

(1) Registered trademark. The MilliGascounter was developed at the University of Applied Science Hamburg under the leadership of Prof. Dr. Paul Scherer

Table of Contents

Page

1. Data Sheets 3
1.1. Type MGC-1 PMMA 3
1.2. Type MGC-1 PMMA 5

2. Initial Operation 7
2.1. Handling after receipt 7
2.2. Installation 8
2.3. Packing Liquid 8
2.4. Filling with Packing Liquid 9
2.5. Setting of the correct Packing Liquid Level 9
2.5.1. PMMA Version (Transparent Casing) 9
2.5.2. PVDF Version 10
2.6. Tube connection 11

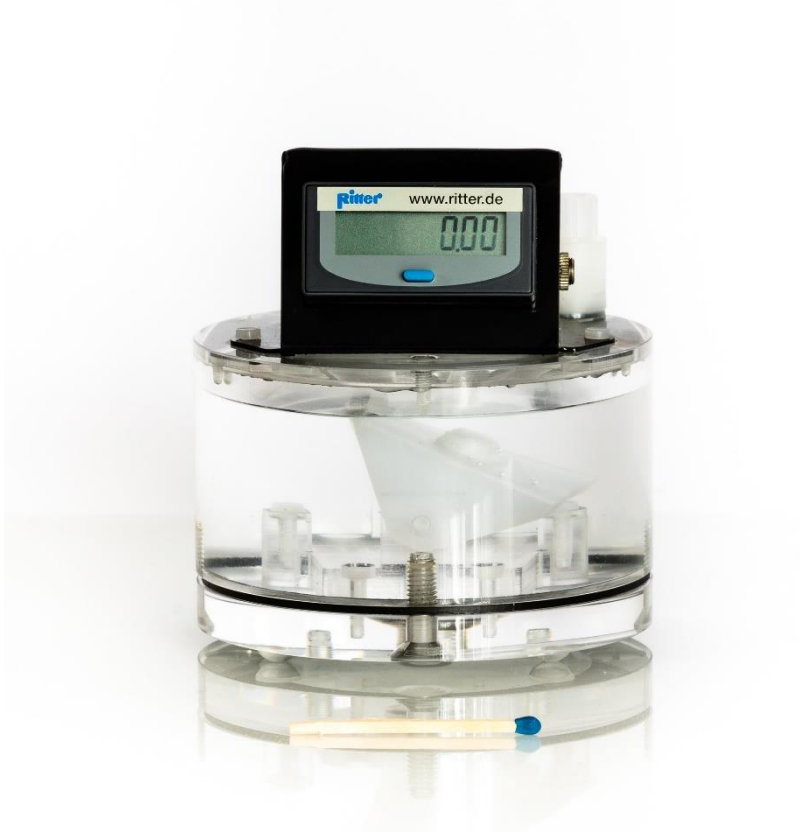
3. Measurement 12
3.1. Measurement principle 12
3.2. Calibration / Measurement Error 12
3.2.1. Static Correction of Manufacturing Tolerances 12
3.2.2. Dynamic Correction of the Measurement Error 13
3.3. Effect of Dead Space Volume 13
3.4. Condensation 13
3.5. Influence of Particles (Dirt & Dust) in the Gas Flow 14
3.6. Effect of Temperature 14
3.7. Effect of System Gas Pressure 14
3.8. Effect of Water Vapour Partial Pressure 15
3.9. Temperature and Pressure Corrections 15
3.10. Special Features with Fermentation Tests 16

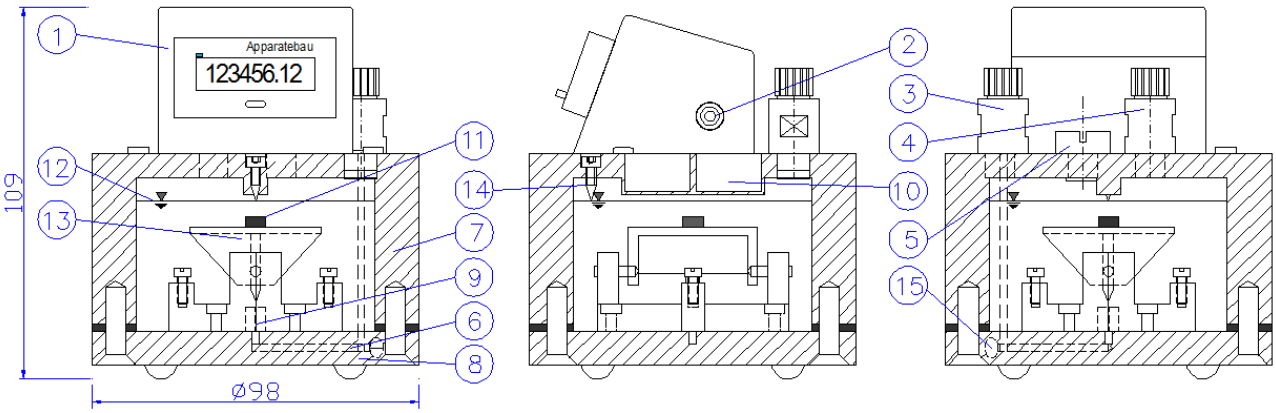
4. Counter unit 17
4.1. Display 17
4.2. Reset Button 17
4.3. Signal Output 17
4.3.1. Reed Contact 17
4.3.2. Output Socket 18

5. Maintenance 19
5.1. Checking the Packing Liquid Level 19
5.2. Exchange of Packing Liquid 19
5.3. Cleaning 19
5.3.1. Cleaning the Micro Capillary Tube 19
5.3.2. Cleaning the MilliGascounter Casing 20
5.4. Counter Unit Battery Exchange 21
5.5. Disassembly / Exchange of the Measurement Cell 21
5.6. Long-term Storage 21

1. Data Sheets

1.1. Type MGC-1 PMMA





Front View | Side View | Rear View

(1) Counter unit with LCD display
(2) Signal output socket (reed contact)
(3) Gas inlet
(4) Gas outlet
(5) Screw plug for filling
(6) Gas inlet channel
(7) Casing
(8) Base plate
(9) Micro capillary tube
(10) Two reed contacts
(11) Permanent magnet
(12) Packing liquid
(13) Measurement cell (tilting body) with twin-chambers
(14) Tracing screw for liquid level
(15) Inspection screw gas inlet channel

