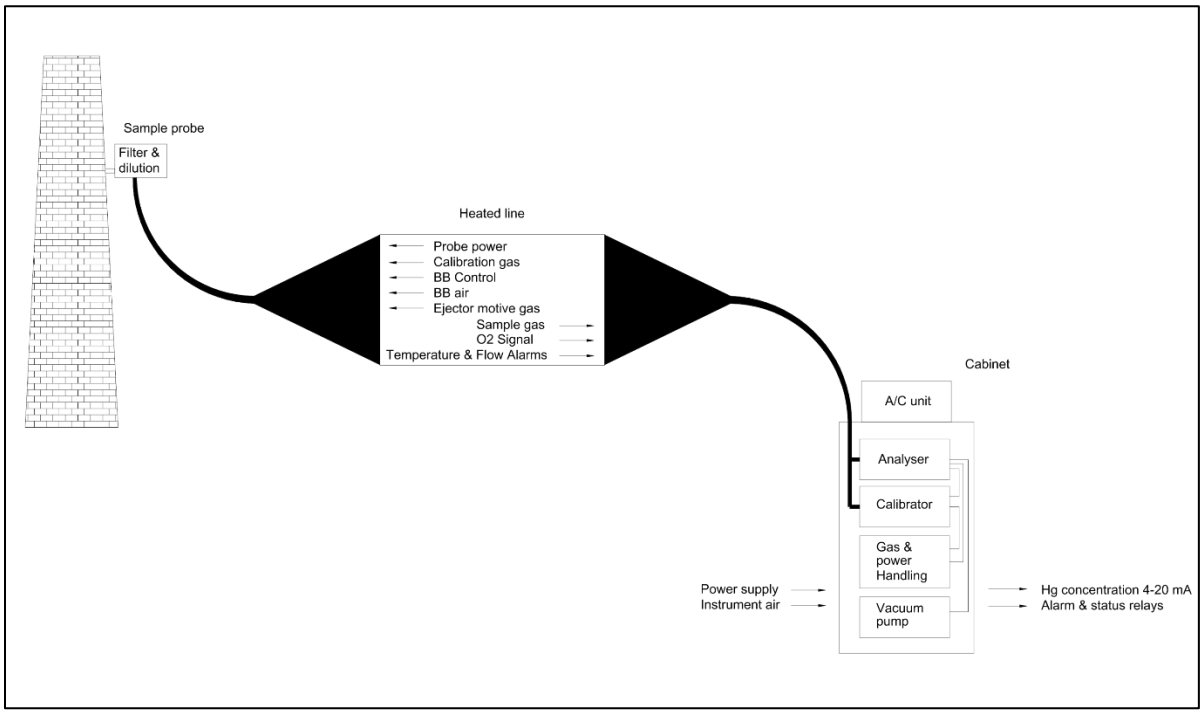



*Figure 1. A general view of the CMM*

# 2. Technical data

## System specifications

| | | |
|---|---|---|
| **Measuring principle** | Cold vapor atomic fluorescence (CVAF) with extractive filtration, dilution and thermal conversion | |
| **Measuring range** | Minimum certified range 0 - 5 µg/m³<br>Maximum certified range 0 - 1000 µg/m³ | |
| **Sample conversion** | Integrated high temperature thermal converter | |
| **Source** | Low pressure mercury vapor lamp | |
| **Minimum detection limit for total mercury** | 0.02 µg/m³, total Hg (complete system, with dilution) | |
| **Operation wavelength** | 253.7 nm | |
| **Power supply** | Standard version: | 400 VAC, 3 x L+N+PE |
| | Power consumption ~ 8kW (the full CMM with heated lines, 25 m) | |
| | US version: | 200 VAC, 3 x L+N+PE |
| **Response time** | Typically < 120 s, depending on the sample line length and measurement time | |
| **Dilution probe** | Operating principle: | Ejector with critical orifice |
| | Material: | SS 316, glass coated sample wetted parts |
| | Operating temperature: | Maximum setting 250 °C (filter housing temperature) |
| | Filter element: | Glass coated SS 316, 2 µm |
| | Dust load: | < 2 g/m$^3$ |
| | Flow alarm: | Yes |
| | **Heated probe tube:** | |
| | Material: | SS 316, glass coated sample wetted parts |
| | Temperature: | Maximum setting 250 °C |
| | Length: | 122 cm<br>60cm (optional) |

| | | |
|---|---|---|
| | Mounting flange: | DP100PN16 |
| **Air conditioning** | Cooling capacity:<br>Internal circulation: | A35 °C / A35 °C 1500 W<br>500 $m^3$/h |
| **Test Gas Generator for $Hg^0$** | Vapor generation from saturated source and dilution<br>Approved for regulatory zero and $Hg^0$ span checks | |
| | Dilution gas flow control:<br>Span gas flow control:<br>Hg source temperature: | MFC 0 – 20 l/min<br>MFC 0 – 20 ml/min<br>1 – 10 °C |
| | Calibration concentration ranges converted to $Hg^0$:<br>Saturated Hg source: | <br>5 µg/$m^3$ |
| **CMM AutoQAL for $HgCl_2$ gas generator** | Operation principle: Liquid $HgCl_2$ solution sprayed and vaporized to dilution gas | |
| | Automatic $HgCl_2$ test gas generator<br>Approved for regulatory $HgCl_2$ span checks<br>Validation interval 4 weeks | |
| | $HgCl_2$ span target value is 70 – 90% of system measuring range | |
| **Detector** | Photon detection unit with photon counting | |
| **Heated sample line** | Standard 230 V version:<br>US 115 V version:<br>Tube size:<br>Core material:<br>Temperature:<br>Fittings:<br>Power density:<br>Dilution and blowback air: | 2 - 47 m (according to site)<br>2 – 23.5 m (according to site)<br>2 * 6/8 mm<br>PFA Teflon core<br>Maximum 200 °C<br>8 mm Swagelok<br>200 watts/meter<br>Unheated 2 * 4/6 mm Teflon core, 6 mm Swagelok |
| | Analyzer and test gas generator are connected to dilution probe with combined heated line which divides into two parts on both ends. | |

| | | |
|---|---|---|
| **Instrument air preparation** | Instrument air inlet: | 6 – 10 bars, 60 l/min, oil free, dew point <-5 °C, 8 mm Swagelok fittings |
| | Instrument air filtration: | 3-stage filter unit |
| | Nitrogen generator: | Capacity 99 % N2, 8 l/min, 5-6 bars, efficiency ratio 20 % |
| | Calibration gas drying: | Absorption dryer, capacity -30 °C |
| | Mercury scrubber: | Absorption scrubber |
| | Vacuum pump: | WOB-L piston twin headed |
| **Input signals** | External standby control | |
| **Output signals** | **5 device status contacts:** System alarm, service request, maintenance status, result valid and concentration alarm<br>4 analog signals (4 - 20 mA) for measurement data<br><br>**Concentration alarm:**<br>Concentration alarm is a user defined concentration alarm signal. It can be defined from MAUI Program settings menu (Concentration alarm limits, Low and High). The alarm is only connected to a digital output signal in the CMM cabinet, and is not visible in MAUI display or measurement data.<br><br>**Bus Output:**<br>Output format: Modbus TCP/IP | |
| **Measuring data outputs** | The CMM system is equipped with 4 analog outputs representing the result total Hg concentration with different ranges. | |
| | Analog output range: | 4 – 20 mA. Active, load 350 Ω max. |
| **Enclosure** | Dimensions without the door handles: (H x W x D): | Control unit 2120 x 600 x 600 cm (cooling unit on top) |
| | Material: | Bake painted steel |
| | IP class: | IP54 |
| **Weight** | Sampling probe: | approximately 27 kg (dilution probe + probe tube) |
| | Cabinet: | approximately 230 kg (the full CMM cabinet) |

| | |
|---|---|
| **Product compliance** | CE, UKCA |
| **Operating system** | Microsoft Windows CE |
| **Application software** | MAUI |

## Performance specifications

| | |
|---|---|
| **Zero-point calibration** | 24 hours |
| **Span calibration** | 24 hours |
| **Zero-point drift** | < 2% of measuring range per calibration interval |
| **Sensitivity drift** | < 2% of measuring range per calibration interval |
| **Linearity deviation** | < 2% of measuring range |

## Sample gas conditions

| | |
|---|---|
| **Sample gas temperature** | Up to 400 °C (max in stack) |
| **Sample gas pressure** | 0.9 – 1.2 bars (in stack) |
| **Sample gas dust content** | 0 – 2 g/m³ |
| **Sample gas temperature** | Up to 400 °C (max in stack) |

## Operating and storage conditions

| | |
|---|---|
| **Control unit ambient temperature** | 5 – 40 °C |
| **Sampling probe ambient temperature** | -20 – 50 °C |
| **Storage temperature** | -20 – 60 °C, non-condensing |

# 3. Preparation use of the system

## 3.1. Package

The Gasmet CMM is shipped in several cardboard boxes. To open a box, first open the lid of the box. Remove any additional smaller items on the top of the contents. Finally lift the contents out of the box.

All gas fittings are closed with caps in order to prevent contamination by dirt and dust. Please do not remove caps until you connect the sample gas lines.

## 3.2. Contents of the Gasmet CMM delivery

The Gasmet CMM delivery contains following parts:

1. System cabinet with air conditioning, electrical connector plate, vacuum pump, instrumentation air processing system and electrical and signal cables inside the cabin
2. The Gasmet CVAF mercury analyzer
3. The Gasmet mercury test gas generator
4. The Gasmet sample probe
5. Heated sample lines (lengths according to the application)
6. Accessories
    - The Gasmet USB flash drive
        - The Gasmet CMM manual
        - The Gasmet CMM technical drawings
    - Printed manuals
    - Filter and O-rings for the sample probe
    - The gasket of the probe, bolts and nuts

Insulation rings 6 pieces

## 3.3. Transportation and storing

All parts of the Gasmet CMM must be stored, installed, and operated in a dry and frost-free place. It is essential to avoid condensation within the analyzer and the test gas generator. The environment should be clean enough so that no dirt will accumulate inside the instrument enclosures. Store the equipment in following conditions:

- 0 - 60 °C storage temperature
- 0 - 95 % relative humidity, non-condensing

None of the individual instruments of the Gasmet CMM should be exposed to strong mechanical vibration or shocks. Shocks during transport, for example, can cause serious damage. When transporting the instruments, use the original boxes with original shock absorbing materials. Transport always all parts of the system separately.

## 3.4. Installation

Improper handling of any components inside the Gasmet CMM may damage the equipment. Thus, adjusting any components inside the Gasmet CMM voids warranty. Be always very careful if you move the instrument.

### 3.4.1. Explosion protection

For your own safety, the Gasmet CMM must not be used in hazardous areas. The standard cabinet is not explosion proof.

Gasmet Technologies Oy takes no responsibility if the Gasmet CMM is used in hazardous areas.

### 3.4.2. Aggressive condensate and temperature

Aggressive condensate may have formed. Wear protected glasses and proper protective clothing. Wear protective gloves, because surfaces' temperatures can be high.

The Gasmet CMM must be mounted vertically. An extreme inclination of the system cabinet may interfere with the operation of the analyzer. The installation location must preferably be free of strong vibrations, as well. It is recommended that the instrument is operated in the following environmental conditions:

- 0 - 40 °C, optimum 15 - 25 °C, non-condensing
- < 90 % relative humidity at 20 °C, non-condensing

The ambient temperature of installation location must preferably be stable. The Gasmet CMM cabinet includes air conditioning unit. Never block the air circulation or use The Gasmet CMM in dusty environments. Dust can block the air circulation and penetrate into the cabinet damaging analyzer's electronics.

## 3.5. Listing of connections

All external power and signal connections and gas connections are located on the connector plate Figure 2 and Table 1). The plate is located on the back side of the cabinet.

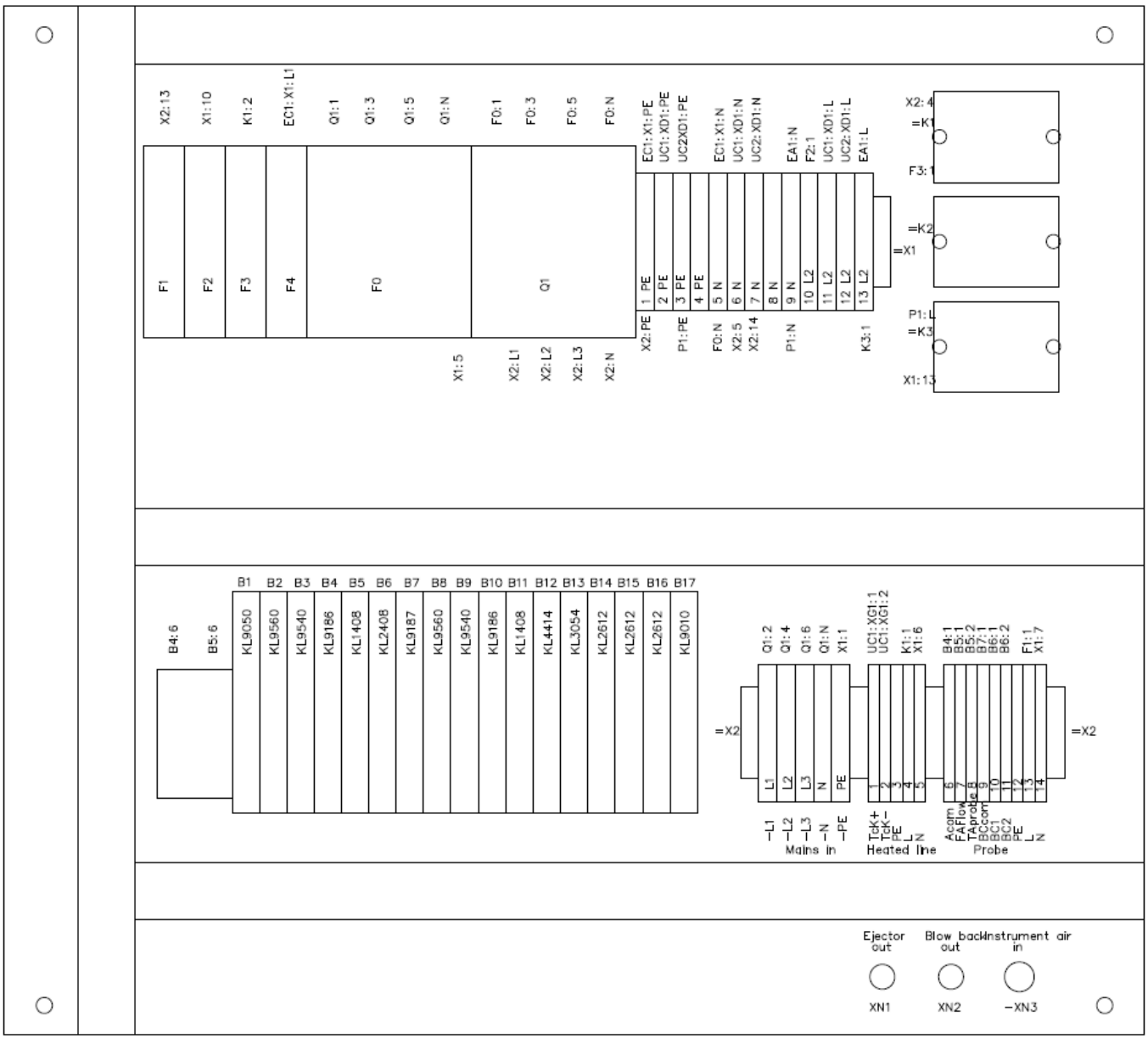



*Figure 2. Connector plate layout*

EPLAN electrical schemes are always included in the Gasmet CMM delivery, as a separate file.

| Module | *Pin* | Signal | Information |
|---|---|---|---|
| B10 KL9186 | 1 | Stand by | Control by free contacts. Closed = standby |
| B11 KL1408 | 1 | Stand by | Control by free contacts. Closed = standby |
| B14 KL2612 | 1 | System alarm | Free contacts. Alarm = open |
| B14 KL2612 | 3 | System alarm | Free contacts. Alarm = open |
| B14 KL2612 | 2 | Service request | Free contacts. Alarm = open |
| B14 KL2612 | 4 | Service request | Free contacts. Alarm = open |
| B15 KL2612 | 1 | Maintenance | Free contacts. Maintenance on = open |
| B15 KL2612 | 3 | Maintenance | Free contacts. Maintenance on = open |
| B15 KL2612 | 2 | Concentration alarm | Free contacts. Alarm = open |
| B15 KL2612 | 4 | Concentration alarm | Free contacts. Alarm = open |
| B16 KL2612 | 1 | Results valid | Free contacts. Results valid = closed |
| B16 KL2612 | 3 | Results valid | Free contacts. Results valid = closed |
| B16 KL2612 | 2 | $O_2$ Sensor Calibration | Free contacts. Calibrate = closed |
| B16 KL2612 | 4 | $O_2$ Sensor Calibration | Free contacts. Calibrate = closed |
| B12 KL4414 | 1 | Hg concentration, analog output1 + | 4 – 20 mA, load max 350 Ω |
| B12 KL4414 | 3 | Hg concentration, analog output1- | 4 – 20 mA, load max 350 Ω |
| B12 KL4414 | 2 | Hg concentration, analog output2 + | 4 – 20 mA, load max 350 Ω |
| B12 KL4414 | 4 | Hg concentration, analog output2- | 4 – 20 mA, load max 350 Ω |
| B12 KL4414 | 5 | Hg concentration, analog output3 + | 4 – 20 mA, load max 350 Ω |
| B12 KL4414 | 7 | Hg concentration, analog output3- | 4 – 20 mA, load max 350 Ω |
| B12 KL4414 | 6 | Hg concentration, analog output4 + | 4 – 20 mA, load max 350 Ω |
| B12 KL4414 | 8 | Hg concentration, analog output4- | 4 – 20 mA, load max 350 Ω |
| B13 KL3054 | 1 | $O_2$ concentration | 4 – 20 mA |
| B13 KL3054 | 3 | $O_2$ concentration | 4 – 20 mA |
| X2 | L1 | Mains in L1 | 230/400 VAC, 16 A, TN-S, 2.5-6.0 $mm^2$ |
| X2 | L2 | Mains in L2 | 230/400 VAC, 16 A, TN-S, 2.5-6.0 $mm^2$ |
| X2 | L3 | Mains in L3 | 230/400 VAC, 6-32 A, TN-S, 2.5-6.0 $mm^2$ |
| X2 | N | Mains in N | 230/400 VAC, 6-32 A, TN-S, 2.5-6.0 $mm^2$ |
| X2 | PE | Mains in PE | 230/400 VAC, 6-32 A, TN-S, 2.5-6.0 $mm^2$ |
| X2 | 1 | TcK+ | Heated line |
| X2 | 2 | TcK- | Heated line |
| X2 | 3 | PE | Heated line |
| X2 | 4 | L | Heated line |
| X2 | 5 | N | Heated line |
| XN1 | | Ejector motive gas to probe | 6 mm OD tube, Swagelok |
| XN2 | | Blowback air to probe | 6 mm OD tube, Swagelok |
| XN3 | | Instrument air in | 6– 8 bars, 8 mm OD tube, Swagelok, 60 l/min |
| XE | PE | Potential equalizer | Potential equalizer bar on the right hand side of the cabinet |

Table 1. Connector plate connections

### 3.5.1. Mains

**Only professional electrician is allowed to do the connections!**

Main supply for the CMM is 230/400 VAC 3*(16-32) A TN-S. The conductor area of an electrical cable is 2.5-6 $mm^2$ and it is depended on the length of the electrical cable and sample line. Electricity and protective earth are connected to connector bar X2. Do not connect power to the system before all electrical and gas connections are properly made.

