3.8. Effect of Water Vapour Partial Pressure [11]

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 “11“). These measurable variables are therefore needed to recal-culate 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:

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

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%.

[11] 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.
- The free volume in the fermentation tank and in the feeder tubing to the Milli-Gascounter should not be smaller than 0.5 ltr. This volume acts as a buffer volume with both eruptive running fermentation processes and reduction of temperature to prevent the generation of under-pressure. Because of this, only tanks which have a free volume of at least 0.5 litres above the test material should be used.
- 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[12] (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.

[12] 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 MilliGacounter 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.

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:**

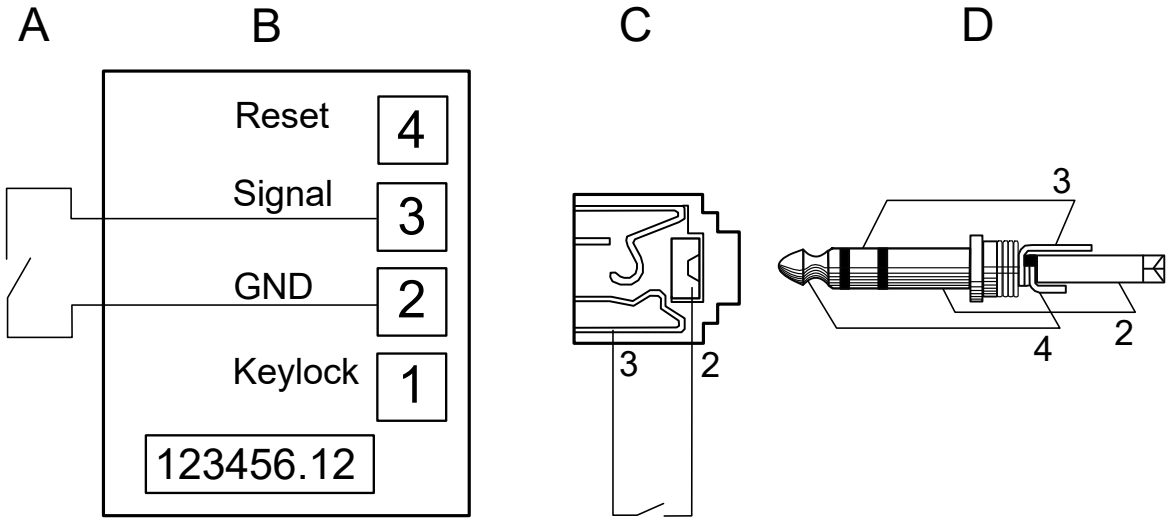
Max. switching power	10	Watt
Max. switching current	0.5	A/DC
Max. switching voltage	100	V/DC
Switch-/closing time, approx.	0.1	sec
Rebound time	< 1	msec
Max. switched contact resistance	150	mOhm

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. 2.3 “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 are floating in the liquid.

5.3. 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 “Packing Liquid”.

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[13]). 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. (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:

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

- 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

There are no measures to be taken for a long-term storage.