Technical Data

Minimum flow rate Q_{min}	1	ml/h	Maximum gas inlet pressure	**100**	**mbar**
Maximum flow rate Q_{max}	1	ltr/h	Minimum gas inlet pressure [5]	8	mbar
Measurement accuracy, approx. [1]	±3	%	Packing liquid quantity, approx.	120	ml
Volume of measurem. chamber, appr. [2]	3	ml	Gas temperature [6]	+10 ~ +60	°C
Min. measuring volume (resolution) [3]	3	ml	Connection gas inlet / outlet: Screw-type tube coupling	Ø 4_i / 6_o	mm
Resolution of indication [4]	0.01	ml	Diameter connecting tube	Ø 4_i / 6_o	mm
Weight without packing liquid, approx.	0.45	kg			

[1] Because of the physical measurement principle, the measurement error is dependent on the flow rate. The **data acquisition software "Rigamo"** (accessory) provides an algorithm, which automatically recalculates the actual measurement data to the real values at the respective actual flow rate on the basis of the calibration curve. Thus, the remaining error can be reduced significantly or the flow rate range can be extended at the constant measurement error of ±3%. The remaining error is better than approx. ±1% across the full flow rate range.

[2] = Nominal value; exact value will be determined by individual calibration

[3] = Volume of measuring chamber

[4] Because of calibration factor with 2 decimals

[5] The minimum gas inlet may be increased if the measurement starts with a high flow rate. In this case a higher pressure is needed until the micro capillary in the base plate is clear of packing liquid.

[6] For complete MGC unit applies: With temperatures > room temperature (e.g. if placed in heating furnace) a foam formation of the packing liquid was monitored in particular cases.

Materials

Casing	Plexiglas (PMMA)
Measurement cell	PVDF (Polyvinylide fluoride)
Screw-type tube coupling	PVDF

Standard Equipment

Electronic counter / LCD display	Twin-chamber measurement cell
Display: 6 digits [ml] + 2 decimals	1.5 m gas connecting tube (PVC)
Pulse Generator V6.0 as signal output (reed contact, floating output)	200 ml packing liquid (hydrochloric acid 1.8 vol% = 0.5 mol/ltr) [1]
1 cleaning rod for micro capillary per each 1 to 5 MGC's	1 Syringe for fine adjustment packing liquid level
Funnel for filling of liquid	1 Level

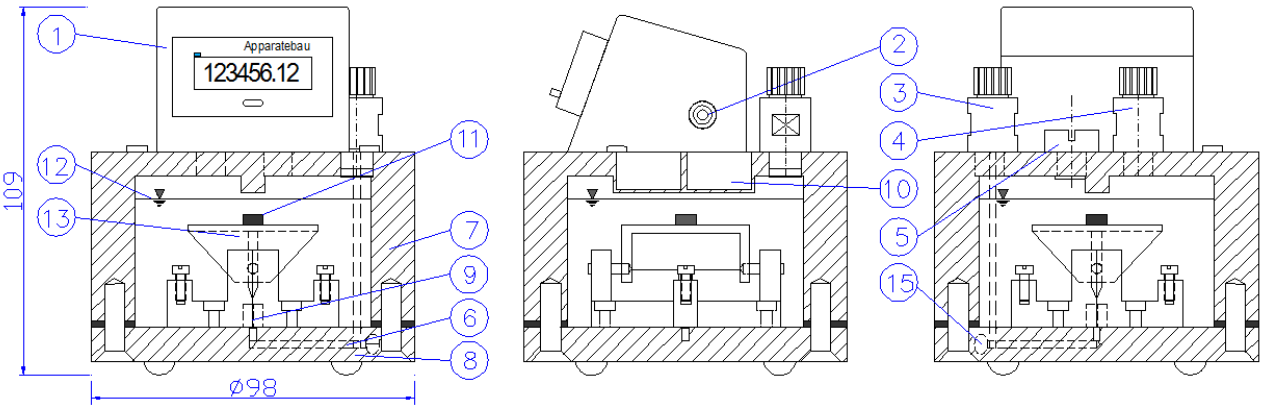
Accessories

Data acquisition software "Rigamo" for Windows®	Packing liquid Silox (for gas mixtures without CO_2)
Gas connecting tube (PVC)	Packing liquid 200 / 500 / 1,000 / 5,000 ml
Filter 0.45 micron for gas inlet tube	Back-pressure valve for gas inlet tube

[1] Because hydrochloric acid is classified as "dangerous good" there are certain restrictions for transportation depending on the mode of transportation, country of destination, and quantity. Please check prior to your purchase order with your handling distributor or with RITTER the details for your individual case.

1.2. Type MGC-1 PMMA





Front View | Side View | Rear View

(1) Counter unit with LCD display
(2) Signal output socket (reed contact)
(3) Gas inlet
(4) Gas outlet
(5) Screw plug for filling
(6) Gas inlet channel
(7) Casing
(8) Base plate
(9) Micro capillary tube
(10) Two reed contacts
(11) Permanent magnet
(12) Packing liquid
(13) Measurement cell (tilting body) with twin-chambers
(15) Inspection screw for gas inlet channel

Technical Data

Minimum flow rate Q_{min}	1	ml/h	Maximum gas inlet pressure	**100**	**mbar**
Maximum flow rate Q_{max}	1	ltr/h	Minimum gas inlet pressure [5]	8	mbar
Measurement accuracy, approx. [1]	±3	%	Packing liquid quantity, approx.	120	ml
Volume of measurem. chamber, appr. [2]	3	ml	Gas temperature [6]	+10 ~ +80	°C
Min. measuring volume (resolution) [3]	3	ml	Connection gas inlet / outlet: Screw-type tube coupling	Ø 4_i / 6_o	mm
Resolution of indication [4]	0.01	ml	Diameter connecting tube	Ø 4_i / 6_o	mm
Weight without packing liquid, approx.	0.6	kg			

[1] Because of the physical measurement principle, the measurement error is dependent on the flow rate. The **data acquisition software "Rigamo"** (accessory) provides an algorithm, which automatically recalculates the actual measurement data to the real values at the respective actual flow rate on the basis of the calibration curve. Thus, the remaining error can be reduced significantly or the flow rate range can be extended at the constant measurement error of ±3%. The remaining error is better than approx. ±1% across the full flow rate range.