### 3.5.2. Signals

Alarm signals, System error, Service request, Maintenance, Concentration and Result Valid are transferred to the control room from connection bar as free relay contacts. The potential free contacts of the relay terminals have nominal voltages of 125 VAC / 30 VDC. Measuring data 4-20 mA and remote signals are active and electrically isolated to 500 V. Analog output scales can be set in the CMM MAUI software.

### 3.5.3. Gases

The system is connected to instrument air (6-8 bars). The air consumption of the system is approximately 60 l/min. Instrument air hose 8 mm OD is connected to XN3.

### 3.5.4. Sample line

When connecting a sample line, it should be remembered that nameplate is on the cabinet side. Sample line is exported to the cabinet though the inlet which located at the top of the cabinet. Inside of the cabinet will only be a line branched parts. Attaching the probe should be ensured that probe can be pulled out of the duct without removing the sample line. Sample line is attached 30 cm intervals by appropriate cable shelf brackets. The minimum bend radius of the sample line is 30 cm. When the sample line is installed must be ensured that line does not bend too much.

The sample line's shorter heated branch is connected to the analyzer and the longer one to the test gas generator. Connectors must be thermally insulated with insulation rings. Electrical and signal lines and gas tubes are connected according to Table 1 and Table 2.

The heated lines may emit odor and/or visible fumes during the first heating to full temperature. The first heating needs to be performed in a well-ventilated area or outside to minimize exposure to the fumes.

### 3.5.5. Probe

Before the probe installation select the optimum sampling point in accordance with general guidelines or agree on a sampling point with the responsible authorities. Place the sampling point in such a way that there is sufficient space for installation and removal of the probe. Easy access to the probe must be ensured to facilitate later maintenance work. Make sure the installation flange has at least 5 degrees downwards orientation compared to the stack.

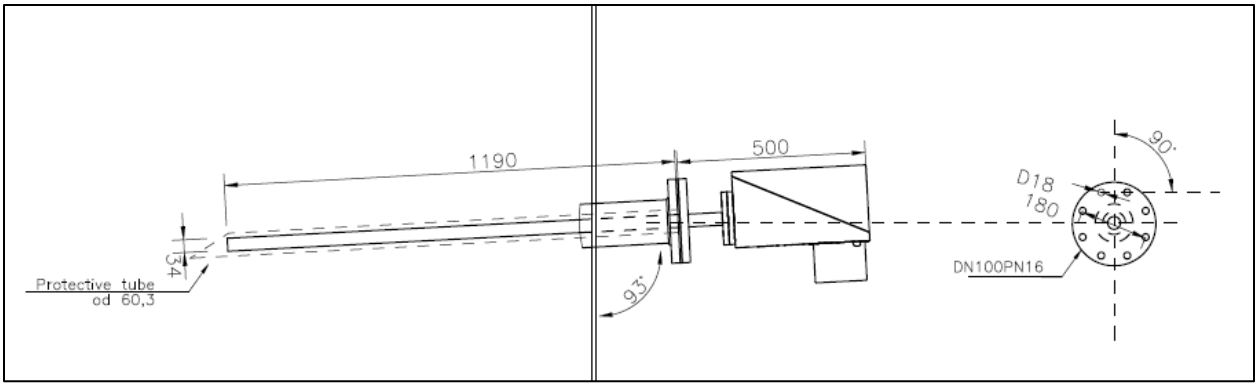



Figure 3. The probe installation

Probe power supply, valve controls, alarm cables and gas tubes are placed inside the sample line. Wires are connected to the terminal box, which is located below the probe. It is beneficial to have instrument air and air pistol near the probe on maintenance point of view (Figure 3 and Table 2).

| **SAMPLE LINE FROM CABINET TO PROBE WIRING** | | | |
|---|---|---|---|
| **Wire Color** | **Signal** | **Probe** | **Cabin** |
| | | | |
| **MAINS SUPPLY FOR PROBE** | | | |
| green/yellow | PE | X1:1 | X2:12 |
| brown | L | X1:4 | X2:13 |
| blue | N | X1:6 | X2:14 |
| | | | |
| **ALARM FROM THE PROBE** | | | |
| shield | shield | X1:2 (PE) | NC (Not Connected) |
| red | TAProbe | X1:11 | X2:8 |
| black | Alarm com | X1:12 | X2:6 |
| orange | FAFlow | X1:13 | X2:7 |
| | | | |
| **OXYGEN SENSOR CONTROL** | | | |
| shield | shield | O2BOX:5 (PE) | NC |
| red | O2ch2 (calib.) | O2BOX:1 | B16:2 |
| black | O2sig | O2BOX:2 | B13:1 |
| brown | O2com | O2BOX:4 | B13:3 |
| grey | 0V (calib.) | O2BOX:3 | B16:4 |
| | | | |
| **VALVE CONTROL** | | | |

| | | | |
|---|---|---|---|
| red | BC1 | X1:8 | X2:10 |
| orange | BC com | X1:9 | X2:9 |
| grey | BC2 | X1:10 | X2:11 |
| | | | |
| **24V SUPPLY** | | | |
| red | void | NC | NC |
| blue | void | NC | NC |
| | | | |
| **LINE HEATING** | | | |
| green | TCK sensor + | - | X2:1 |
| white | TCK sensor - | - | X2:2 |
| green/yellow | PE | - | X2:3 |
| brown | L (mains) | - | X2:4 |
| blue | N | - | X2:5 |

*Table 2. Probe connections*

### 3.5.6. A/C unit

The Gasmet CCM system includes a thermostat to control the cabinet temperature. On the right-hand side of the thermostat is attached a cable with prewired connector (Table 3). Air-conditioned cabinet temperature is factory set to 28 °C.

| Connector | Pin | Signal | Colour |
|---|---|---|---|
| :X1 | L1 | Mains in L | BROWN |
| :X1 | N | Mains in N | BLUE |
| :X1 | PE | Mains in PE | GNYE |
| :X1 | 4 | Alarm out | BLACK |
| :X1 | 5 | Alarm out | WHITE |

*Table 3. A/C unit connections*

### 3.5.7. Analyzer

Analyzer signal, power and tube connectors are located on the back panel of the analyzer, see Figure 4 and Table 4. All wires and tubes which are indented to be attached to the analyzer, except heated line, are already attached to the bracket on the back of the analyzer's self.

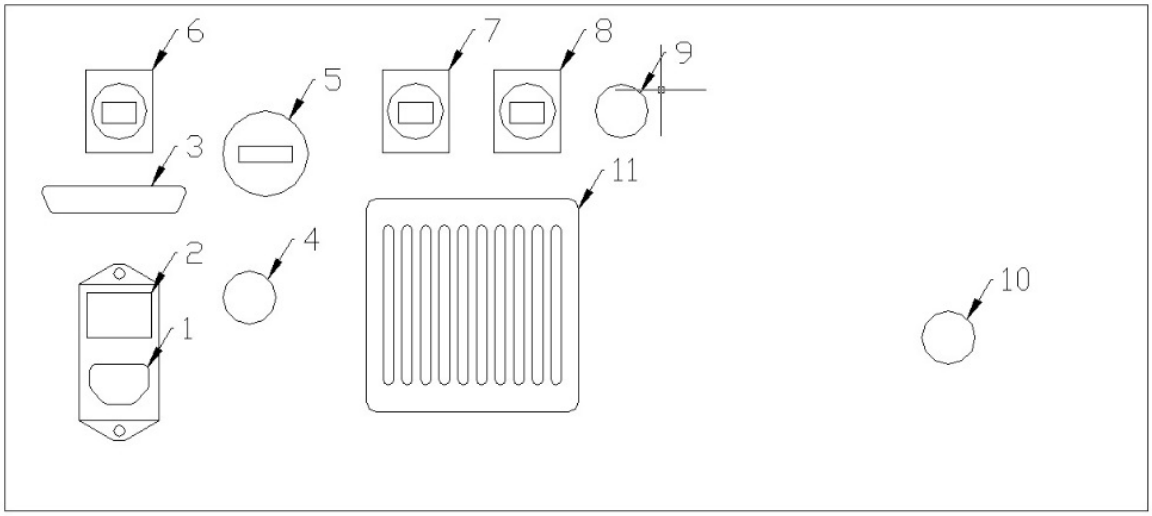



*Figure 4. Analyzer back plate layout*

| Ref | Signal | Connector | Information |
|---|---|---|---|
| 1 | Mains in | IEC C14 | |
| 2 | | Fuse holder | 2* 240/4AT |
| 3 | Sensors | 10 pins connector | DFK-MSTB 2,5/10-STF-5,0 |
| 4 | Vacuum pump connector | 6 mm Swagelok PFA | |
| 5 | USB | USB 2.0 | For memory stick |
| 6 | I/O control | Ethernet connector RJ-45 | K-bus |
| 7 | Remote access connector | Ethernet connector RJ-45 | CERHOST software or FTP-Protocol |
| 8 | Test gas generator control | Ethernet connector RJ-45 | |
| 9 | I/O power | Socket | 24 VDC |
| 10 | Sample gas in | 8 mm Swagelok T-connector | Other end of T-connector connected to drain |
| 11 | Cooling | FAN | |

*Table 4. Analyzer connections*

### 3.5.8. Test gas generator

Test gas generator signal, power and tube connectors are located on the back panel of the analyzer, see Figure 5 and Table 5. All wires and tubes which are indented to be attached to the test gas generator, except the heated line, are already attached to the bracket on the back of the test gas generator's shelf.

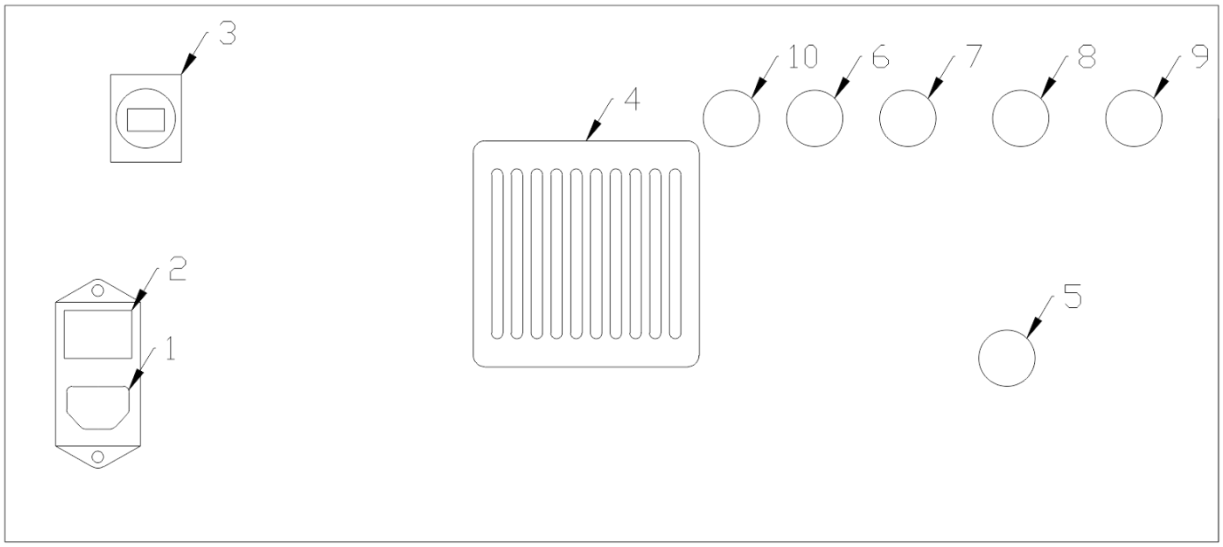



*Figure 5. Test gas generator back plate layout*

| Ref | Signal | Connector | Information |
|---|---|---|---|
| 1 | Mains in | IEC C14 | |
| 2 | | Fuse holder | 2* 240/4AT |
| 3 | Control | Ethernet connector RJ-45 | |
| 4 | Cooling | FAN | |
| 5 | Calibration gas out | 8 mm Swagelok | |
| 6 | $HgCl_2$ Waste | ¼" Swagelok PFA (optional) | |
| 7 | $HgCl_2$ Input | ¼" Swagelok PFA (optional) | |
| 8 | Zero gas input | 6 mm Swagelok | |
| 9 | Bath gas input | 6 mm Swagelok | |
| 10 | Waste gas out | 6 mm Swagelok | |

*Table 5. Test gas generator connections*

# 4. Modbus

Modbus is communication protocol, initially developed as serial communication protocol, for transferring data over serial lines between different electronic devices. The device requesting the information is called “Modbus Master” or “Modbus Client”. The device supplying the requested information is called “Modbus Slave” or “Modbus Server”. In a standard Modbus network, there is only one Master and can have multiple slaves. For more details check Modbus application protocol specification documentation.

MAUI supports the following communication methods to connect to external systems.

- Modbus TCP

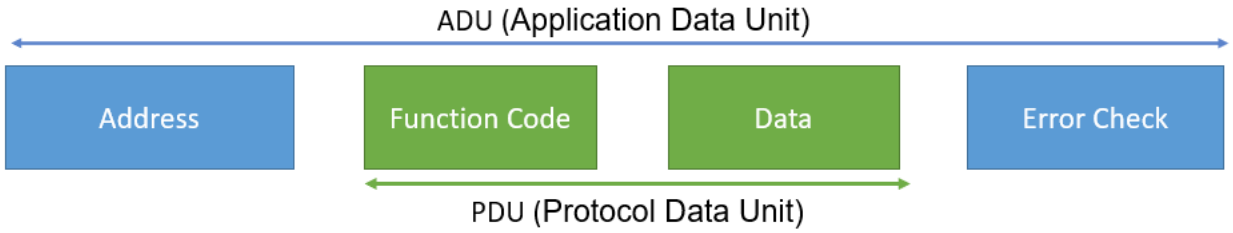
MAUI can act as Slave/Server or Master/Client depending on the configurations. Consequently, the external master can request result data directly from MAUI. When Modbus is activated, MAUI monitors the output port for any requests, and replies to valid messages with latest results information.

MAUI can process and respond immediately to any number of requests sent by the master. The only requirement is that there is a 2 ms interval between messages, otherwise the message is interpreted as one message. Also, if there is a delay longer than 2 ms between characters in the request message, the message is interpreted as two separate messages.

## 4.1. Modbus Frame Format

The MODBUS protocol defines a simple protocol data unit PDU, independent of underlying communication layer. If there is a need of additional fields, that can be added to ADU by the network or buses.

The Modbus RTU format follows the data with a cyclic redundancy check to ensure the reliability of data during transmission. TCP/IP does not require CRC calculation, as lower layers already provide checksum protection.



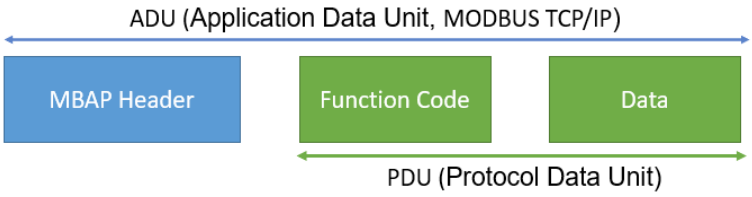

PDU cannot exceed 253 bytes irrespective of underlying communication layer (RS232, RS485, TCP/IP)

| | Address | PDU (Function code + Data) | Error Check (CRC) |
|---|---|---|---|
| RS232/RS485 | 1 byte | 253 bytes | 2 bytes |
| TCP/IP | 7 bytes | 253 bytes | - |

## 4.2. Modbus TCP

Modbus TCP is a Modbus variant used for communications over TCP/IP networks, connecting over port 502.

- TCP/IP Port: 502, configurable
- MBAP Header is 7 bytes long.




## 4.3. Passive & Active

MAUI have two modes of operation, User can select only one option at a time under configurations.

- Send result passively
  - Data is sent passively to Modbus slave address whenever data is updated in MAUI
  - Data is sent to remote Modbus server using FC-16 command, check Modbus application protocol specification documentation for function code 16.
- If above option (Send results passively) is not used, by default, MAUI acts as server, and wait for input commands.

## 4.4. Data Encoding

To support floating-point number (32-bit IEEE-754 single-precision float), byte order is

- Hight byte first
- High word first

## 4.5. Data Storage & signals to/from MAUI

Information is stored in the device (MAUI) in 2 different tables.

| Coil/Register Number | Data Address | Type/Access | Table | Size (Data type) | MAUI Usage | Function code |
|---|---|---|---|---|---|---|
| 1-9999 | 0000 to 270E | Read-Write | Discrete Output Coils | 1 bit | 64 channels for alarms (Digital output signals) | 01 (Reading) |
| 40001-49999 | 0000 to 270E | Read-Write | Output Holding Registers | 16 bits | Measurement values (Analog output signals)<br>*Floating point | 03 (Reading) |

* Analog input/output values are transmitted in IEEE-754 single precision floating point format, as floating-point format is not a part of the Modbus specification, MAUI uses two Modbus registers to accommodate float point value consisting of a sign bit, an 8-bit exponent and a 23-bit mantissa in the big-endian format as MSW-LSW.

| **Request PDU:** | | |
|---|---|---|
| Function code | 1 Byte | **0x01** |
| Starting Address | 2 Bytes | 0x0000 to 0x003F |
| Quantity of coils | 2 Bytes | 1 to 64 (0x0001-0x0040) |

## 4.6. Supported Function codes

| **Function code** | **Function code (Hex)** | **Function** | **Description** |
|---|---|---|---|
| 01 | 0x01 | read *n* bits | Read Coils, request for bit by bit addressed data from master (client) to slave (server) |
| 03 | 0x03 | read *n* words | Read Holding Registers, request for word by word addressed data from master (client) to slave (server) |
| 06 | 0x06 | write 1 word | Write Single Register, sending word address data from master (client) to slave (server) |

## 4.7. Address Allocation, function codes & response

### 4.7.1. Reading & Writing Coils (Digital Signals, FC-1)

Valid Coil Number: 1-64, First Address: 0x0000 (Hex), 64-coils are supported.
Valid Address range (Hex): 0x0000 - 0x003F

#### 4.7.1.1. FC-01 (0x01) Reading Coils

This function code is used to read digital signals.

| **Response PDU:** | | |
|---|---|---|
| Function code | 1 Byte | **0x01** |
| Byte count | 1 Byte | **N*** |
| Coil Status | **n Byte** | n = N or N+1 |

***N** = Quantity of Outputs / 8, if the remainder is different of 0 => N = N+1

| **Error:** | | |
|---|---|---|
| Function code | 1 Byte | **Function code + 0x80** |
| Exception code | 1 Byte | 01 or 02 or 03 or 04 |

Address Mapping on MAUI side for digital output signals.

| COIL Number (address hex) | BIT position (64-bit) | Description | Status | Group |
|---|---|---|---|---|
| 1 (0000) | BIT 0 | System Alarm (Overall system) | 0=No Alarm, 1=Alarm<br><br>For Result valid signal<br>1=Result is valid<br>0=Result is not valid | Overall system status signals |
| 2 (0001) | BIT 1 | Service Alarm (Overall system) | | |
| 3 (0002) | BIT 2 | Maintenance (Overall system) | | |
| 4 (0003) | BIT 3 | Result Valid (Overall system) | | |
| 5 (0004) | BIT 4 | Concentration Alarm (Overall system) | | |
| 6 (0005) | BIT 5 | N/A | Reserved, value 0 | |
| 7 (0006) | BIT 6 | N/A | | |
| 8 (0007) | BIT 7 | N/A | | |
| 9 (0008) | BIT 8 | Bath Temperature | 0=No Alarm, 1=Alarm | System alarms |
| 10 (0009) | BIT 9 | Evaporator Temperature | | |
| 11 (000A) | BIT 10 | Probe Temperature | | |
| 12 (000B) | BIT 11 | Instrument Air Pressure | | |
| 13 (000C) | BIT 12 | Lamp Temperature | | |
| 14 (000D) | BIT 13 | Oven Temperature | | |
| 15 (000E) | BIT 14 | Cell Temperature | | |
| 16 (000F) | BIT 15 | Line Temperature | | |
| 17 (0010) | BIT 16 | Cell Pressure | | |
| 18 (0011) | BIT 17 | Detector Error | | |
| 19 (0012) | BIT 18 | N/A | Reserved, value 0 | |
| 20 (0013) | BIT 19 | N/A | | |
| 21 (0014) | BIT 20 | N/A | | |
| 22 (0015) | BIT 21 | N/A | | |
| 23 (0016) | BIT 22 | N/A | | |
| 24 (0017) | BIT 23 | N/A | | |
| 25 (0018) | BIT 24 | Bath Pressure | 0=No Alarm, 1=Alarm | Service alarms |
| 26 (0019) | BIT 25 | Bath Flow | | |
| 27 (001A) | BIT 26 | Dilution Flow | | |
| 28 (001B) | BIT 27 | Cabinet Temperature | | |
| 29 (001C) | BIT 28 | Instrument Air Pressure | | |
| 30 (001D) | BIT 29 | Cabinet Cooler | | |
| 31 (001E) | BIT 30 | Pump | | |
| 32 (001F) | BIT 31 | Zero Check Error | | |
| 33 (0020) | BIT 32 | Hg0 Span Adjustment Error | | |
| 34 (0021) | BIT 33 | HgCl2 Span Check Error | | |
| 35 (0022) | BIT 34 | Hg0 Linearity Check Error | | |
| 36 (0023) | BIT 35 | Flow Alarm | | |
| 37 (0024) | BIT 36 | N2 Generator Pressure | | |
| 38 (0025) | BIT 37 | Ejector Pump Pressure | | |
| 39 (0026) | BIT 38 | Hg0 Span Check Error | Reserved, value 0 | |
| 40 (0027) | BIT 39 | N/A | | |

| | | | | |
|---|---|---|---|---|
| 41 (0028) | BIT 40 | Measuring Not Active | 0=Not Active, 1=Active | Ongoing operation (Maintenance) |
| 42 (0029) | BIT 41 | Manual Mode | | |
| 43 (002A) | BIT 42 | Flushing Sample | | |
| 44 (002B) | BIT 43 | Blowback | | |
| 45 (002C) | BIT 44 | Flushing | | |
| 46 (002D) | BIT 45 | Linearity Check | | |
| 47 (002E) | BIT 46 | Span Check | | |
| 48 (002F) | BIT 47 | Zero Check | | |
| 49 (0030) | BIT 48 | Standby | 0=Not Active, 1=Active | Result valid alarms |
| 50 (0031) | BIT 49 | System Alarm | | |
| 51 (0032) | BIT 50 | No Active Analyzed Result | | |
| 52 (0033) | BIT 51 | Result Range Exceeded | | |
| 53 (0034) | BIT 52 | Maintenance | | |
| 54 (0035) | BIT 53 | N/A | Reserved, value 0 | |
| 55 (0036) | BIT 54 | N/A | | |
| 56 (0037) | BIT 55 | N/A | | |
| 57 (0038) | BIT 56 | N/A | Reserved, value 0 | Reserved |
| 58 (0039) | BIT 57 | N/A | | |
| 59 (003A) | BIT 58 | N/A | | |
| 60 (003B) | BIT 59 | N/A | | |
| 61 (003C) | BIT 60 | N/A | | |
| 62 (003D) | BIT 61 | N/A | | |
| 63 (003E) | BIT 62 | N/A | | |
| 64 (003F) | BIT 63 | N/A | | |

### 4.7.2. Measurand Block: (Reading Data from MAUI, FC-3)

In the PDU Registers are addressed starting at zero. Two Modbus registers are used to accommodate floating point values (32-bit), starting address is 0 or always multiple of 2 and quantity of registers is also multiple of 2.

#### 4.7.2.1. Hg Measurement data

Register Number: 40001, First Register Address: 0x0000 Hex
Valid Address range (Hex): 0x0000 - 0x0001

Total components: 1
Total registers: 1*2 = 2 (two Modbus registers for measured value to accommodate floating point value)

| MAUI Components | Register Number | Register Address (Hex) | Coding (32-bit) |
|---|---|---|---|
| Hg | 40001-40002 | 0000 - 0001 | Float |

#### 4.7.2.2. Zero check data

Register Number: 40051, First Register Address: 0x0032 Hex
Valid Address range (Hex): 0x0032 - 0x0037

The last zero check result along with date/time and target, can be read using FC-3 command from the following registers:
Total components: 3
Total registers: 2*3 = 6 (two Modbus registers to accommodate 32-bit value)

| MAUI Components | Description | Register Number | Register Address (Hex) | Coding (32-bit) |
|---|---|---|---|---|
| Zero check | Result | 40051-40052 | 0032-0033 | Float |
| | Target | 40053-40054 | 0034-0035 | Float |
| | Date/Time | 40055-40056 | 0036-0037 | UINT32 (Epoch Unix Timestamp) |

#### 4.7.2.3. $HgCl_2$ span check data

Register Number: 40071, First Register Address: 0x0046 Hex
Valid Address range (Hex): 0x0046 - 0x004B

The latest/last HgCl2 span check results along with date/time and target, can be read using FC-3 command from the following registers:
Total components: 3
Total registers: 2*3 = 6 (two Modbus registers to accommodate 32-bit value)

| MAUI Components | Description | Register Number | Register Address (Hex) | Coding (32-bit) |
|---|---|---|---|---|
| HgCl2 span check | Result | 40071-40072 | 0046-0047 | Float |
| | Target | 40073-40074 | 0048-0049 | Float |
| | Date/Time | 40075-40076 | 004A-004B | UINT32 (Epoch Unix Timestamp) |

#### 4.7.2.4. Hg0 span check data

Register Number: 40091, First Register Address: 0x005A Hex
Valid Address range (Hex): 0x005A - 0x005F

The last Hg0 span check result along with date/time and target, can be read using FC-3 command from the following registers:
Total components: 3
Total registers: 2*3 = 6 (two Modbus registers to accommodate 32-bit value)

| MAUI Components | Description | Register Number | Register Address (Hex) | Coding (32-bit) |
|---|---|---|---|---|
| Hg0 span check | Result | 40091-40092 | 005A-005B | Float |
| | Target | 40093-40094 | 005C-005D | Float |
| | Date/Time | 40095-40096 | 005E-005F | UINT32 (Epoch Unix Timestamp) |

### 4.7.3. FC-06 (0x06) Write single register

This function code is used to write a single holding register. Modbus holding register address 150 (0x0096) is used for Modbus own commands.

| **Request PDU:** | | |
|---|---|---|
| Function code | 1 Byte | **0x06** |
| Register Address | 2 Bytes | 0x0096 |
| Register Value | 2 Bytes | 0x0000 to 0xFFFF |

| **Response PDU:** | | |
|---|---|---|
| Function code | 1 Byte | **0x06** |
| Register Address | 2 Bytes | 0x0096 |
| Register Value | 2 Bytes | 0x0000 to 0xFFFF |

| **Error:** | | |
|---|---|---|
| Error code | 1 Byte | 0x86 |
| Exception code | 1 Byte | 01 or 02 or 03 or 04 |

The functions supported are listed as follows:

| Function name | Register Number (Address in Hex) | Register value | Description |
|---|---|---|---|
| Cancel measurement | 40151 (0x0096) | 10 | Cancel any ongoing operation<br><br>This command cancels any ongoing operation and put MAUI in idle state. MAUI is ready to start continuous measurement |

| | | | |
|---|---|---|---|
| Start measurement | | 11 | This command will start continuous measurement |
| Start zero check | | 12 | Start zero check routine<br>In case this is triggered in Idle state, MAUI will start manual zero check routine, and at the end of the routine MAUI keeps manual mode on.<br>To exit manual mode, send cancel measurement command.<br>In case this is triggered in continuous measurement, MAUI will start zero check routine after the ongoing measurement cycle is finished. If “follow Hg0 span adjustment” is selected, MAUI will automatically start the Hg0 span adjustment routine after zero check. MAUI will resume the continuous measurement after triggered operation is complete. |
| Start Hg0 span adjustment | | 13 | Start Hg0 span adjustment routine<br>In case this is triggered in Idle state, MAUI will start manual Hg0 span adjustment routine, and at the end of the routine MAUI keeps manual mode on.<br>To exit manual mode, send cancel measurement command.<br><br>In case this is triggered in continuous measurement, MAUI will start Hg0 span adjustment routine, after the ongoing measurement cycle is finished.<br>MAUI will resume the continuous measurement after triggered operation is complete. |
| Start HgCl2 span check | | 14 | Start HgCl2 span check<br><br>In case this is triggered in Idle state, MAUI will start HgCl2 span check routine, and at the end of the routine MAUI keeps manual mode on.<br>To exit manual mode, send cancel measurement command.<br><br>In case this is triggered in continuous measurement, MAUI will start HgCl2 span check routine after the ongoing measurement cycle is finished. MAUI will resume the continuous measurement after triggered operation is complete. |
| Start Hg0 span check | | 15 | Start Hg0 span check routine. |

| | | | |
|---|---|---|---|
| | | | In case this is triggered in Idle state, MAUI will start manual Hg0 span check routine, and at the end of the routine MAUI keeps manual mode on.<br>To exit manual mode, send cancel measurement command.<br><br>In case this is triggered in continuous measurement, MAUI will start Hg0 span check routine, after the ongoing measurement cycle is finished.<br>MAUI will resume the continuous measurement after triggered operation is complete.<br><br>Available only if AutoQAL module is not active. |

- Cancel measurement, only possible if any operation is ongoing, in case no operation is ongoing, request will be discarded.
- Start continuous measurement, only possible if system (MAUI) is in idle state, i.e. no measurement ongoing.
- The requests will be discarded if MAUI is Standby mode, first exit standby mode to start/trigger any measurement from Modbus

The commands are added in queue in ascending order, MAUI will start the next command if there is another command to process after it finishes the first one irrespective of continuous or manual mode. The command queue will be cleared upon canceling the ongoing operation either by “Cancel measurement” command via Modbus or pressing “Measure” button manually.

### 4.7.4. Modbus Exceptions

Error codes supported are defined as follows:

| Error code | Description |
|---|---|
| 1 | Invalid function or subfunction |
| 2 | Invalid request address |
| 3 | Invalid number of registers in request |
| 4 | Error processing data value |

# 5. Initialization

## 5.1. Adding Hg to test gas generator

### 5.1.1. Precautions for safe handling

Read the mercury safety data sheet and act accordingly.

### 5.1.2. Adding metallic mercury to test gas generator

Before starting to use the system for mercury measurements, it is required to add atomic mercury to the test gas generator. Atomic mercury is used to calibrate the system daily. Work at sufficient well-ventilated room temperature (or below) and use the protective equipment listed in the mercury safety data sheet.

1. Remove the heated line and pull the test gas generator (lower unit) out of the cabinet (shelf slides out).
    - **For safety reasons the power cable should always be removed from the test gas generator, when its cover is opened!**
2. Remove the cover of the test gas generator by removing screws from case's ends and sides by 3 mm Allen key. The bottom screws of the front and rear panels need not to be removed.
3. The mercury compress is located on the front of the test gas generator from the front view, right. Open the grey enclosure of the mercury compress by removing four screws. Use 3 mm Allen key.
4. Open the mercury compress by using 2.5 mm Allen key.
5. Inside the compress is a U-shape glass tube (Figure 7 and Figure 6.). Remove the tube carefully and fill it with mercury according to Figure 6 below. Use pipette and pipette bulb. It is important that the level of mercury is above the top of the bend.

#### 5.1.2.1. Practical tips for filling

Note, do always according to the safety data sheet / laws / factory rules or instructions etc., if any

- It is a good idea to fill of the U-shape glass in a low-edged plastic box, so if any mercury drops, they will not harm the device. (Figure 8)
- It is a good idea to put a sealed garbage bag and hand towels next to the filling place. If any work equipment etc. are contaminated, they can be thrown into the bag.
- Put the U-glass for example on the insulation nozzle (Figure 8)
- Fill the glass only a little at a time, as mercury easily rises up into the pipette bulb and then you have to throw it in the garbage. (Figure 9 and Figure 10)
- If you accidentally fill up too much, tilt the glass and then take the mercury off by using pipette. Mercury can be put back in the bottle. (Figure 11)

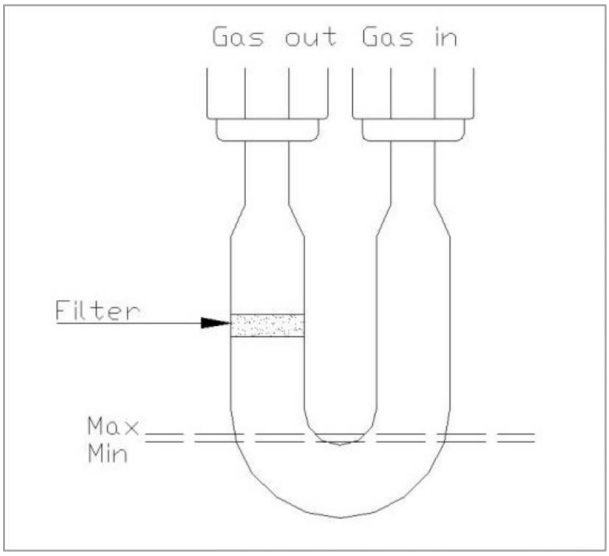



*Figure 6. U-shape glass tube mercury container*

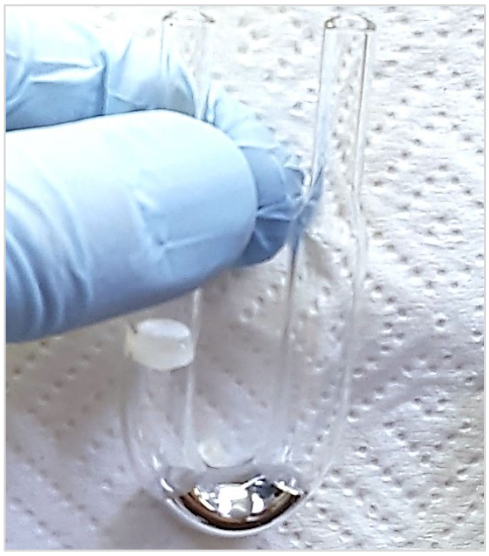


*Figure 7. The right amount of mercury*

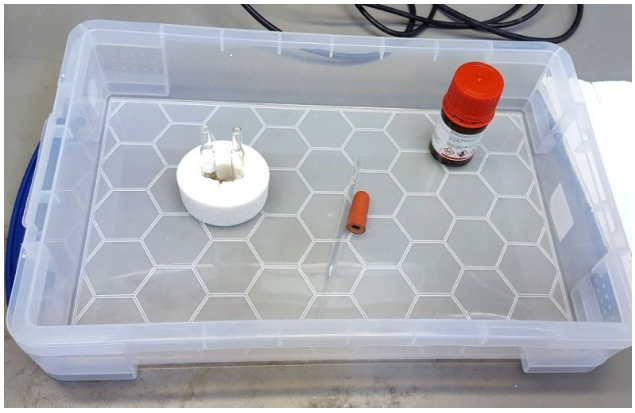


*Figure 8. A low-edged plastic box and equipment*

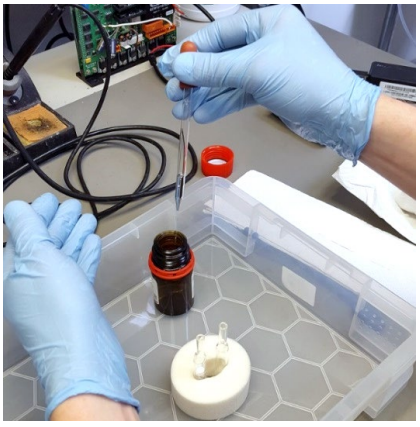


*Figure 9. Fill the glass only a little at a time*

*Figure 10. Filling the glass*

*Figure 11. Emptying the glass*

6. Tighten the pipe connectors gently but firmly by hand, be careful that you do not cause any forces on the glass tube. Insert the tube in place. The filter inside the u-tube is located on the outlet sideside.Nuts of the fittings should be parallel to U-pipe.
7. Press the tube in place, in line the connector nuts with the pack plate (Figures 13. - 15.) Note that if no alignment has been made, the glass tube can break and mercury has access to the test gas generator (Figure 12. and Figure 16.).
8. Run the points 1-4 in the reverse order.