[2] = Nominal value; exact value will be determined by individual calibration

[3] = Volume of measuring chamber

[4] Because of calibration factor with 2 decimals

[5] The minimum gas inlet may be increased if the measurement starts with a high flow rate. In this case a higher pressure is needed until the micro capillary in the base plate is clear of packing liquid.

[6] For complete MGC unit applies: With temperatures > room temperature (e.g. if placed in heating furnace) a foam formation of the packing liquid was monitored in particular cases.

Materials

Casing / measurement cell	PVDF (Polyvinylide fluoride)
Screw-type tube coupling	PVDF

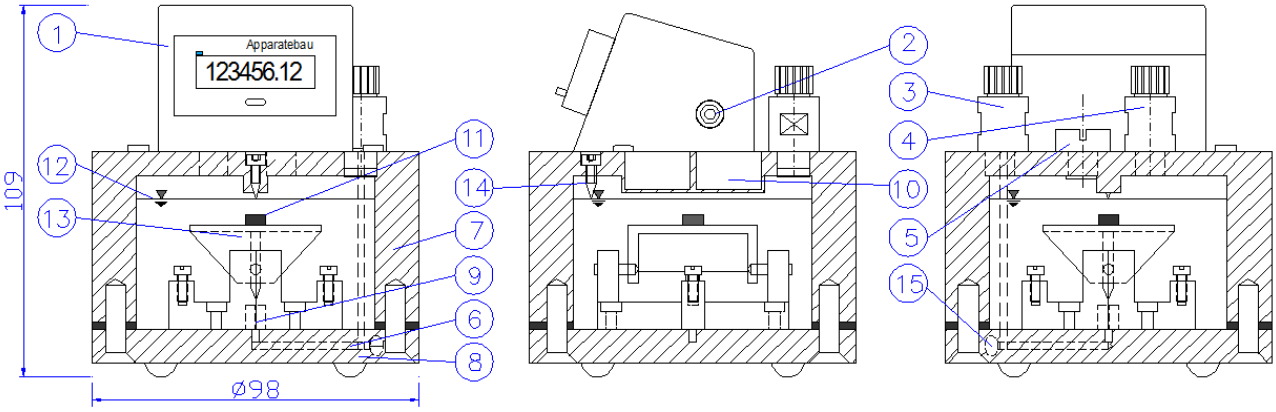
Standard Equipment

Electronic counter / LCD display	Twin-chamber measurement cell
Display: 6 digits [ml] + 2 decimals	1.5 m gas connecting tube Polytetrafluoroethylene (PTFE – Teflon®)
Pulse Generator V6.0 as signal output (reed contact, floating output)	200 ml packing liquid (hydrochloric acid 1.8 vol% = 0.5 mol/ltr) [7]
1 cleaning rod for micro capillary per each 1 to 5 MGC's	1 Syringe for fine adjustment packing liquid level
Funnel for filling of liquid	1 Level

Accessories

Data acquisition software "Rigamo" for Windows®	Packing liquid Silox (for gas mixtures without CO_2)
Gas connecting tube Polytetrafluoroethylene (PTFE – Teflon®)	Packing liquid 200 / 500 / 1,000 / 5,000 ml
Filter 0.45 micron for gas inlet tube	Back-pressure valve for gas inlet tube

[7] Because hydrochloric acid is classified as "dangerous good" there are certain restrictions for transportation depending on the mode of transportation, country of destination, and quantity. Please check prior to your purchase order with your handling distributor or with RITTER the details for your individual case.



(1) Counter unit with LCD display
(2) Signal output (reed contact)
(3) Gas inlet
(4) Gas outlet
(5) Screw plug for filling
(6) Gas inlet channel
(7) Casing
(8) Base plate
(9) Micro capillary tube
(10) Two reed contacts
(11) Permanent magnet
(12) Packing liquid
(13) Measurement cell (tilting body) with twin-chambers
(14) Tracing screw for liquid level (PMMA version only)
(15) Inspection screw gas inlet channel

2. Initial Operation

2.1. Handling after receipt

a) Please read these operation instructions carefully to guarantee a long and trouble-free operation.

b) Unpack the MilliGascounter carefully. The box contains:
- 1 MilliGascounter
- 1 bottle (200ml) of packing liquid (hydrochloric acid 1.8 vol% = 0.5 mol/ltr) [10]
  Option for gas mixtures without CO_2: packing liquid Silox
- 1.5 m connecting tube
- 1 funnel for filling of packing liquid
- 1 syringe per each 1 to 5 MGC's (for fine adjustment of the packing liquid level)
- 1 Level for horizontal alignment of the MilliGascounter
- 1 cleaning tool (PMMA rod with inserted wire) per each 1 to 5 MGC's



[10] Because hydrochloric acid is classified as "dangerous good" there are certain restrictions for transportation depending on the mode of transportation, country of destination, and quantity. Please check prior to your purchase order with your handling distributor or with RITTER the details for your individual case.

2.2. Installation

a) The MilliGascounter should be installed on a horizontal, solid and vibration-free base. Please use the provided spirit level for an approx. horizontal alignment. Thus, the MilliGascounter will have the same position as during calibration.

b) If condensation from the gas to be measured can possibly occur inside of the MilliGascounter please refer to par. 3.4 “Condensation”.

c) **When using hydrochloric acid solution as a packing liquid:** When the packing liquid evaporates, hydrochloric acid vapour may escape from the gas outlet of the MilliGascounter. It is therefore recommended that the supplied tube is connected to the gas outlet and the escaping gas is diverted away from the MilliGascounter to prevent corrosion of the MilliGascounter’s counter unit.

In addition, the tube can be directed into a water bottle to neutralise any hydrochloric acid vapour that may be present. When using several MilliGascounters at one location, a neutralisation bottle with a connection possibility of up to 9 MilliGascounters can be supplied. The neutralisation bottle is filled with simple tap water. It is recommended to fill the neutralisation bottle with fresh tap water before each new series of tests.