*Figure 12. Incorrectly connector nuts*

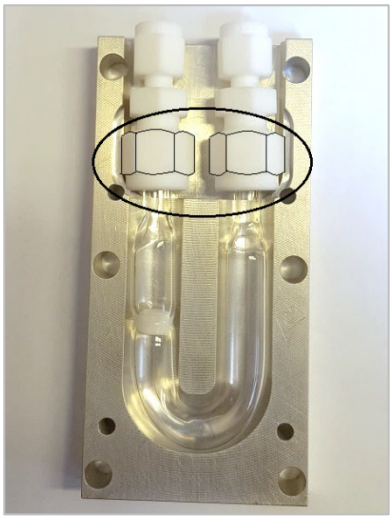


*Figure 13. Correctly aligned nuts*

*Figure 14. Correctly aligned connector connector nuts*

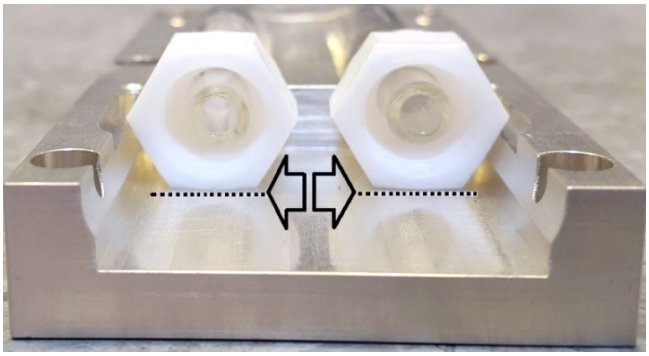


*Figure 15. Correctly aligned connector nuts*

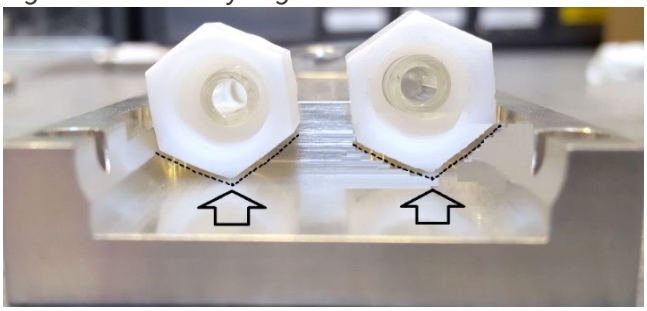


*Figure 16. Incorrectly aligned connector nuts*

## 5.2. Adding $HgCl_2$ to test gas generator (CMM AutoQAL)

Concentration of the $HgCl_2$ solution must be chosen for the measurement range that will be used for QAL3 checks. Test gas concentration should be between 70 % and 90% of that range. Suggested concentration for the solution can be found in the Test gas generator menu after range has been chosen (Figure 18). Write the actual concentration of the liquid on *$HgCl_2$ liquid concentration* field on the same page. Calculated span target for that concentration is shown on next field. Save settings by pressing OK.

If measurement range in CMM AutoQAL is Hg 5 µg/m3, then it is recommended to use HgCl2 solution with 0.5 ppm Hg in 1 M HCl in water. Respectively, if the measurement range is 10 µg/m3 then the recommended HgCl2 solution is 1.0 ppm Hg in 1 M HCl in water. The HCl concentration in the solution is high in order to extend the shelf life of the liquid used in CMM AutoQAL. However, very high HCl-concentration may have some effect on the CMM Hg-measurement results. Therefore, if very high Hg concentrations are fed for example with HovaCal, then it is recommended to use solutions with lower HCl-concentrations.

Fill the $HgCl_2$ solution bottle with liquid having the concentration saved to Test Gas Generator Settings and place it in the red bottle holder on the back panel of the test gas generator. Connect the tube from the solution bottle to the $HgCl_2$ inlet of test gas generator.

In the manual menu there is a $HgCl_2$ Refill button that starts a sequence that fills the hoses and the pump with fresh liquid from the bottle and removes the air bubbles from the system. If you are changing from one concentration liquid to another, it is good idea to run the refill sequence once with an empty bottle and then with bottle filled with new concentration. This way different concentrations will not mix. Remember to update new concentration to the Test Gas Generator Settings.

## 5.3. Pressure controllers and pressures

Changes in the ejector pump pressure and the $N_2$-generator pressure can be seen in the mercury measurement result. Therefore, those pressures are adjusted with precision pressure regulators, the values are measured with pressure sensors and the pressures are having tight error limits. The pressure values are also logged to the results file.

After connecting pressured air, adjust the pressure controllers

- **Main system pressure** must be set lower than minimum pressure of supply at any time. System will not function correctly if main pressure starts to float with supply pressure.
- **Dilution gas: $N_2$ generator** pressure is adjusted to 5.0 bar, it is important that it is at least 0,3 bar less than main system pressure. The $N_2$ generator pressure effects on the $N_2$-generator efficiency.
- **Dilution gas: ejector pump** pressure is adjusted to 4,5 bar, it is important that it is at least 0,3 bar less than the $N_2$ generator pressure. . The ejector pump motive gas pressure effects on the vacuum that the ejector creates. It therefore effects on the amount of sample gas taken from the stack and also effects the dilution ratio at the ejector.
- **Test gas generator: Zero gas** must be set to 3.0 bars
- **Test gas generator: Hg bath** must be set to 3.0 bars

- **Blowback** must be set to 4.0 bars
- NOTE: Installation site instrument air supply must always stay above main system pressure setting. If the supply pressure minimum value is lower than expected, re-adjust pressures so that the following rule is valid:

  Minimum supply pressure > Main system pressure > N2 Generator > Ejector Pump > 4,5 bar

If it is not possible to set pressures to values above because of low or unreliable supply pressure, separate dedicated compressor for CMM must be used.

## 5.4. Start-up

Make sure that all connections (power cable, instrument air, analyzer and test gas generator cables, heated line and probe) are connected correctly. Be convinced that there is $Hg^0$ inside the compress, $HgCl_2$ tubes (CMM AutoQAL) are connected and pressure regulators are adjusted.

Turn the main fuses, residual current device and main power switch to the “on” position one by one. These are located on the rear panel of the cabin. Make sure that the A/C unit starts and that there are no alarms on its display. Switch on the test gas generator and the analyzer both at the same time (switches are on the front panel).

After switching on the power, check that all settings are correct. The heating process of the system takes about 2 hours.

### 5.4.1. Settings of the analyzer

The analyzer settings control the operation of the analyzer and the continuous measurement cycle (Figure 17). The controls are explained in detail in the table below (Table 6).

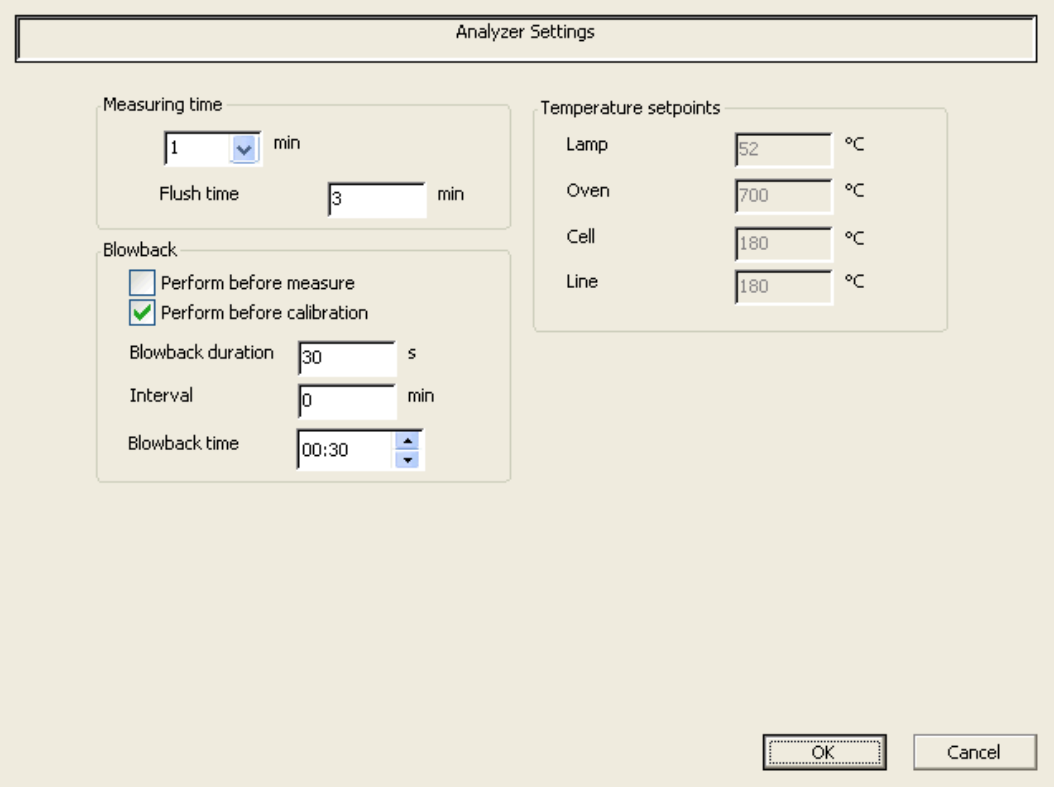



*Figure 17. Analyzer settings*

| Parameter | Value | Description |
|---|---|---|
| **Measuring time group** | | |
| Measuring time | x min | Defines the measuring time. Please note that the measuring time must be a multiple of 1 minute. |
| Flush time | x min | Defines sample flushing time before first measuring on continuous mode. |
| **Blowback group** | | |
| Perform before measure | Yes / No | If ticked, performs a blowback of the probe filter before starting or resuming a measurement sequence. |
| Perform before calibration | Yes / No | If ticked, performs a blowback of the probe filter before starting a calibration sequence. |
| Blowback duration | 0 – X s | Duration of the blowback. |
| Interval | 0 - X min | Defines the time interval of automatic blowbacks during normal continuous measurement. The next blowback is performed after the time interval has elapsed from the previous blowback. zero indicates blowback is not performed during continues measurement. |

| | | |
|---|---|---|
| Blowback time | | Defines the time of day when first blowback should be performed. |
| **Pressure calibration group (Not visible in basic user mode)** | | |
| Pressure calibration | x mbar | Calibration value for sample cell pressure sensor. |
| **Temperature settings group** | | |
| Lamp** | | Defines the lamp temperature setpoint. |
| Oven** | 700 °C | Defines the converter oven temperature setpoint. |
| Cell** | 180 °C | Defines the sample cell temperature setpoint. |
| Line** | 180 °C | Defines the heated line temperature setpoint. |

*Table 6. Analyzer settings (example parameters only, not for reference)** – Read-only in basic user mode but editable in service mode*

### 5.4.2. Settings of the test gas generator

The test gas generator settings control the operation of the test gas generator and the various calibrations performed (Figure 18, Figure 19). The controls are explained in detail in the table below (Table 7).

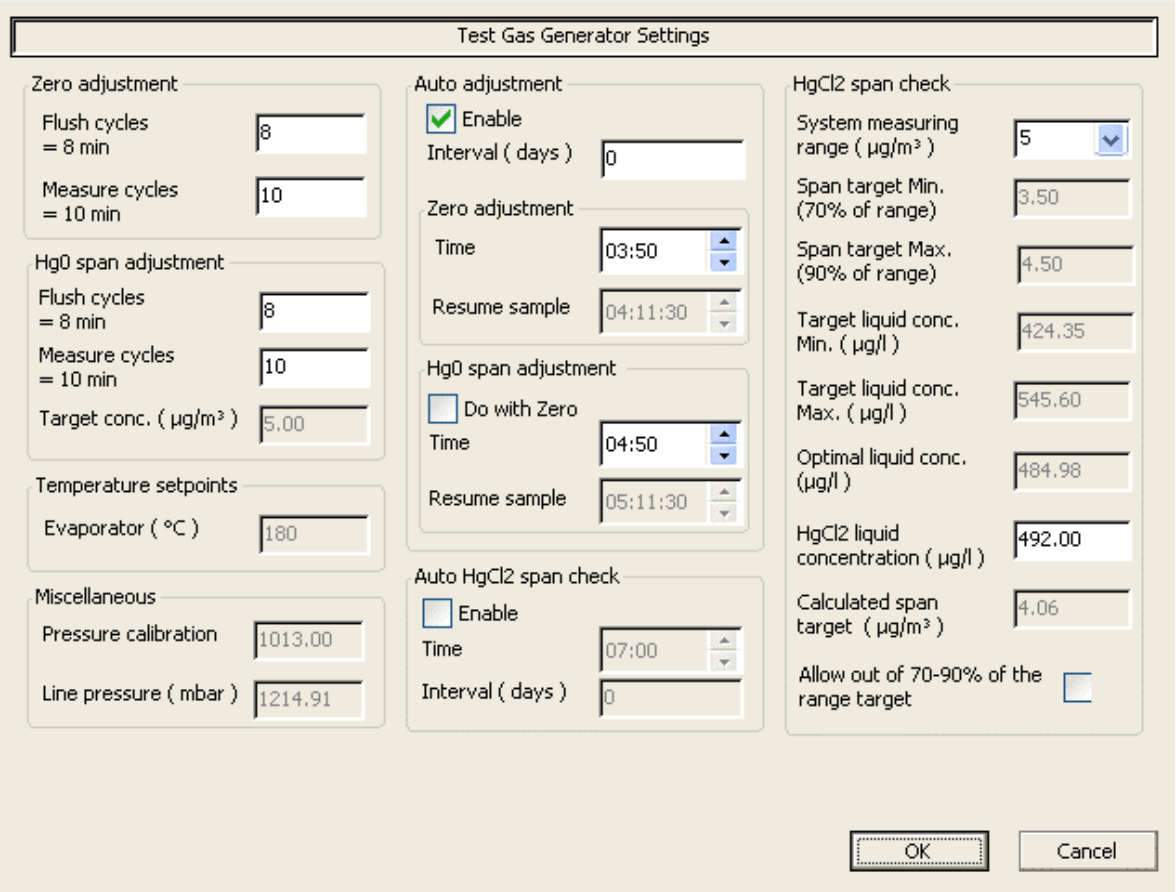



*Figure 18. Test gas generator settings if AutoQAL module is enabled (example parameters only, not for reference)*

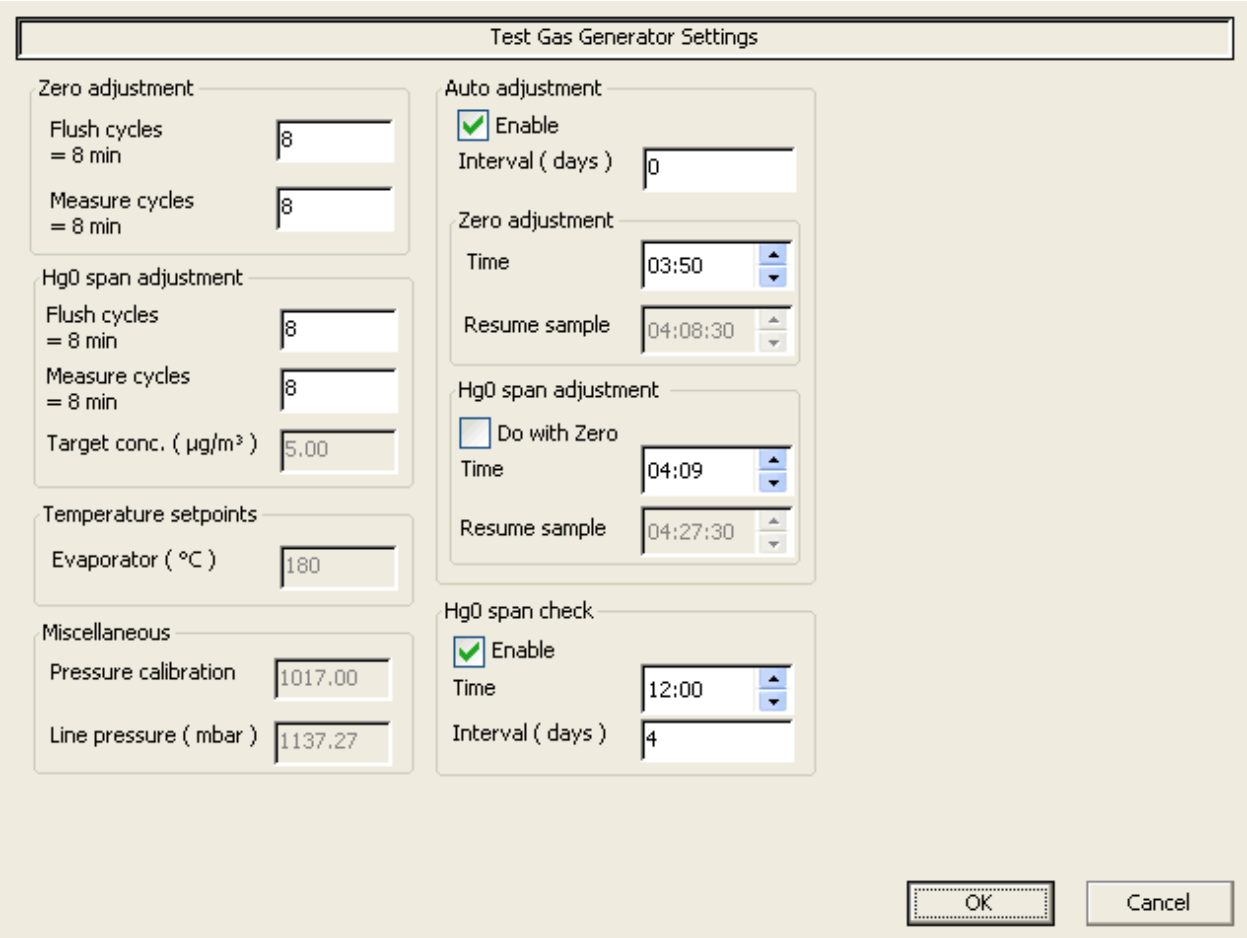



*Figure 19. Test gas generator settings if AutoQAL module is disabled (example parameters only, not for reference)*

| Parameter | Value | Description |
|---|---|---|
| **Zero adjustment group** | | |
| Flush cycles = 8 min | 0 - X | Number of zero flush cycles to perform before starting zero adjustment. One cycle is a multiple of the measurement time defined in 'Analyzer settings'. |
| Measure cycles = 10 min | 0 - X | Number of zero measure cycles to perform. |
| **$Hg^0$ Span adjustment group** | | |
| Flush cycles = 8 min | 0 - X | Number of span flush cycles to perform before starting span adjustment. One cycle is a multiple of the measurement time defined in 'Analyzer settings'. |

| | | |
|---|---|---|
| Measure cycles = 10 min | 0 - X | Number of $Hg^0$ span measure cycles to perform. |
| Target conc. (µg/m$^3$)* | | $Hg^0$ span adjustment target value. |
| **Temperature set points group** | | |
| Evaporator (°C)** | | Defines the evaporator temperature setpoint. |
| **Miscallaneous** | | |
| Pressure calibration** | | Calibration value for bath pressure sensor. |
| Line pressure (mbar)* | | Bath pressure on last $Hg^0$ calibration. |
| **Auto adjustment group** | | |
| Enable | Yes / No | Enable/disable automatic zero & Hg0 adjustment. |
| Interval (days) | 0 – X days | Defines the interval of the zero adjustment, zero indicates adjustment should be performed every day. |
| **Zero adjustment** | | |
| Time | | Defines the time of day when the zero adjustment should be performed. Zero adjustment time cannot be set after Hg0 span adjustment time if both adjustments are set to be performed separately. |
| Resume sample* | | Shows estimated calculated time when sample measurement will resume after zero adjustment. |
| **Hg0 span adjustment** | | |
| Do with Zero | | If ticked, perform Hg0 span adjustment after zero adjustment automatically |
| Time | | Defines the time of day when $Hg^0$ span adjustment should be performed. $Hg^0$ span adjustment time cannot be set before zero adjustment if both zero & $Hg^0$ span adjustment are set to be performed separately. $Hg^0$ adjustment would not be performed if zero adjustment is not done. |
| Resume sample* | | Shows estimated calculated time when sample measurement will resume after Hg0 span adjustment. |
| **Auto HgCl2 span check group [visible if AutoQAL module is enabled]** | | |
| Enable | | Enable/disable automatic HgCl2 span check |
| Time | | Defines the time of day when HgCl2 span check should be performed.<br>HgCl2 span check time cannot be set before Zero & $Hg^0$ span adjustment time. |
| Interval | | Defines the interval of the HgCl2 span check, zero indicates HgCl2 span check should be performed every day. |
| **$HgCl_2$ Span check group [visible if AutoQAL module is enabled]** | | |

| | | |
|---|---|---|
| System measuring range (µg/m$^3$) | | List of supported measuring ranges |
| Span target Min. (70% of range)* | | Minimum calculated span target based on selected system measuring range. |
| Span target Max. (90% of range)* | | Maximum calculated span target based on selected system measuring range. |
| Target liquid conc. Min. (ug/l)* | | Minimum calculated target liquid concentration based on selected measuring range. |
| Target liquid conc. Max (ug/l)* | | Maximum calculated target liquid concentration based on selected measuring range. |
| Optimal liquid conc. (ug/l)* | | Recommended optimal liquid concentration based on selected measuring range. |
| HgCl2 liquid concentration (ug/l) | | Used HgCl2 solution concentration value |
| Calculated span target* | | Calculated span target based on input liquid concentration. Calculated span target range is 1-1500. |
| Allow out of 70-90% of the range target | | User selection for allowing HgCl2 span target out of 70-90% of the range target. |
| **Auto Hg0 span check group [visible if AutoQAL module is disabled]** | | |
| Enable | | Enable/disable automatic Hg0 span check |
| Time | | Defines the time of day when Hg0 span check should be performed.<br>Hg0 span check time cannot be set before Zero & Hg$^0$ span adjustment time. |
| Interval | | Defines the interval of the Hg0 span check, zero indicates Hg0 span check should be performed every day. |

*Table 7. Test gas generator settings. * – Read-only ** – Read-only in basic user mode but editable in service mode*

### 5.4.3. Settings of the program

The program settings can be accessed from the caption bar of the main screen (Figure 20). Please note that none of the settings pages can be accessed during measuring. Program settings control the saving of measured results to files and define the measurement range of the system. The controls are explained in detail in the table below Table 8).

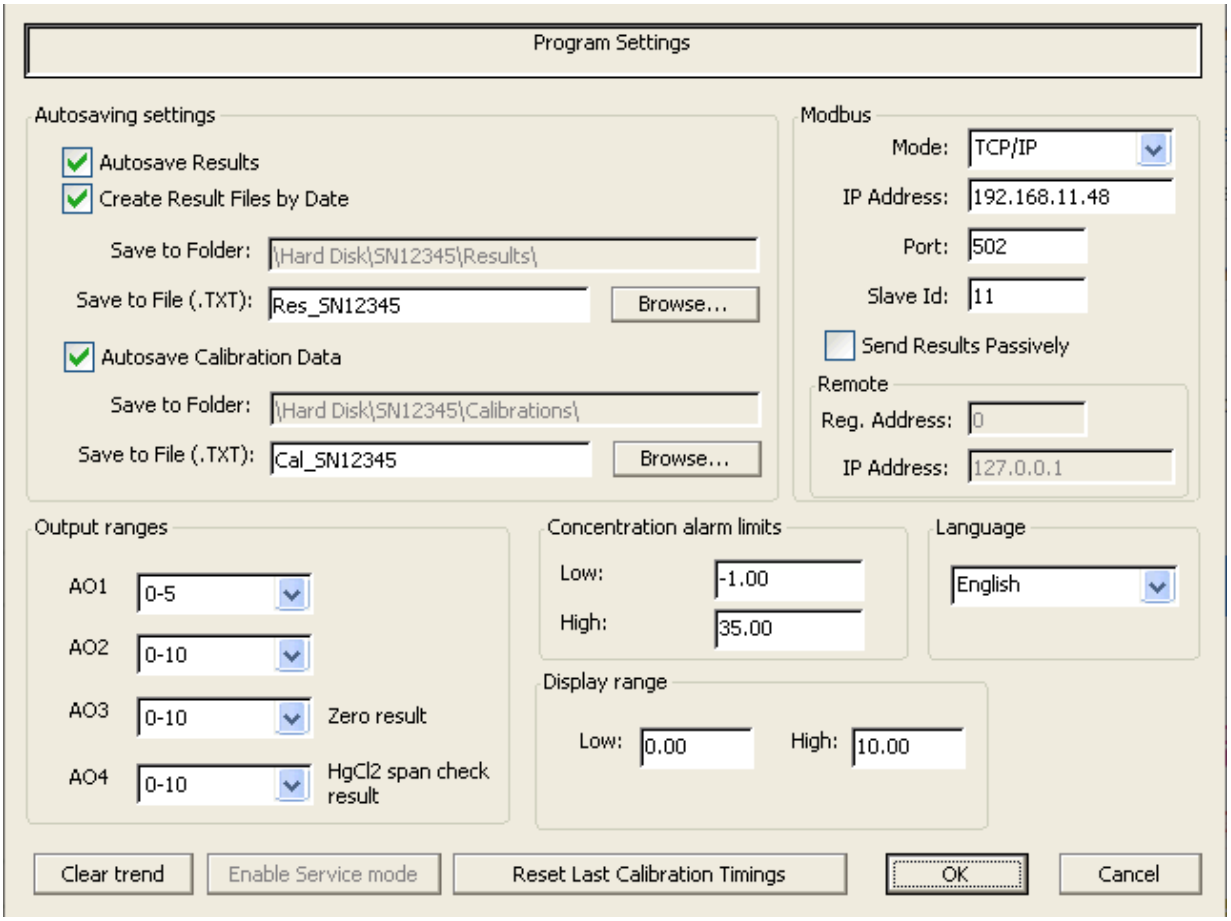



*Figure 20. Program settings (example parameters only, not for reference)*

| Parameter | Value | Description |
|---|---|---|
| **Autosaving settings group** | | |
| Autosave results | Yes / No | If the control is ticked, a result file with the defined name is generated to the selected folder. For each measurement, a new line is added to the file. |
| Create Result Files by Date | Yes / No | If the control is ticked, a new result file is created each day. There is limit in windows CE to have maximum number of files (999) in a folder.<br><br>In case maximum number of files reaches, MAUI will archive old result folder to folder name "SNXXXXX_Archive_YYYYMMDD" e.g, SN2000_Archive_20001203 in parent folder of results folder path.<br><br>MAUI will create new result file to the same old result path e.g., if old result path was \Hard Disk2\SNXXXXX\Results\, the result file will be created in the specified results folder. |

| | | |
|---|---|---|
| | | Support package functionality will skip archive folders when creating support package for diagnostic purposes.” |
| Save to Folder | | Defines the folder for result files. |
| Save to File (.TXT) | | Defines the name of the result file. |
| Autosave Calibration Data | Yes / No | If the control is ticked, a calibration file with the defined name is generated to the selected folder. For each calibration or check, a new line or lines are added to the file. |
| Save to Folder | | Defines the folder for calibration files. |
| Save to File (.TXT) | | Defines the name of the calibration file. |
| Save analyzer parameters** | Yes / No | Saves the analyzer parameters to the result file. |
| Save calibration parameters** | Yes / No | Saves the calibration parameters to the result file. |
| Save test gas generator parameters** | Yes / No | Saves the test gas generator parameters to the result file. |
| **Output ranges group** | | |
| A01 | min - max | Output range for analog output 1. |
| A02 | min - max | Output range for analog output 2. |
| A03 | min - max | Output range for analog output 3.,A03 is dedicated for Zero result. Zero check result is written to A03 after zero check routine. |
| A04 | min - max | Output range for analog output 4. A04 is dedicated either for HgCl2 (if AutoQAL module is enabled) or Hg0 span check (if AutoQAL module is disabled) result. HgCl2 / Hg0 span check is written to A04 after HgCl2 / Hg0span check routine. |
| **Concentration alarm limit group** | | |
| Low | | Concentration alarm low limit |
| High | | Concentration alarm high limit |
| **Display range group** | | |
| Low | | Low level for display scaling. |
| High | | High level for display scaling. |
| **Language group** | English / German / French / Spanish / Italian / Simplified Chinese / Japanese | This will be the user interface language; default setting is English. If the setup package does not include your language, please inquire from your local distributor.<br>Provided language DLL file should be copied to installation path to make it work, if chosen language |

| | | | |
|---|---|---|---|
| | | / Finnish / Swedish / Dutch / Traditional Chinese / Korean / Polish / Russian | DLL file is missing, English language will be used as default language. |
| **Others** | | | |
| Clear trend | | | Clears the data in the trend view. |
| Reset Last Calibration Timings | | | Reset timings when last calibration happened |
| **Modbus group** | | | |
| Mode | | None, TCP/IP<br>Default: None | MAUI supports only TCP/IP Modbus implementation. |
| IP Address (Local) | | Default: 127.0.0.1 | Local server IP address |
| Port | | 1 to 65535<br>Default: 502 | TCP port, TCP port 502 is reserved for MODBUS communications |
| Slave Id | | 0-255<br>Default: 11 | Modbus slave id |
| Send Result Passively | | Yes / No<br>Default: No | In case of Yes, Mercury (Hg) measurement data (live) will be sent to slave device passively using Modbus FC-16, whenever data is available/updated in MAUI. This follow analog A01 channel. |
| Remote | Reg. Address | 0-9998<br>Default: 0 | First register in the remote server for passive data |
| | IP Address | Default: 127.0.0.1 | Remote server IP address |

Table 8. Program setting.** – Read-only in basic user mode but editable in service mode

| Parameter | Value | Description |
|---|---|---|
| **Modbus group** | | |
| Mode | None, TCP/IP<br>Default: None | MAUI supports only TCP/IP Modbus implementation. |

| | | | |
|---|---|---|---|
| IP Address (Local) | | Default: 127.0.0.1 | Local server IP address |
| Port | | 1 to 65535<br>Default: 502 | TCP port, TCP port 502 is reserved for MODBUS communications |
| Slave Id | | 0-255<br>Default: 11 | Modbus slave id |
| Send Result Passively | | Yes / No<br>Default: No | In case of Yes, Mercury (Hg) measurement data (live) will be sent to slave device passively using Modbus FC-16, whenever data is available/updated in MAUI. This follow analog A01 channel. |
| Remote | Reg. Address | 0-9998<br>Default: 0 | First register in the remote server for passive data |
| | IP Address | Default: 127.0.0.1 | Remote server IP address |

### 5.4.4. User Level Access

*User Mode* button on the main screen opens up a dialog, where you can select the User Level Access. In order to access the service mode, a password is needed. User can enable or disable the AutoQAL module in this view (Figure 21).

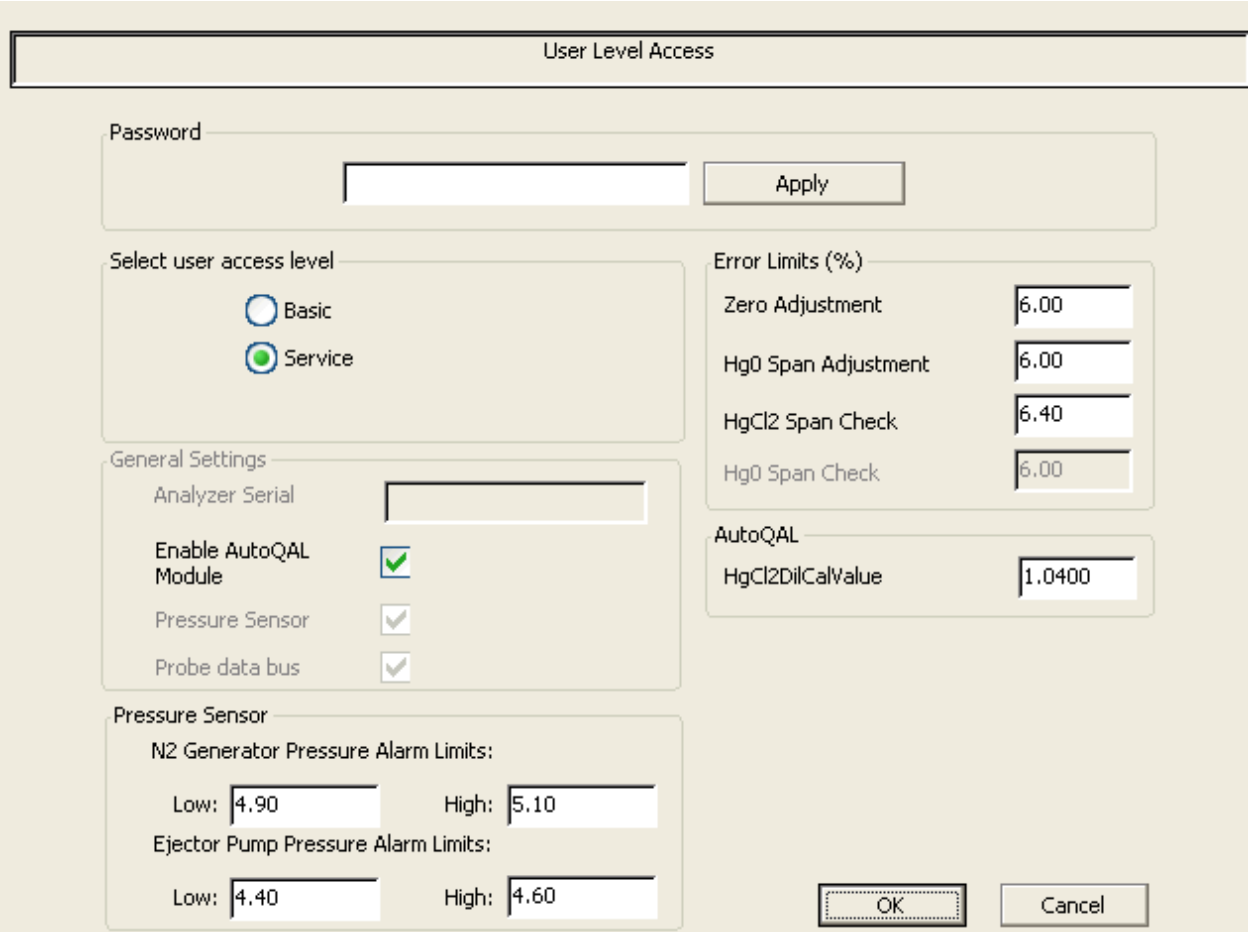



*Figure 21. User Level Access in Service mode (example parameters only, not for reference)*

In this dialog, the following settings can be seen:

- Analyzer Serial number
- Enable AutoQAL Module (Probe data bus option)
- Pressure Sensor: alarm limits for $N_2$ Generator pressure and ejector pump pressure
- Error limits

# 6. Instructions

## 6.1. Warnings

Before you start to operate with the Gasmet CMM, read this *Manual* carefully and thoroughly. If you do not understand something or you are unsure what to do, please contact the nearest distributor or Gasmet Technologies Oy main office.