Further information can be found in the data sheet for the neutralisation bottle, which can be obtained from RITTER by writing to mailbox@ritter.de.

2.3. Packing Liquid

When and if the measured gas mixture contains CO_2, the fraction of CO_2 dissolves in the packing liquid and outgases at the liquid surface, thus not being measured by the measurement cell.

To avoid this dissolving and outgassing process to the greatest possible extend, hydrochloric acid solution 1.8 vol% (= 0.5 mol/ltr) is supplied along with the MilliGascounter as standard packing liquid. This packing liquid should be used for filling **only** as the calibration is valid with this liquid only. (If a different liquid is used, unavoidable measurement errors will occur due to the different liquid properties like viscosity or surface tension.)

The packing liquid “Silox” can be supplied as an option if the measured gas mixture contains **no** CO_2.

Please note when handling the packing liquid “hydrochloric acid solution”:

- The HCl solution is corrosive due to pH value.
- Avoid direct contact with skin and eyes as well as inhalation of vapours.
- May be corrosive to metals.
- Keep container tightly sealed.
- Recommended storage temperature: 15 – 25°C
- Emergency phone no.: Poison Centre Munich, Tel. +49-89-19240
  or your national Poison Center

Approximately 120 ml of liquid are needed for one filling of the MilliGascounter.

2.4. Filling with Packing Liquid

- Unscrew the screw plug for filling (5).
- Place the supplied funnel into the filling hole.
- Remove any gas tubing at the gas outlet (4) for venting.
- Pour the provided packing liquid through the funnel into the casing.

For fine adjustment of the packing liquid level (16) please refer to par. 2.5. “Setting of the correct Packing Liquid Level”.

Screw the screw plug for filling (5) to the casing with a maximum torque of 1 Nm otherwise the thread might break. (In general, this torque is described as “hand-tight”.)



2.5. Setting of the correct Packing Liquid Level

2.5.1. PMMA Version (Transparent Casing)

a) Please use the provided spirit level for an approx. horizontal alignment. Thus, the MilliGascounter will have the same position as during calibration.

b) Fill in as much packaging liquid until the liquid completely covers the measuring cell.

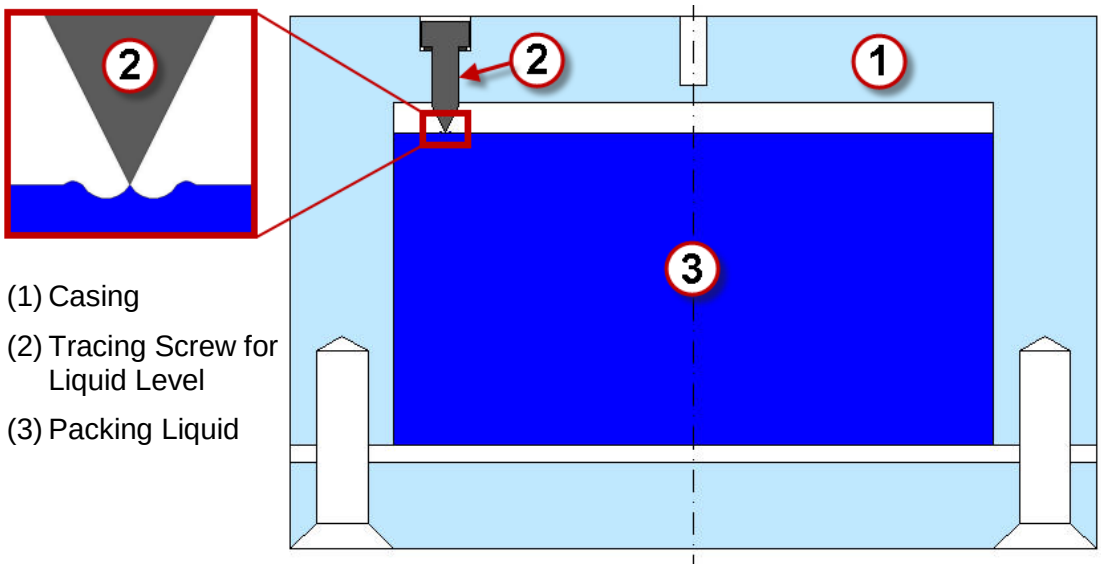
c) Tilt the MilliGascounter twice in such a way that the measuring cell tits twice. For doing so, hold the MilliGascounter in front of you, looking to the display of counter unit. Tilt the MilliGascounter once to the right and once to the left side. Thus a potential air entrapment within the two measuring chambers will be eliminated.

d) Remove the connection tube from the gas inlet nozzle or put the gas inlet to atmospheric pressure. Please wait for approx. two minutes. (The liquid level inside the casing will then be levelled with the liquid level inside the vertical gas inlet channel during that time.)

e) Make the fine adjustments according to the following instructions. For increasing or lowering of the packing liquid, the use of the supplied syringe is recommended.

At the upper part of the casing (1) a tracing screw (2) is located to set the correct level of the packing liquid (3).

By all means, the position of this screw must not be changed!



(1) Casing

(2) Tracing Screw for Liquid Level

(3) Packing Liquid

The MilliGascounter is filled correctly when tip of the tracing screw (2) just slightly touches the surface of the packing liquid (3). (With respect to the surface tension of the packing liquid, a small liquid cone is lifted towards the tip of the screw.)

2.5.2. PVDF Version

a) Please use the provided spirit level for an approx. horizontal alignment. Thus, the MilliGascounter will have the same position as during calibration.

b) Fill in as much packaging liquid until the liquid level is filled up to approx. the middle of the sight glass located in the casing wall beneath the counter unit.

c) Tilt the MilliGascounter twice in such a way that the measuring cell tits twice. For doing so, hold the MilliGascounter in front of you, looking to the display of counter unit. Tilt the MilliGascounter once to the right and once to the left side. Thus, a potential air entrapment within the two measuring chambers will be eliminated.

d) Remove the connection tube from the gas inlet nozzle or put the gas inlet to atmospheric pressure. Please wait for approx. two minutes. (The liquid level inside the casing will then be levelled with the liquid level inside the vertical gas inlet channel during that time.)

e) For increasing or lowering of the packing liquid, the use of the supplied syringe is recommended (see left photo below).