## 6.2. Operation

The software measures, analyzes results and performs automatic span, zero, or linearity checks in addition to calibration. To perform these functions, the software controls both the mercury analyzer and the attached test gas generator unit via an Ethernet interface.

### 6.2.1. Operation chart

The system operates normally in accordance with parameters entered in the system. The operation chart is shown below (Figure 22). The manual mode makes it possible to control the system and perform each operation immediately.

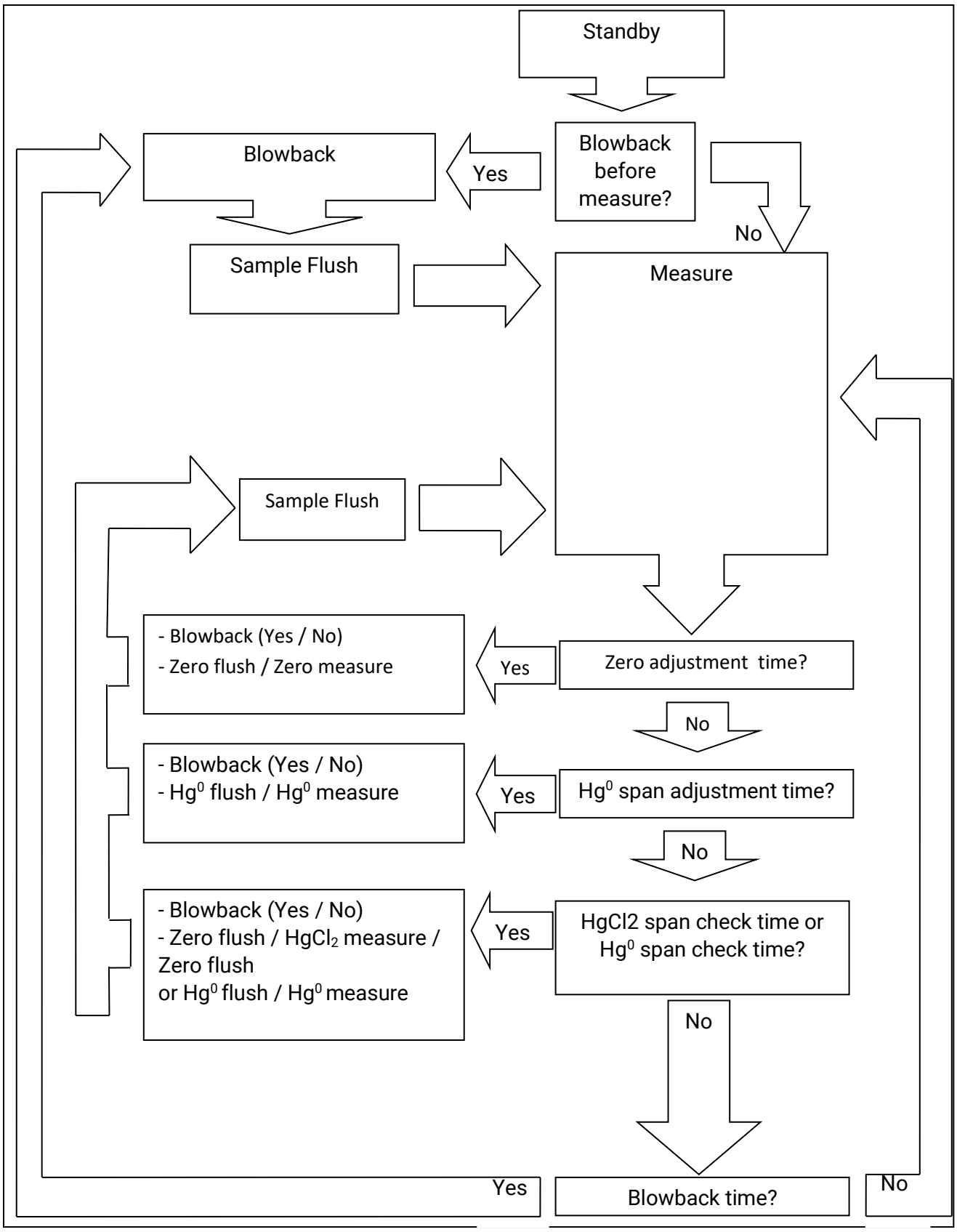



*Figure 22. The operation chart*

During continuous measurement, automatic adjustments and checks are not performed in case of any system alarm. Meanwhile, software will keep on trying for up to half an hour to perform adjustments or checks.

Automatic $Hg^0$ span adjustment during continuous measuring would not be performed if zero adjustment has not been done.

### 6.2.2. Software operation

The program functions and operation are fully controllable via the controls provided on the touch screen interface as shown in the image below (Figure 23).

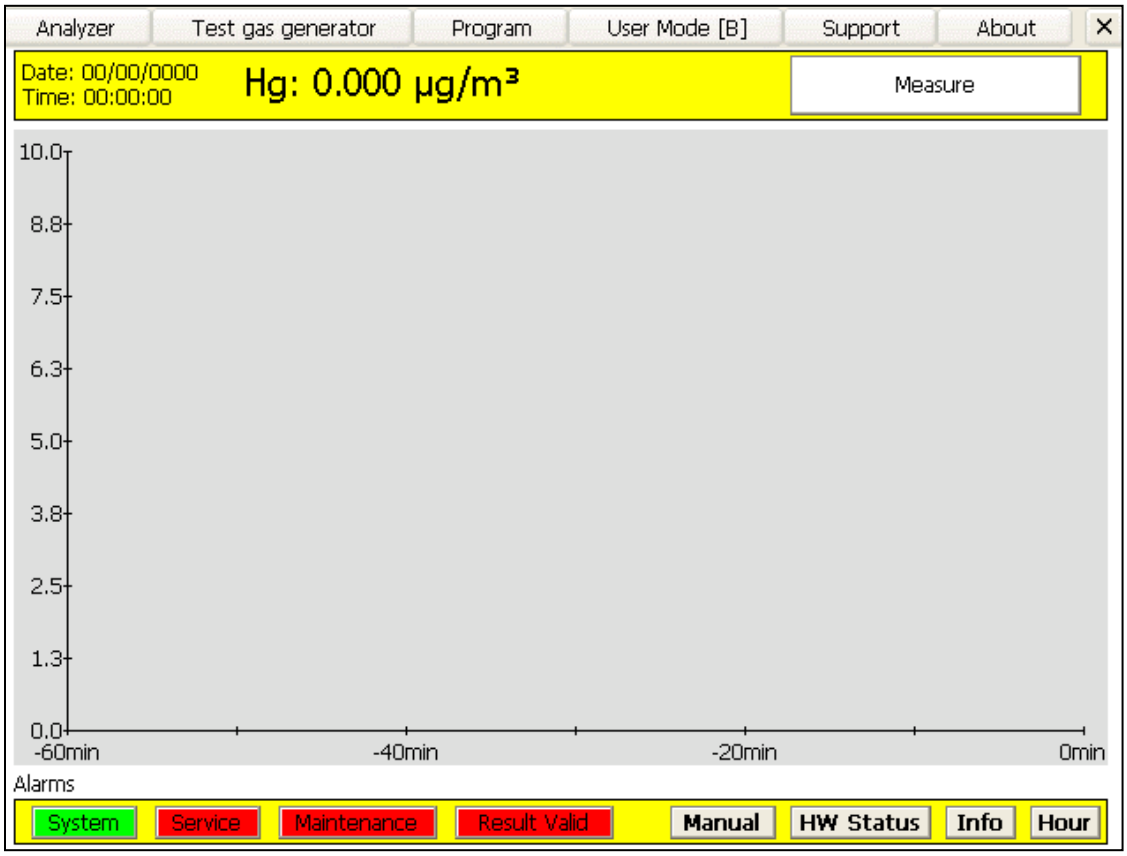



*Figure 23. View of the main program screen.*

All the settings can be accessed via the buttons in the menu bar at the top of the screen. The settings are defined during the installation and should not be changed. The continuous measurement can be started and stopped from the *Measure* button. The red buttons in the bottom of the screen, open a control each to view the individual reasons for each of the alarms. When there are no alarms, the buttons are all green in color. The *Manual* button opens a control dialog to manually perform measurements and pilot hardware on the test gas generator and/or analyzer. *Hour* button switches the on-screen trend between *Day* and *Hour* view. The name of the button indicates which view is active. Please note that the software cannot be closed, or the settings be accessed while measuring or in manual mode.

If any of the alarms (Instrument air pressure, line temperature, cell temperature, probe temperature) is active, continuous measurement will stop, but will be resumed automatically if none of the alarms (Instrument air pressure, line temperature, cell temperature, probe temperature) are active.

### 6.2.3. HW status

The *HW Status* button opens a dialog that displays the current values, target values & status of the most important parameters of both the analyzer and test gas generator. The following table shows list of important parameters. Status indicates if there is any corresponding alarm active for that parameter. In case of alarm “NOK” is displayed and “OK” when no alarm.

| | | **Target** | **Status** |
|---|---|---|---|
| **Analyzer** | | | |
| Lamp temperature (°C) | | | |
| Oven temperature (°C) | | | |
| Cell temperature (°C) | | | |
| Line temperature (°C) | | | |
| Cell pressure (mbar) | | | |
| Ambient pressure (mbar) | | | |
| Detector counts | | | |
| Oxygen (%) | | | |
| **Test gas generator** | | | |
| Bath temperature (°C) | | | |
| Evaporator temperature (°C) | | | |
| Bath flow (ml/min) | | | |
| Dilution flow (l/min) | | | |
| | | | |
| Bath pressure (mbar) | | | |
| **Last Adjustments** | | | |
| Hg0 span (µg/m³) | | | |
| Zero (µg/m³) | | | |
| **Pressure sensor** | | | |
| N2 generator pressure (bar) | | | |
| Ejector pump pressure (bar) | | | |

*Table 9. ‘HW Status’ dialog parameters*

The *Update* button sets the dialog in a continuous update mode where parameters are updated every second except *'Detector counts'* and *'Last Adjustments"* values. *Detector counts* are updated after every measurement and *'Last adjustments'* values are updated after Zero/$Hg^0$ span adjustment.

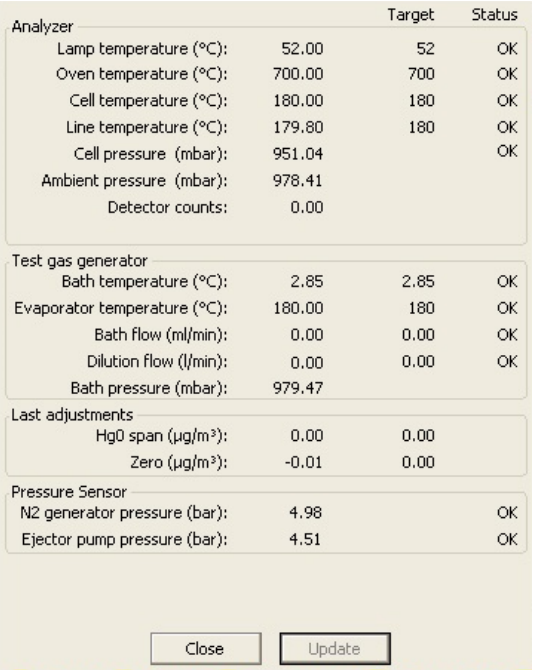



*Figure 24. 'HW Status' dialog*

### 6.2.4. Info view

*Info* button opens a dialog that displays the last zero check, $HgCl_2$ and Hg0 span check in tabular form. Information such as the date and time of the check, target and result values (µg/$m^3$), as well as the status (Pass / Fail and Set span level achieved / Set span level not achieved) is shown. At startup of MAUI, this information is loaded from calibration file.

Information regarding internal $Hg^0$ span adjustment, is not available in this window. It is available under *HW Status*. Zero check is always performed after zero adjustment irrespective of zero adjustment started manually or automatically.


*Figure 25. Adjustment information in Info view*

### 6.2.5. Support

*Support* button creates a customer support package in USB flash drive including the following files

- Log file
- Calibration file
- Result file(s)
- Program Settings file

*Figure 26. Calibration Information*

Please insert the USB flash drive before starting the support package creation. The support package creation might take a while depending on number of files to be copied.


*Figure 27. Support Package*

### 6.2.6. User Mode

User access levels in MAUI can be categorized as

- [B] – Basic mode
- [S] – Service mode

MAUI is always started in Basic mode. User can change access level by opening 'User Mode' dialog and entering password.

### 6.2.7. About

*About* button in the menu bar at the top of the screen displays information regarding analyzer serial number and MAUI software version.

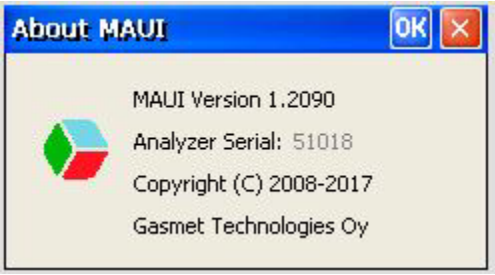



*Figure 28. About MAUI*

### 6.2.8. Automatic adjustments and starting of a continuous measurement

When the Measure button in the main program view is clicked, the program measures in continuous mode. In continuous mode, in addition to measuring the concentration of mercury, the software can perform automatic zero and span adjustments, span checks and blowbacks of the probe filter depending on which options are activated in the settings of the software. See the flowchart in *Figure 22.*

Once continuous measuring is started, the *Measure* button text indicates what type of operation is being performed and how much time it will take for the operation to complete. Clicking the *Measure* button during a measurement will immediately cancel continuous measuring and the software will revert back to the idle state.

Automatic adjustments won't start in case of any system alarm or any critical service alarms.
If system alarm or critical service alarm gets active during ongoing adjustment operation, adjustment operation will be interrupted, and interrupt message will be written to log file.

### 6.2.9. Manual mode operation

Manual operation mode can be entered by pressing the *Manual* button at the bottom of the screen as shown in Figure 23**.** The program remains in manual mode even when the manual mode panel is closed until continuous measuring is resumed by pressing the *Measure* button. Manual mode is used mainly be service personnel to debug hardware operation and run manual measurements and calibrations. Please note that some of the functions in the panel activate other functions in the panel as well while others cannot be activated without disabling another previously activated function. Automatic functions like calibrations or span checks are disabled if any manual function is active. The functions of the manual mode panel are discussed in the following table (Table 10).

| Function | Description |
|---|---|
| Measure Zero | Measures Zero gas. |
| Measure $Hg^0$ Span | Measures $Hg^0$ Span gas. |
| Blowback | Performs probe filter cleaning. |
| Zero Check | Performs zero adjustment routine. |
| $Hg^0$ Span Adjustment | Performs normal $Hg^0$ adjustment routine and defines new adjustment factors. |
| $Hg^0$ Linearity Check | Performs $Hg^0$ linearity check routine. |
| $HgCl_2$ Span Check | Performs normal $HgCl_2$ span check routine. |
| Hg0 Span Check | Performs normal Hg0 span check routine (available only if AutoQAL module is disabled). |
| Measure HgCl2 span | Measures HgCl2 span gas. |
| HgCl2 Solution Refill | Perform refilling HgCl2 routine, this operation takes 2 minutes. |
| Exit | Hide manual use window. |

*Table 10. Manual mode operation*

The following manual operations cannot be started in case of any system alarm or any critical service alarms:

> Measure $Hg^0$ Span
> Zero check
> $Hg^0$ span adjustment
> $Hg^0$ linearity check
> $HgCl_2$ span check
> $Hg^0$ span check
> Measure $HgCl_2$ Span

The critical service alarms are the following:

> Path pressure
> Bath flow
> Dilution flow
> Instrument air pressure
> $N_2$ generator pressure
> Ejector pump pressure

#### 6.2.9.1. $HgCl_2$ span check (CMM AutoQAL)

$HgCl_2$ span checks and QAL3 checks are two distinct processes. However, the results of $HgCl_2$ span checks can be used as evidence for QAL3 compliance.

QAL3 compliance criteria may vary, depending on the geography as well as the local regulations. AutoQAL comes with default internal acceptance limits. However, these default limits may not align with the specific limits required by the local authorities. This means, that if the system displays “set span level not achieved” after a $HgCl_2$- span check, it does not necessarily imply that the QAL3 check will fail, but the results might need to be interpreted and the system span levels to be adjusted in accordance to the specific local regulatory requirements. Adjustment of span levels is typically

performed during commissioning. Supplier needs to be contacted, in case span levels need to be changed afterwards.

$HgCl_2$ check is performed automatically a maximum of three times on subsequent days. Service alarm will be triggered if no acceptable results will be obtained during these tests. The Service alarm will be accompanied with information specifying, that the alarm source is the $HgCl_2$ test gas generator.

Default $HgCl_2$ span test interval has been set to four weeks.

$HgCl_2$ span check can be started from the manual operations menu, which can be followed in the main screen (Figure 29**)**. In the $HgCl_2$ span check display there is an accept button that stays grey until flushes have been performed and the average of last five values is calculated. After that the button will turn red or green, depending if the result is within allowed error limits or not. When the button is red or green, the result can be accepted and passed (green) or failed (red) result is saved and the check is ended. It can take a while for result to settle, so if the button is red user should wait for longer time to see final result before accepting it. In manual mode the test runs until result is accepted by pressing the accept button or cancelled by pressing the measure button. In scheduled checks the system waits until result is within limits or up to 40 minutes before saving the final result.

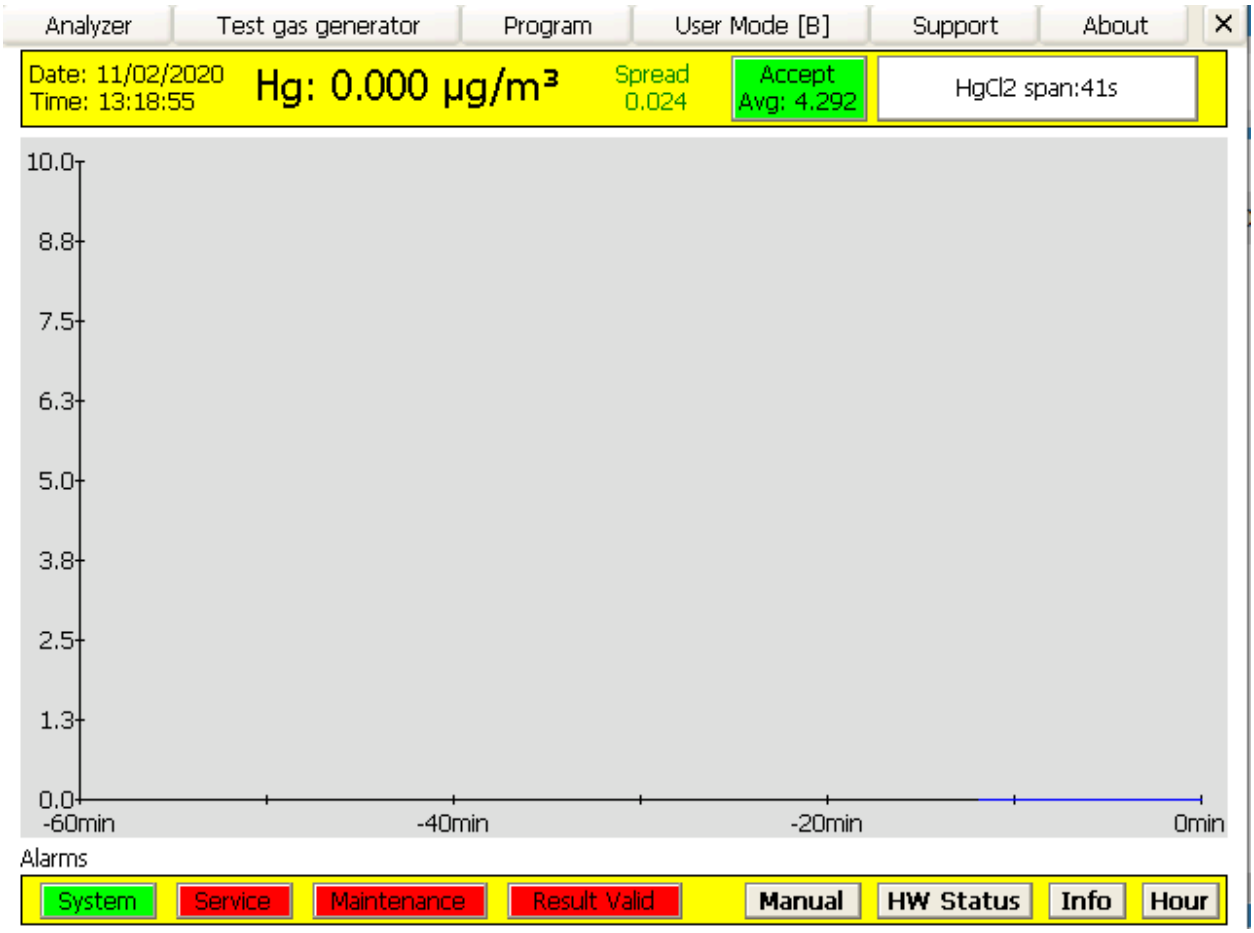



*Figure 29. On-going $HgCl_2$ span check*

## 6.3. Interrupted use

Normally the system can run continuously. Measurement of the system can be interrupted during the stoppage or any other plant maintenance break, when the system is flushed with instrument air. The system can be also set to standby mode by using external relay control.

### 6.3.1. Switching off the system

Before switching off the Gasmet CMM, flush well the complete system with zero gas by pressing “Measure Zero” from manual use window.

Best way to switch the power off is using the main switches. Switching the main switches off will shut down the complete system and the system will be easy to restart. There is no need to switch off each part of the system individually.

### 6.3.2. Restarting of the system

When restarting the system, ensure first that all connectors are in place and that it is safe to turn on the power. Instrument air supply and the readings of pressure reducers should be checked.

The power switches are located on the rear panel of the enclosure. Switch the power on. After switching the power on the sample cell, the evaporator, and the Hg converter start to heat to the target temperature. The heating process will take altogether about 2 hours.

It is needed to make the calibration until the system is warmed up. Calibration can be performed manually but the system can be also set to make automatic calibration after first measurement.

After calibration, the measurement can be placed on the *Measure* button.

## 6.4. Service and maintenance during use

In order for the system to operate reliably, it is important that it is correctly maintained.

### 6.4.1. Maintenance plan

The maintenance required depends strongly on the application (Table 11). The maintenance work procedures are described in this manual.

| Maintenance interval | Maintenance work |
|---|---|
| Once per week | System visual inspection |
| 6-12 months | Changing the HgCl2 solution (CMM AutoQAL) |
| 12 months | Replacement of the light source |
| 12 months | Replacement of the vacuum pump, depending on condition |
| 2 years | Replacement of the active carbon filters and unit |
| 3 years | Replacement of the dessicant drier unit |
| 3 years | Replacement of the glass-coated sample tube |
| 5 years | Replacement of the probe filter |

*Table 11. Maintenance plan*

## 6.5. Troubleshooting

The following table (Table 12) describes various alarms that may arise while operating the CMM.

| | Function | Alarm | Meaning | Treatment |
|---|---|---|---|---|
| **System alarm** | The system alarm is activated when there is a serious hardware problem that prevents performing reliable measurements. By clicking alarm button will be displayed with the fields that cause the alarm colored in red. Please note the control will not update when open, it is only a snapshot of alarms from the moment the button to view | Bath Temperature | The bath temperature differs more than 0.2 °C from the setting. | Check the temperature of the bath on *HW Status* tab. Restart the test gas generator. If it doesn't help, contact the service. |
| | | Evaporator Temperature | The evaporator temperature differs more than 10 °C from the setting. | Check the temperature of the evaporator on *HW Status* tab. Restart the test gas generator. If it doesn't help, contact the service. |
| | | Probe Temperature | The probe temperature differs more that 10 °C or probe tube temperature differs more than 30 °C from the setting. | Check the temperature of the probe (temperature controller is attach to the probe). If temperature is OK, check the alarm wires. Otherwise, contact the service. |
| | | Instrument air Pressure | Instrument air pressure is too low. | Check that instrument air input gauge shows proper pressure values. If not, find out why instrument air supply is down in the plant. If there is sufficient pressure reading (min 6 bars), then open the flowmeter fully and adjust all |

| | | | | |
|---|---|---|---|---|
| | the alarms was pressed. | | | pressures according to the recommended values and recalibrate the system. |
| | | Lamp Temperature | The mercury lamp temperature differs more than 5 °C from the setting. | Check the temperature of the lamp on *HW Status* tab. Restart the analyzer. If it doesn't help, contact the service. |
| | | Oven Temperature | The oven temperature differs more than 50 °C from the setting. | Check the temperature of the oven on *HW Status* tab. Restart the analyzer. If it doesn't help, contact the service. |
| | | Cell Temperature | The sample cell temperature differs more than 10 °C from the setting. | Check the temperature of the cell on *HW Status* tab. Restart the analyzer. If it doesn't help, contact the service. |
| | | Line Temperature | The sample line temperature differs more than 10 °C from the setting. | Check the temperature of the line on *HW Status* tab. Restart the analyzer. If it doesn't help, contact the service. |
| | | Cell Pressure | Cell pressure is less than 30 or more than 100 millibars. | Check the pressure of the cell on *HW Status* tab. Check the pump and the vacuum line between the pump and the cell for leakages. Check that there are no blockages in pipes and that fittings are tightly closed. If it doesn't help, contact the service. |
| | | Detector Error | Photomultiplier error. | Restart the analyzer. If it doesn't help, contact the service. |

| | | **Function** | **Alarm** | **Meaning** | **Treatment** |
|---|---|---|---|---|---|
| **Service Re** | | The service request alarm is activated when the system requires servicing by qualified service personnel. In this case the 'Service' button will be colored red indicating system servicing is required. By clicking the 'Service' button will be | Bath Pressure | The bath pressure is too high. | Check the pressure of the bath on *HW Status* tab. Restart the analyzer. If it doesn't help, contact the service. |
| | | | Bath Flow | The bath flow rate differs from the setpoint. | Check the instrument air supply and be sure that fittings are tightly closed. Do manual $Hg^0$ measurement and check the flow on *HW Status* tab. Restart the test gas generator. If it doesn't help, contact the service. |
| | | | Dilution Flow | The dilution flow rate differs from the setpoint. | Check the instrument air supply and be sure that fittings are tightly closed. Do manual zero measurement and check the flow on *HW Status* tab. Restart the test gas generator. If it |

| | | | | | |
|---|---|---|---|---|---|
| **q u e s t** | | displayed specific active service warning(s). | | | doesn't help, contact the service. |
| | | | Cabinet Temperature | The temperature inside the cabinet >40 °C. | Check the radiator function and filters, as well as the ambient temperature. |
| | | | Instrument air Pressure | Instrument air pressure is too low. | Check the pressure. |
| | | | Cabinet Cooler | Cabinet A/C unit doesn't work. | Read the fault code from thermostat's screen and determine the operation from cabinet cooler 's manual. |
| | | | Pump | Vacuum pump's maintenance interval is full. | The pump needs to be serviced. |
| | | | Zero Check Error | System doesn't pass Zero Check after Zero Adjustment. | Do manual Zero Adjustment and Check the flows on *HW Status* tab. |
| | | | $Hg^0$ Span Adjustment Error | System doesn't pass $Hg^0$ Span Check after $Hg^0$ Span Adjustment | Do manual Span Adjustment and check the flows on *HW Status* tab. |
| | | | $HgCl_2$ Span Check Error | System doesn't pass $HgCl_2$ Span Check. | Check that there is HgCl2 liquid left in the reservoir bottle and that the set liquid concentration is correct. Do manual $HgCl_2$ Span Check and check the flows on *HW Status* tab. |
| | | | $Hg^0$ Linearity Check Error | System doesn't pass $Hg^0$ Linearity Check. | Contact the service. |
| | | | Flow Alarm | Sample flow too low. | Do manual blow back and check the filter at probe. |
| | | | $N_2$ generator Pressure | Alarm is active if measured $N_2$ generator pressure is less/greater than the alarm limit | If instrument air pressure is ok then readjust $N_2$ generator pressure regulator. |
| | | | Ejector Pump pressure | Alarm is active if measured ejector pump pressure is less/greater than the alarm limit | If $N_2$ Generator pressure is ok then readjust ejector pump pressure regulator. |
| | | | $Hg^0$ Span Check Error | System doesn't pass $Hg^0$ Span Check | Do manual Hg0 Span Check. |

| | **Function** | **Alarm** | **Meaning** | **Treatment** |
|---|---|---|---|---|
| | The maintenance signal indicates if manual or automatic system maintenance is being performed. | Measuring Not Active | Measurement is interrupted | Push *Measure* button, if you want to continue measurement. |
| | | Manual Mode | System is in Manual Mode. | Push *Measure* button, if you want to exit Manual Mode. |
| | | Flushing sample | System is flushing with the sample gas. | Wait. |

| | | | | |
|---|---|---|---|---|
| **Maintenance** | This signal activates whenever the system is performing other operations besides normal sample measuring in continuous mode. The maintenance button will be colored red and can be clicked open like the other alarm buttons to view reasons for activation. | Blowback | System is purging the filter of the probe. | In automatic mode, Blowback is scheduled. The system returns to normal measurement routine after Blowback. On manual mode Blowback can be stopped from a manual operating window. |
| | | Flushing | System is flushing with the test gas. | Wait. |
| | | Linearity Check | Linearity test is going on. | In automatic mode, linearity test is timed, and the system returns to normal measurement routine of a minute. |
| | | Span Check | Span Check is going on. | In automatic mode, Span Check is timed, and the system returns to normal measurement routine of a minute. |
| | | Zero Check | Zero Check is going on. | In automatic mode, Zero Check is timed, and the system returns to normal measurement routine of a minute. |

| | **Function** | **Alarm** | **Meaning** | **Treatment** |
|---|---|---|---|---|
| Result Valid | The result valid signal indicates when the mercury analyzer has measured at least one valid result regardless of the type, calibration or sample. System alarms, setting the system to standby or exceeding the analogue output range will activate this alarm. | Standby | The system on hold because the measurement of the system has been suspended or forced to sleep mode using external control. | Release the external control. |
| | | System Alarm | System has failed. | Find fault by pressing System Alarm light. |
| | | No Active Analysed Result | The system has not yet made any measurement. | Start the measurement. |
| | | Result Range Exceeded | Measurement range has been exceeded. | If the measurement range is exceeded frequently, it would be wise to increase the range. |
| | | Maintenance | Maintenance signal is activated during manual mode or whenever the system is performing other operations besides normal sample measuring in continuous mode. | In Manual mode, Push Measure button, if you want to exit Manual Mode. In automatic mode, maintenance operations are timed, and the system returns to normal measurement routine after completion of the operation. |

*Table 12. Alarms in the CMM*

## 6.6. Files

The system stores the measurement and calibration results into files. The system also maintains a log file, which can be useful in cases of problems.

### 6.6.1. Result files

The result file contains the measurement results and is saved to a user defined path as defined in the 'Program settings'. A new line is added to the file for every completed measurement. The columns in the result and calibration files are <TAB> delimited for easy porting to other applications. See Figure 30 below for an example on a typical results file. The result file is ASCII text in format and it contains the following columns, some of which can be optionally logged by selecting saving options from the 'Program settings' 'Autosaving settings' group.

- The date and time of the measurement
- Serial number of the analyzer
- The analyzed result of the measurement
- Mode of the measurement (0=Manual 1=Automatic)
- Detector counts
- Lamp temperature
- Cell pressure
- Ambient pressure
- Converter oven temperature
- Sample cell temperature
- Heated line temperature
- Oxygen concentration at sample gas
- Photomultiplier tube counts when measuring zero
- Signal coefficient
- Bath temperature
- Evaporator temperature
- Bath pressure
- Flow through the mercury bath
- Test gas dilution flow
- $HgCl_2$ solution flow (CMM AutoQAL)
- Produced Hg0 concentration at calibration
- Measuring state
- $N_2$ Generator pressure
- Ejector pump pressure
- System alarms

- Service alarms
- Result valid

| Date | Time | Serial | Result | Mode | Counts | LampT | CellP | AmbientP | OvenT | CellT | LineT | Oxygen | ZeroC | Coeff | BathT | EvapT | BathP | BathF | DilutionF | PumpF | HgCal | Meas | SystemAlarm | ServiceAlarms | ResultValid |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 18-01-18 | 00:00:08 | 21 | 0.671 | 1 | 2464.3333 | 49 | 49.39 | 997.04 | 700 | 180 | 180 | 19.33 | 1908 | 0.0012154 | 2.58 | 180 | 993.6 | 0 | 0 | 0 | 0 | 80 | 0000000000 | 00000100000000 | 00000 |
| 18-01-18 | 00:01:08 | 21 | 0.668 | 1 | 2462.5166 | 49 | 49.4 | 997.07 | 700 | 180 | 180 | 19.32 | 1908 | 0.0012154 | 2.58 | 180 | 993.6 | 0 | 0 | 0 | 0 | 80 | 0000000000 | 00000100000000 | 00000 |
| 18-01-18 | 00:02:08 | 21 | 0.663 | 1 | 2458.2666 | 49 | 49.39 | 997.11 | 700 | 180 | 180 | 19.33 | 1908 | 0.0012154 | 2.57 | 180 | 993.7 | 0 | 0 | 0 | 0 | 80 | 0000000000 | 00000100000000 | 00000 |
| 18-01-18 | 00:03:08 | 21 | 0.668 | 1 | 2462.4834 | 49 | 49.39 | 997.1 | 699.9 | 180 | 180 | 19.34 | 1908 | 0.0012154 | 2.59 | 180 | 993.6 | 0 | 0 | 0 | 0 | 80 | 0000000000 | 00000100000000 | 00000 |
| 18-01-18 | 00:04:08 | 21 | 0.658 | 1 | 2453.7834 | 49 | 49.4 | 997.18 | 700 | 180 | 180 | 19.33 | 1908 | 0.0012154 | 2.58 | 180 | 993.7 | 0 | 0 | 0 | 0 | 80 | 0000000000 | 00000100000000 | 00000 |

*Figure 30. Result file (example values)*

#### 6.6.1.1. Measuring State:

Measuring state is the combination of two activities, main activity and sub activity.

| Code | Main Activity |
|---|---|
| 1 | Zero Check |
| 2 | Hg0 Span Calibration |
| 3 | Hg0 Span Check |
| 4 | HgCl2 Span Check (CMM AutoQAL) |
| 5 | Hg0 Linearity Check |
| 80 | Sample Measurement |

*Table 13. Main Activity*

| Code | Sub Activity |
|---|---|
| 1 | Zero Flushing |
| 2 | Zero Measuring |
| 3 | Hg0 Span Flushing |
| 4 | Hg0 Span Measuring |
| 5 | HgCl2 Span Flushing (CMM AutoQAL) |
| 6 | HgCl2 Span Measuring (CMM AutoQAL) |

*Table 14. Sub Activity*

For Example, 12 states that Zero measuring (Sub activity) during Zero Check (Main activity). For the sample measurement, there is no sub activity and measuring state value is always 80.