The MilliGascounter is filled correctly when the liquid level matches the indicated dot in the middle of the sight glass (see right photo below).





2.6. Tube connection

The gas source can be connected to the gas inlet tube coupling (3) of the MilliGascounter by means of the supplied PVC tube (MGC PMMA version) or Teflon® tube (MGC PVDF version).

Open the screw plug at the gas inlet port (3) and push the plug some centimeters onto the end of the tube. Push this tube end down onto the cone inside of the gas inlet port and screw the screw plug tight then.

Please note:

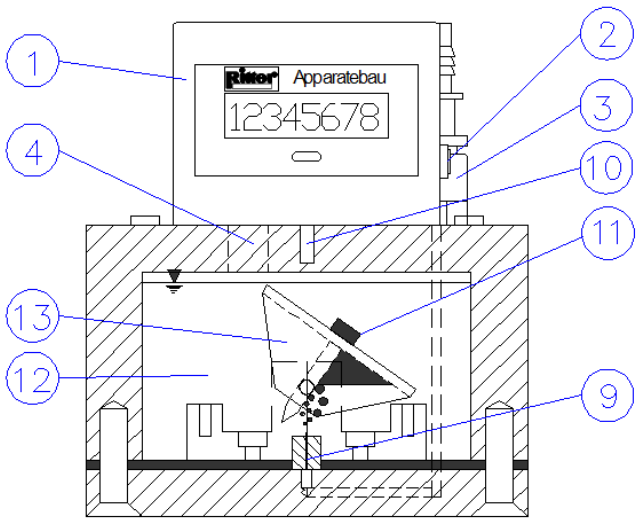
When tightening the screw plug, **do not** use a tool! Tighten the nut with two fingers “hand-tight”. Otherwise, the thread of the coupling element within the MGC casing material might be overwound thus destroying the gas-tight connection between coupling element and casing.

According to the requirements the gas outlet tube coupling (4) may be connected to an onward system or device by means of the supplied tube in the same way as described before.

If not using the supplied tube please use gas-tight tubing for connection to the MilliGascounter. Silicone tube is not suitable and simple rubber tubing is only conditionally suitable.

3. Measurement

3.1. Measurement principle



The gas to be measured flows in via the gas inlet nozzle (3), through the micro capillary tube (9) located at the base of the MilliGascounter and up into the liquid casing which is filled with a packing liquid (12).

The gas rises as small gas bubbles through the packing liquid, up and into the measurement cell (13). The measurement cell consists of two measuring chambers, which are filled alternatingly by the rising gas bubbles. When a measuring chamber is filled, the buoyancy of the filled chamber causes the measurement cell to abruptly tip over into such a position that the second measuring chamber begins to fill and the first empties.

The measurement of gas volume therefore occurs in discrete steps by counting the tilts of the measurement cell (13) with a resolution of approximately 3 ml (= content of one measuring chamber, please refer to par. 3.2. below). This “residual error” (= max. 3 ml) caused by the resolution should be taken into account when estimating/calculating the total measurement error.

The tilting procedure of the measurement cell creates by the permanent magnet (11) on top of the cell and one of the two magnetic sensors (reed contacts) (10) a pulse which is registered by the counter unit (1).

For external data logging (PC) the switching pulses of the second reed contact can be obtained via the signal output socket (2). (Please refer to par. 4.3 “Signal Output”).

The measured gas exits through the gas outlet nozzle (4).

3.2. Calibration / Measurement Error

3.2.1. Static Correction of Manufacturing Tolerances

Because of manufacturing tolerances, the exact (real) volume of a measurement cell is generally ≠ 3.0 ml. Therefore, it is determined by an individual calibration of each MilliGascounter unit. This real cell volume…

- is determined at the standard flow rate of 500 ml/h,
- is stated in the calibration certificate,
- is programmed into the counter unit.

The number of tilts of the measurement cell during a measurement is multiplied by the cell volume programmed into the counter unit and the result is displayed as volume at the counter unit.
Please note however: Because the calibration factor programmed into the counter unit is determined at the standard flow rate of 500 ml/h, the volume displayed at the counter is exactly valid at this flow rate only. At lower flow rates a too large volume

will be displayed (positive measurement error), at lower flow rates a too small one (negative measurement error). In order to prevent, respectively to minimise these errors, the optional data acquisition software “Rigamo” provides an automatic dynamic correction of the measurement error across the full flow rate range. For further information please refer to the following par. 3.2.2.

3.2.2. Dynamic Correction of the Measurement Error

Because of the physical measurement principal, the measurement error is dependent on the flow rate. The error is approx. +3% at min. flow rate and -3% at max. flow rate.

A data acquisition software “Rigamo” is available as accessory which provides -among other features- an automatic correction of the dynamic (= flow rate dependent) measurement error. Basing on the individual calibration curve of each MilliGascounter unit, the algorithm of this software automatically recalculates the actual measurement data into the real values of gas volume and flow rate. **The remaining error is better than approximately ±1% across the full flow rate range.**

3.3. Effect of Dead Space Volume

The dead space volume is defined as the volume of the total gas pipe line system between the gas source and the MilliGascounter (for fermentation tests: including the volume of the fermentation vessel above the substrate).

If the measurement of the gas volume starts at ambient pressure (gauge pressure in the dead space volume = ambient pressure), the generated gas volume causes an increase of the pressure in the pipe system only at first. Only after exceeding the minimum gas inlet pressure of 5 mbar the measuring of the gas volume by the MilliGascounter starts.

Due to the design of the MilliGascounter this overpressure of 5 mbar will remain in the dead space volume at the end of the test. The deficit volume caused by this effect has to be added to the measured volume and it is calculated as follows:

$$V_D = V_{DS} x (\frac{P_a + P_{DS}}{P_a} - 1)$$

whereby

V_D	=	Deficit volume	
V_{DS}	=	Dead space volume	
P_a	=	Actual ambient pressure	[mbar]
P_{DS}	=	Remaining pressure in dead space volume **= 5**	[mbar]

3.4. Condensation

If the gas to be measured contains water vapour or another condensable gas, it is necessary to make sure that the gas does not condense inside the MilliGascounter. This can be achieved through *cooling* the gas to room temperature before-hand or through using a *condensation trap*. The easiest way to cool the gas is using proportionately longer gas inlet tubing or a metal pipe (e.g. 20 cm long); if necessary, the gas inlet tubing can be put into a water bath.