#### 6.6.1.2. System Alarms

There are 10 system alarms represented by 10-bits, each bit represents one alarm. 0=No Alarm, 1=Alarm

| Bath Temperature | Evaporator Temperature | Probe Temperature | Instrument air Pressure | Lamp Temperature | Oven Temperature | Cell Temperature | Line Temperature | Cell Pressure | Detector Error |
|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |

*Table 15. System alarms*

#### 6.6.1.3. Service alarms:

There are 16 service alarms represented by 16 bits, each bit represents one alarm. 0=No Alarm, 1=Alarm

| Bath Pressure | Bath Flow | Dilution Flow | Cabinet Temperature | Instrument air Pressure | Cabinet Cooler | Pump | Zero Check Error | Hg0 Span Adjustment Error | Hg0 Span Check Error | HgCl2 Span Check Error | Hg0 Linearity Check Error | HgCl2 Linearity Check Error | Flow Alarm | N2 Generator pressure | Ejector pump pressure |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |

*Table 16. Service alarms*

#### 6.6.1.4. Result Valid:

There are 5 result valid alarms represented by 5 bits, each bit represents one alarm. 0=No Alarm, 1=Alarm

| Standby | System Alarm | No Active Analysed Result | Result Range Exceeded | Maintenance |
|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 |
| 1 | 1 | 1 | 1 | 1 |

*Table 17. Result Valid*

### 6.6.2. Calibration files

The calibration file has its own path and file name for saving in 'Program settings'. The calibration file contains the results of zero calibration, span calibration and linearity check (see Figure 31). The calibration file contains the following columns:

- The date, start and end time of the calibration or check performed
- Serial number of the analyzer
- Mode of calibration (0=Manual 1=Automatic)
- The type of adjustment or check performed
- Status of performed calibration (Pass, Fail)
- The measured $Hg^0$ concentration at zero level
- The measured $Hg^0$ concentration at span level
- The measured $HgCl_2$ concentration at span level (CMM AutoQAL)
- The measured $Hg^0$ concentration at linearity check levels
- The measured $HgCl_2$ concentration at linearity check levels (CMM AutoQAL)
- Target concentration
- Error limit as fraction of full range
- Spread value of HgCl2 span check calculations
- Error limit for Spread value of HgCl2 span check as fraction of full test range

- Photomultiplier tube counts
- Photomultiplier tube counts at zero level
- Ambient pressure during check
- Signal coefficient
- Flow through the mercury bath
- Test gas dilution flow
- $Hg^0$ bath pressure
- $Hg^0$ bath temperature
- Evaporator temperature
- $HgCl_2$ solution flow (CMM AutoQAL)
- Water concentration at test gas (CMM AutoQAL)
- $HgCl_2$ solution concentration (CMM AutoQAL)
- Oxygen concentration of test gas

| Date | StartTime | EndTime | SerialNur | Mode | Type | Status | ZeroResu | Hg0SpanF | HgCl2Spa | Hg0LinRe | HgCl2LinF | Target | ErrorLimit | Spread | SpreadEr | Counts | ZeroCoun | AmbientP | Coeff | BathFlow | DilutionF | BathPress | BathTemp | Evaporato | PumpFlov | Water | HgCl2Liqu | Oxygen |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6.2.2020 | 3:51:29 | 4:09:31 | 19512 | 1 | ZERO | Pass | -0.002 | 0 | 0 | 0 | 0 | 0 | 0.2 | 0 | 0 | 2038 | 2038 | 997.613 | 0.001122 | 0.015 | 5.994 | 998.333 | 2.98 | 179.99 | 0 | 0 | 975.2 | 20.74 |
| 6.2.2020 | 4:51:03 | 5:09:05 | 19512 | 1 | SPANCAL_Hg0 | Pass | 0 | 4.96 | 0 | 0 | 0 | 5.028 | 0.2 | 0 | 0 | 6462 | 2038 | 999.171 | 0.001136 | 11.992 | 5.995 | 1189.025 | 2.98 | 179.96 | 0 | 0 | 975.2 | 20.81 |
| 6.2.2020 | 14:47:36 | 15:04:39 | 19512 | 0 | SPANCHECK_HgCl2 | Pass | 0 | 0 | 7.959 | 0 | 0 | 8.04 | 0.64 | 0.043 | 0.64 | 9039 | 2038 | 1007.236 | 0.001136 | 0.015 | 5.882 | 1007.733 | 2.928 | 179.98 | 50 | 1.05 | 975.2 | 20.9 |

*Figure 31. Calibration file (example values)*

### 6.6.3. Log files

The system log file (SystemLog.txt) is saved to the same path used for saving calibration data. SystemLogEng.txt file is also created, if selected user language is other than English. The system log file logs number of system hardware related problems, errors and status information. See Figure 32 and Table 18 below for a typical example of some error conditions and the format of the log file.

```
28/01/2011      12:59:50        CMM system log created.
28/01/2011      13:01:05        Hg0 Span calibration error, result: 0.00, target: 5.00±4.02.
28/01/2011      13:01:36        No acknowledgement received from PMT when starting measurement!
28/01/2011      13:02:18        HgCl2 Span check error, result: 0.00, target: 66.00±4.03.
28/01/2011      13:02:49        No acknowledgement received from PMT when starting measurement!
28/01/2011      13:10:01        Cannot close PMT COM port!
```

*Figure 32. Log files (example values)*

| Message | Explanation |
|---|---|
| CMM system log created. | Creation date of the file and first entry. |
| Starting CMM Version: <Version_Number> | CMM version information |
| Error - Cannot communicate with test gas generator: <code> <description> | There was an error communicating with the test gas generator, check IP, power and Ethernet cable. |
| Error - Cannot communicate with analyzer: <code> <description> | There was an error communicating with the analyzer, check IP, power and Ethernet cable. |
| $Hg^0$ Span calibration error, result: X, target: Y±Z. | $Hg^0$ span calibration has failed. System servicing is possibly required. |
| $Hg^0$ Span check error, result: X, target: Y±Z. | $Hg^0$ span check has failed. System servicing is possibly required. |
| $HgCl_2$ Span check error, result: X, target: Y±Z. | $HgCl_2$ span check has failed. System servicing is possibly required. |
| $Hg^0$ Linearity check error, result: X, limit: ±Y. | Linearity check has failed. System servicing is possibly required. |
| Zero calibration error, result: X, limit: ±Y. | Zero calibration has failed. System servicing is possibly required. |
| User mode changed to <user mode> | User access level information |
| Standby mode activated, measurement stopped | Ongoing measurement will stop automatically if Standby mode is activated. In case of continuous measurement, measurement will resume automatically when standby mode is deactivated. |
| Instrument air pressure is too low, measurement stopped | Measurement stops automatically if instrument air pressure is too low. Check instrument air pressure level. |
| Measurement stopped, Cell Temp Alarm=%d, Line Temp Alarm=%d, Probe Temp Alarm=%d | Ongoing measurement will stop automatically if any of these alarms is active (Line temperature, Cell temperature, Probe temperature alarm). In case of continuous measurement, measurement will resume automatically if these alarms are not active anymore.<br>1 = Active alarm, 0 = Alarm is not active |
| Resuming measurement | Resuming continuous measurement |
| Hg0 Bath temperature is not within limits. value: %.2f, Low: %.2f, High: %.2f | Hg0 bath temperature is not within defined limits. |
| **Photomultiplier communication related issues** | |
| Cannot close COM port handle! | There is an error handling the photomultiplier RS232 communications port, the device is not responding when cancelling a measurement or exiting the program. |
| Invalid COM port handle! | There is an error handling the photomultiplier RS232 communications port, the device is not responding when starting a measurement or reinitializing the PMT. |
| PMT Gate Status Error | There is an error handling the photomultiplier RS232 communications port, Restart the analyzer. If it doesn't help, contact the service. |
| Cannot create PMT stop event! | |
| Cannot create PMT control thread! | |
| Cannot set COM port timeouts! | |
| Cannot set COM parameters! | |
| Cannot turn off PMT high voltage! | |
| Cannot turn on PMT high voltage! | |
| Cannot kill PMT count disabling! | |
| Cannot deactivete PMT gate! | |
| Cannot set PMT number! | |
| Cannot set PMT counting time! | |
| Cannot start PMT! | |
| Error in PMT read data! | |

*Table 18. All possible log messages*

# 7. Service Instructions

## 7.1. Service instructions for user

The ejector pressure and the $N_2$-generator pressure have a strong effect on the Hg-measurement result. If there is something strange in the measurement results, then always first check that pressures are ok. For example, if the ejector pressure would decrease 0.5 bar from the setup value, then the Hg-measurement result would increase about 9%. When adjusting the pressures, you must keep in mind that the pressure regulators need a pressure difference to work properly. The regulators must be adjusted precisely, and the pressure provided from the facility must be above the adjusted system pressure all the time.

### 7.1.1. Visual inspection

The visual inspection of the CMM is recommended to be done regularly. When making the visual inspection, check that:

- Instrument air consumption is correct, about 40 to 50 l/min
- Pressures are correct
- Sampling probe, sample lines and gas connectors are in good condition, no leakages or dirt inside
- The color of instrument air dryer material is light
- Sample cell and evaporator temperatures are correct, 180 °C
- Hg converter temperature is correct, about 700 °C
- Sample line temperature is correct, 180 °C
- Cabinet temperature is correct, max ~30 °C
- Air conditioning system is in good condition (A/C unit is clean of dust, temperatures are OK)
- There is no dust inside the cabin

### 7.1.2. Replacement of probe filter plate

The replacement frequency of the filters depends a lot on the quality of the measured sample gas. In the beginning of the operation after installation, it is recommended to check the quality of the filter quite often, so that the correct replacement frequency can be established. It is important not to change the flow direction through the filter, so notice the dirty side mark on top of the filter plate.

1. Do blowback.
2. Switch off the measurement.
3. Open the hood of the probe.
4. Loosen the filter clamp with 6 mm Allen key (Figure 33).
5. Remove the filter carefully.

6. Clean or change the filter and run the points 1-5 in the reverse order.

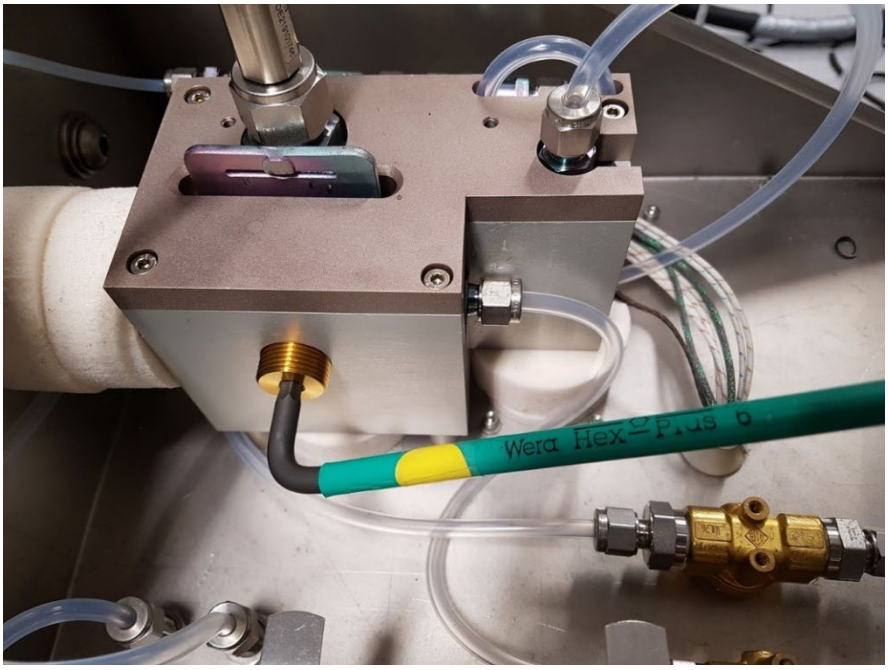



*Figure 33. Loosening the clamp of the filter*

### 7.1.3. Cartridge filter changing

The cartridge filters are changed.

1. Stop the measurement and turn off the instrument air by using the main system pressure regulator.
2. Open the filter housings by pressing the black levers and rotating the housings


*Figure 34. Filter housings*

3. Remove the cartridge filters by rotating them.

*Figure 35. Cartridge filter*

4. Install the new cartridge filters, put the housings back on, turn on the instrument air and start the measurement.

### 7.1.4. Replacing the absorption dryer

The absorption dryer of instrument air has to be changed, if it has changed color from blue (like in the in the picture) to pink.

*Figure 36. Absorption dryer material*

1. Stop the measurement and turn off the instrument air by using the main system pressure regulator.
2. Remove the right side wall of the CMM cabinet to get easy access to the components.
3. Remove the absorption dryer unit.
4. Replace it with new unit
5. Put the side wall back and turn on the instrument air.

### 7.1.5. Exchange of liquids (CMM AutoQAL)

If reservoir bottle is refilled from the same batch of $HgCl_2$ solution as the old one, it can be simply filled on top of the old liquid. If the remaining solution in the reservoir bottle is older than 6 months, it should be fully replaced. After filling $HgCl_2$ Refill function should be run from the manual menu to get rid of possible air bubbles caused by the filling. If the $HgCl_2$ solution bottle is filled with solution that has different concentration than before, $HgCl_2$ Refill function should be run once with emptied reservoir bottle before filling it with the new liquid. $HgCl_2$ Refill function should then be run a second time to fill system with the new solution. This way the two different solutions don't mix inside the system. Remember to set the correct concentration value of the new solution to the Test Gas Generator settings page.

### 7.1.6. Zero and span adjustments

In normal use system makes zero and span adjustments automatically. They can be made also manually from *Manual* control. It is easy to check that the parameters of the adjustments are on the correct level by pressing *HW Status* button.

### 7.1.7. Linearity check

Linearity check with Hg0 can be made from the manual menu. In the linearity check a fixed sequence of test gas is automatically fed to the CMM: 0%, 60%, 40%, 80%, 20% and 0% of the target concentration. The result of the linearity check can be seen from the calibrations file. If the result of the check is above the set limit, the system gives a service request.

## 7.2. Service instructions for professional

### 7.2.1. Program initialization

MAUI is the software for operating and controlling the Gasmet CMM via an Ethernet connection to the analyzer and test gas generator units. MAUI runs on an industrial panel PC with a touch screen interface and Windows CE operating system. Other Windows versions are not supported.

1. Create a folder named 'MAUI' on the local 'Hard Disk' of the Windows CE panel PC device. Copy the executable and the program settings file to the '\Hard Disk\MAUI' folder.
2. Next, access the startup manager, 'StartMan' in the Windows CE 'Start' menu. Click the 'New' button and enter the name of the software in the dialog box, select the type 'ShellCommand' and enter an optional program description if desired and accept by pressing 'OK'.

   In the 'Edit Item' dialog, choose 'Autostart' in the 'Startup Options'. Navigate to the next tab, 'Shell Command' and enter the full path of the executable in the 'Enter Shell command' text box. For example, "'\Hard Disk\MAUI\MAUI.exe'. Close the dialog by pressing 'OK'.

   Press the 'Save' button and 'Exit' the startup manager. Now, every time the panel PC is started, the CMM application software will launch as well. To test this functionality, select 'Reset' from the Windows 'Start' menu.

### 7.2.2. Replacing the lamp

The optical power of the lamp decreases with time and it must be replaced periodically.

1. Pull out the analyzer from the cabin. The heated line has to be removed in order that it is possible to pull out a shelf and analyzer.
    - **For safety reasons the power cable should always be removed from the analyzer, when its cover is opened!**
2. Remove the cover of the analyzer by removing 14 screws which are located around the housing. Use 3 mm Allen key. There is no need to remove the lower screws of front and back panels.
3. Unscrew the white, plastic screw and remove the lamp from its holder.
4. Put a new lamp back to the holder. Make sure that the lamp is at the right angle (see a mark on a lamp base). Tighten the screw with your finger. Connect a cable of the lamp. Turn the analyzer on for lamp adjustment.

   If the lamp has no mark on the lamp base, feed span $Hg^0$ and check the counts. Rotate the lamp few degrees and then check the counts again. Continue this until you find the angle where you get the maximum counts and then tighten the screw. Notice that there might be two opposite side maximums with different intensity.
5. Remove the power cable and put the cover back.
6. Turn the analyzer back on. Wait until all temperatures have stabilized and then recalibrate the analyzer.

#### 7.2.2.1. Lamp disposal method

Mercury lamp contains a small amount of mercury. For this reason, it should be delivered to a sorting station as hazardous waste for proper handling.

# 8. Technical terms and symbols

| Term | Explanation |
|---|---|
| A | Ampere, unit of current |
| A/C unit | A thermostat to control cabinet temperature |
| Bar | Unit of pressure |
| CCMS | Continuous Mercury Monitoring System |
| CVAF | Cold Vapor Atomic Fluorecence |
| Hg | Mercury |
| $HgCl_2$ | Mercury dichloride |
| $Hg^0$ | Atomic mercury |
| $Hg^{2+}$ | Oxidized mercury |
| MAUI | MAUI is the software for operating and controlling the Gasmet CMM system |
| Mercury lamp | The light source of the analyzer |
| Photomultiplier/detector | The component that measures the low intensity of UV light and converts this value into electrical signal |
| VAC | Symbol for the voltage in an alternating current (AC) circuit |

# Abbreviations

MSW most significant word
LSW least significant word
MSB most significant byte
LSB least significant byte

MEI Modbus Encapsulated Interface
TCP Transport Control Protocol
IP Internet Protocol
ADU Application Data Unit
PDU Protocol Data Unit
CRC Cyclic redundancy check

FC Function code

# Appendix A: Gasmet Sales and Support Offices


| MANUFACTURER | SUBSIDIARY IN GERMANY |
|---|---|
| **Gasmet Technologies Oy**<br>Mestarintie 6,<br>01730 Vantaa, Finland<br>contact@gasmet.fi<br>+358 9 7590 0400 | **Gasmet Technologies GmbH**<br>Ostring 4, 76131 Karlsruhe, Holstenstraße 27, 24568 Kaltenkirchen, Germany<br>sekretariat@gasmet.com<br>+49 721 62656-0 |
| **SUBSIDIARY IN UNITED KINGDOM** | **SUBSIDIARY IN NORTH AMERICA** |
| **Gasmet Technologies (UK) Ltd.**<br>Woolleys Farm, Welford Road, Naseby Northampton, NN6 6DP, United Kingdom<br>contact.uk@gasmet.com<br>+44 1908 227722 | **Gasmet Technologies Inc.**<br>5865 McLaughlin Rd. Unit #1, Mississauga ON L5R 1B8, Canada<br>sales@gasmet.com<br>(+1) 866 685 0050 |
| **SUBSIDIARY IN ASIA** | **SUBSIDIARY IN SWITZERLAND** |
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