If condensation cannot be avoided, the MilliGascounter should be installed in such a way, that the condensation present in the gas inlet tubing cannot flow into it[7]. At the same time such a condensation trap also prevents the reverse, i.e. it prevents the packing liquid from flowing backwards into the gas supply line or to the gas source (fermentation tank). This can occur as a result of a drop in temperature within the gas source/gas supply line system (fermentation equipment) creating an under-pressure. Appropriate condensation traps can be supplied upon request by Ritter. If condensation gets into the MilliGascounter nevertheless, it will collect at the bottom of the packing liquid casing and can be siphoned off with a pipette.

3.5. Influence of Particles (Dirt & Dust) in the Gas Flow

If the gas flow in the incoming tubes or in the micro capillary tube is obstructed by particles or liquid, the calibration factor will be affected. Therefore, dust particles have to be absorbed by a suitable filter and the inner surface of the tubes from the gas source must be dry.

3.6. Effect of Temperature

Because of the extreme resolution of the MilliGascounter in the millilitre range, “volume flows” can also be registered as a consequence of changes in temperature. A temperature rise [or decrease] at the gas source or respectively in the supply system causes an expansion [or contraction] of the gas present in the system proportional to its volume. Whereas an expansion of the gas generates a “virtual” gas flow (with a corresponding display at the counter unit), a contraction causes an under-pressure in the supply system. This under-pressure enables packing liquid to flow through the micro capillary tube into the gas feeder tubing. Packing liquid in the gas feeder tubing causes

⇒ an increased admission pressure,
⇒ a time delay until the first display on the counter unit
(until the micro capillary tubing is once again free of packing liquid),
⇒ erroneous measurement deviations.

No actual measurement should therefore be started until the temperature of the total system has been adjusted[8]. An expansion of the gas during adjustment of the temperature and the subsequent build-up of an overpressure can simultaneously be used as an operational check of the MilliGascounter (description of reset button, please refer to par. 4.2. “Reset Button”).

The room temperature should remain approximately the same during the whole of the measurement period. (Please mind a temperature decrease during the night and over the weekend.) Otherwise the temperature has to be monitored so that an integrating correction of the measurement values can be made (please refer also to: „Temperature- and Pressure corrections“). Another alternative is the installation of the MilliGascounter, gas feeder tubing and gas source in a temperature-controlled cupboard.

3.7. Effect of System Gas Pressure

A rise [decrease] in pressure at the gas source or respectively in the gas supply system causes an expansion [contraction] of the gas present, proportional to its volume. The same therefore applies to air pressure as was mentioned in the previous Section on the Effect of Temperature.

---

[11] We recommend the use of condensation traps when the MilliGascounter is connected to a fermentation tank, and in particular with thermophile fermentation processes. A lot of water vapour can escape particularly in those cases.

[12] With fermentation tests: After equalization with the fermentation temperature.

3.8. Effect of Water Vapour Partial Pressure[9]

If the measurement result has to be corrected for the volumetric share of water vapour, the values in the following table 1, which take the temperature into account, can be used in the equation listed under par. 3.9. below:

Temp. °C	Water vapour partial pressure mbar (psi)		Temp. °C	Water vapour partial pressure mbar (psi)		Temp °C	Water vapour partial pressure mbar (psi)
15	17.0 (0.246)		20	23.4 (0.339)		25	31.7 (0.459)
16	18.1 (0.262)		21	24.9 (0.361)		30	42.6 (0.617)
17	19.4 (0.281)		22	26.4 (.0383)		35	56.4 (0.817)
18	20.6 (0.299)		23	28.1 (0.407)		40	73.9 (1.071)
19	22.0 (0.319)		24	29.9 (0.433)		45	95.9 (1.390)

Table 1: Values of water vapour partial pressure

3.9. Temperature and Pressure Corrections

The MilliGascounter is a volumetric gas meter and therefore measures gas volume in the actual operating state existing at the time of measurement. The gas volume is dependent on gas temperature, air pressure and water vapour partial pressure (for water vapour partial pressure refer to footnote “10“). These measurable variables are therefore needed to recalculate to norm conditions. The gas temperature is to be measured at the gas **outlet**.

According to the general gas laws the following equation is used for temperature and pressure corrections:

$$V_N = V_i \times \frac{P_a - P_V + P_L}{P_N} \times \frac{T_N}{T_a}$$

whereby

V_N	=	Norm-Volume	in	[ltr]
V_i	=	Indicated (displayed) Volume	in	[ltr]
P_a	=	Actual Air Pressure	in	[mbar-absolute]
P_V	=	Water vapour partial pressure	in	[mbar]
P_L	=	Pressure of the Liquid Column above the Measurement Chamber	**= 1**	[mbar]
P_N	=	Norm-Pressure	**= 1013.25**	[mbar]
T_N	=	Norm-Temperature	**= 273.15**	[Kelvin]
T_a	=	Actual Temperature	in	[Kelvin]

If the exact air pressure is not known, the norm-pressure can in that case be used.

Air pressure swings of 980 - 1050hPa create errors in the range of -3.3% to +3.7%.

---

[13] The information in this par. 3.8 is valid only for gases which contain water vapour **and** if the volume of the water vapour **must be** mathematically eliminated from the measurement result. If the water vapour is a „natural“ element of the gas and its volume should therefore be taken into account, then no (partial-)pressure correction should be carried out. In that case, $p_V = 0$ must be used in the equation listed under par. 3.9.

3.10. Special Features with Fermentation Tests

- In incubators without compulsory ventilation, uneven temperature distribution can cause under-pressure in the reaction vessels.
- To determine the total gas production as accurately as possible, it is advisable to leaven the released CO_2 in the fermentation tank to pH 1-2 after the fermentation test has ended. However, this can lead to foam formation and wetting of the tubing.
- The MilliGascounter was calibrated at room temperature (21ºC). If the in-house standard temperature is 21°C as well (instead of the international standard of 0°C / 273.15 K), the temperature correction is not necessary when the gas is cooled down to 21°C. With a fermentation temperature of 37ºC this is obtained when using a connecting tubing with a length of 1.5 m.
- Experiments to determine the methanogenic potential of organic substances in the laboratory of Prof. Dr. Paul Scherer[14] (University of Applied Sciences Hamburg, Paul.Scherer@rzbd.haw-hamburg.de) have shown that the dry matter content of the seed sludge has not only an influence on the velocity of the gas production, but also on the total amount of produced gas. Of course in all cases parallel to the gas production of a test substance a reference without added organics was subtracted. Based on these findings it is recommended to use in such experiments at least 3% dry matter content of a seed sludge. It is important to homogenize the sludge by a mixer before use. It is also of importance that thickened sewage sludge often contains small amounts of polymers to support the coagulation. But added polymers often contain substantial amounts of biodegradable alkanes to facilitate the addition. These additives increase the background production of biogas during a test period. If the background production of biogas is too high this could complicate the calculation of the gas production of the test substance.
- But if the gas production of the seed sludge is too low then in some situations it can occur that the pressure in the test flasks drops down below the atmospheric pressure. According to the principle of connected tubes this can lead to a flow of oily packing liquid into the test trial vessel. In such cases it is recommended to increase the background gas production by the addition of cellulose powder (e.g., Avicel). Also the test approach should be started at room temperature so that the temperature in the incubators (mostly 35-37°C) increases smoothly generating thereby a small overpressure.

---

[14] Scherer, P.A. (2001) Influence of high solid content on anaerobic degradation tests measured online by a MilliGascounter® station for biogas. In: Proceedings of the 9th World Congress on “Anaerobic Digestion 2001” (L. van Velsen, W. Verstraete, Eds.), Antwerpen

4. Counter unit

4.1. Display

The real cell volume is determined by an individual calibration of each MilliGascounter unit and it is programmed into the counter unit. The number of tilts of the measurement cell during a measurement is multiplied by the programmed cell volume and the result is displayed as volume at the counter unit. The volume is displayed in milli-liters (6 digits) with a resolution of 0.01 ml.

Please note when using the "Rigamo" data acquisition software:

- The **display unit of the MilliGascounter** includes a calibration factor which corrects the deviation of the measurement data from the real value at the standard flow rate of 500 ml/h (0.5 ltr/h).
- In contrast, the **software RIGAMO** corrects the measurement data at the respective current flow rate. As a result, the volume values shown on the display and by RIGAMO may differ if the MilliGascounter is operated for a longer period of time with a flow rate that deviates significantly from the standard flow rate.
- **If no individual calibration data file was selected and designated to a MilliGascounter, no correction of the measurement data will be performed.**

4.2. Reset Button

The blue reset button is located under the digital display. A press of the reset button erases the measurement value memory and sets the display back to zero. The calibration factor remains preserved in the counter unit.

4.3. Signal Output

4.3.1. Reed Contact

- **Function:**

  The measurement of the flowing gas volume occurs by counting the number of tilts of the measurement cell (13) by means of a permanent magnet (11) and two magnetic sensors (reed contacts). The magnet is located at the top of the measurement cell; the reed contacts are located within the cover on top of the casing.

  The tilting procedure of the measurement cell closes the two reed contacts. The first one triggers a counter pulse at the counter unit (1). Additionally, the second reed contact works as a pulse generator (V6.0) and can be used as signal output from the MilliGascounter to an external data acquisition system. Please note that the counter unit **displays** a **gas volume** in ml. In contrast, the **pulses** provided at the **output socket** are equivalent to the **number of tilts** of the measurement cell. For further information please refer to par. 3.2.2.

  The reed contact of the signal output works as a potential-free closing contact.

- **Electrical Data:**

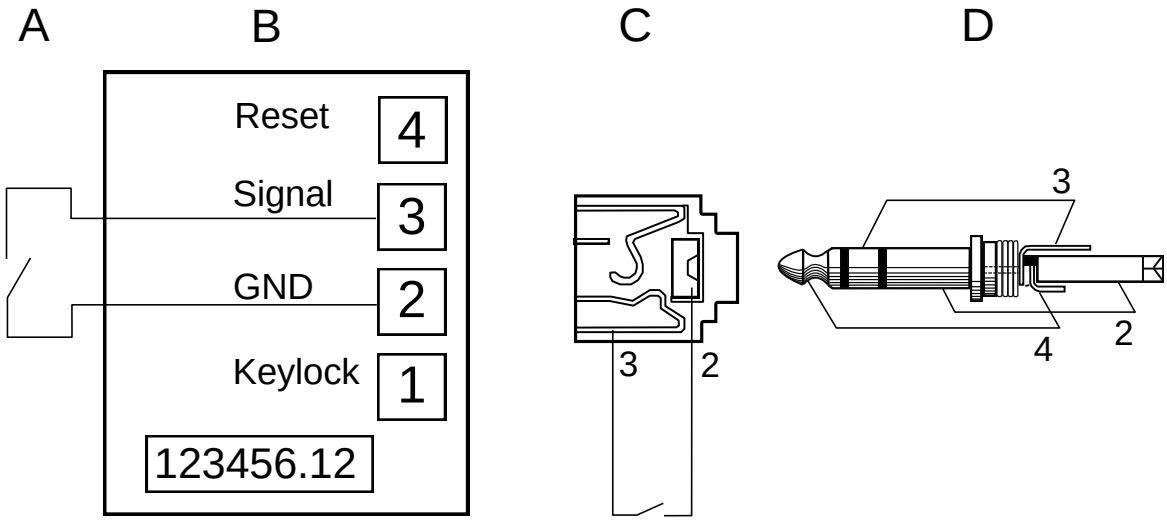
Max. switching power	10	Watt
Max. switching current	0.5	A/DC
Max. switching voltage	100	V/DC
Switch-/closing time, approx.	0.1	sec
Rebound time	< 1	msec
Max. switched contact resistance	150	mOhm

4.3.2. Output Socket

The switching pulses of the reed contact can be obtained at the output socket (2).

Attention: The switch pulses of the reed contact are equal to the number of tilts of the measurement cell. The pulses therefore represent the uncorrected (not calibrated) measured gas volume. The gas volume obtained via the signal output socket must therefore be multiplied by the calibration factor to get the true gas volume.

The output socket is a standard 3.5 mm stereo socket, into which a compatible jack plug can be inserted (identical to a jack plug of Walkman cassette players).



Legend:

Part	Function
A	Reed Contact no. 1 for counter
B	Counter and LCD display
C	Reed Contact no. 2 for output signal and Output Socket
D	Jack plug (3.5 mm stereo socket)

Pin / Contact of Jack Plug	Function
2	Ground
3	Signal
4	Not used

5. Maintenance

5.1. Checking the Packing Liquid Level

The rate of evaporation of the packing liquid in the MilliGascounter is very slow but dependent upon the gas flow rate as well as the operating temperature. Also the diameter of the gas outlet nozzle (4) contributes to it. Therefore, the evaporation can be diminished even more by closing the outlet with a stopper and piercing it with a syringe needle. To ensure stable measurement accuracy therefore, the packing liquid level must be checked from time to time. (Regarding the correct level please refer to par. c) “When using hydrochloric acid solution as a packing liquid: When the packing liquid evaporates, hydrochloric acid vapour may escape from the gas outlet of the MilliGascounter. It is therefore recommended that the supplied tube is connected to the gas outlet and the escaping gas is diverted away from the MilliGascounter to prevent corrosion of the MilliGascounter’s counter unit.

In addition, the tube can be directed into a water bottle to neutralise any hydrochloric acid vapour that may be present. When using several MilliGascounters at one location, a neutralisation bottle with a connection possibility of up to 9 MilliGascounters can be supplied. The neutralisation bottle is filled with simple tap water. It is recommended to fill the neutralisation bottle with fresh tap water before each new series of tests.

Further information can be found in the data sheet for the neutralisation bottle, which can be obtained from RITTER by writing to mailbox@ritter.de.

Packing Liquid”.

5.2. Exchange of Packing Liquid

An exchange of the packing liquid

- is **necessary** when particles or substances of the gas, which are imposed to the liquid, create a bubbling of foaming of the liquid,
- is **recommended** when a visible large quantity of particles is floating in the liquid.

5.3. Cleaning

5.3.1. Cleaning the Micro Capillary Tube

The free cross-section of the micro capillary outlet (9) on the bottom of the liquid container has a substantial influence on the measurement accuracy. A narrowed gas outlet primarily influences the gas pressure, which can then also increase to over 30 mbar in the gas supply lines and cause a pulsating gas flow. This leads to erroneous measurement deviations. The micro capillary tubing should therefore be cleaned occasionally.

a) To do this, empty the MilliGascounter by either pouring out the packing liquid through the gas outlet nozzle (4) or by sucking it out through this nozzle with a pipette.

b) Remove the 4 closing screws underneath the casing base plate.

c) Remove the 4 screws of the fixture of the measurement cell support (bearing block) which is located at the base plate.

d) The micro capillary should only be cleaned with the cleaning rod containing a fine wire delivered for this purpose with the MilliGascounter. A wire with a smaller diameter would not have the desired cleaning effect; a larger diameter could

damage the micro capillary and consequently lead to an alteration in the calibration and **measurement error**.

e) Re-assemble the fixture of the measurement cell to its original position.

f) Re-assemble the casing base plate to the casing. Please mind the proper position of the sealing ring. The tightening sequence of the 4 base plate screws should be such that one screw pair positioned at opposite sides of the casing base plate is tightened first followed by the second screw pair (not all screws one after the other in circumferential direction). The **torque for tightening the screws** must not exceed **3 Nm** (“hand-tight”) to avoid a damage of the plastic threads.

g) Fill the MilliGascounter with liquid according to par. 2.3 ff “Packing Liquid”.

5.3.2. Cleaning the MilliGascounter Casing The MiliGascounter casing can be cleaned with cleaning agents that do not attack PMMA material, for example washing-up liquid. For opening the casing, please follow the instructions according par. 5.3.1 (a) to (c).

General cleaning:

- Warm water plus washing-up liquid
- Commercially available cleaning products suitable for PMMA
- The Fermentation Bottles are dishwasher safe (max. 60°C / 140°F)

Heavy soiling:

- Isopropanol or benzene-free cleaning petrol

Disinfection:

- Isopropanol (2-Propanol)

Please do not use:
(Substances would cause stress cracks)

- Organic substances
- Acetone
- Benzene
- Ethanol
- Alcohol
- Any benzene-containing petrol/gasoline
- Any dilution of synthetic resin

5.4. Counter Unit Battery Exchange

The counter unit is equipped with a lithium battery (2 V) with a life-time of 4 to 5 years (information without engagement[10]). Unfortunately, the battery cannot be exchanged because it is welded to its support.

Therefore, the MilliGascounter has to be sent back to the manufacturer for changing of the counter unit.

5.5. Disassembly / Exchange of the Measurement Cell

If it should become necessary to exchange the measurement cell, it is recommended to return the whole unit to the manufacturer. If this is not possible or if it is uneconomical, the measurement cell (including the cell bearing block) can be exchanged as follows:

- Follow the instructions according par. 5.3.1 (a) to (c)
- After having received the replacement cell (including the cell bearing block), follow the instructions according par. 5.3. (d) to (g) for re-assembling the cell.

After the assembly is completed, it is recommended to perform the following function tests:

- Free swinging: Hold the MilliGascounter upside down and swing the whole unit. The measurement cell should swing free and easily.
- Gas tightness of the MilliGascounter: Close the gas outlet nozzle (4) by inserting a sealed tube. Apply a gas pressure of approx. 10 to 20 mbar to the gas inlet and monitor the pressure indication (manometer). The pressure should remain constant.

5.6. Long-term Storage

If the MilliGascounter is filled with hydrochloric acid solution, it must be emptied and rinsed with water.

Storage should be in a dry room at room temperature.

[10] Besides tolerances during manufacturing the storage and working temperature of the battery / MilliGascounter affects the working life.