ID China bio-gas experimentations
法国发起发展组织昆明办公室“沼气池优化管理”研究

PERFORMANCE TEST OF TWO MODELS OF GAS FLOW METERS
针对两种气体流量计的测试研究

Report - July 2013 报告时间：2013 年 7 月

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1 ABSTRACT 摘要

As part of its commitment to provide continuous support to the more than 2500 families using a biogas digester build by Initiative Développement China (ID China), the NGO has engaged in a one year study focused on optimising the management of biogas digesters.

As part of this project, ID China has tested the performance of two models of gas meters which could be candidate devices for a campaign of long-term measurements. The potential uses of the gas meters include keeping track of the gas consumption of the families for monitoring purposes, as well as running experiments, such as testing different feedstocks or management options and observing their impact on the gas production. Furthermore, certain carbon emission certification standards might, in the future, require measurements of typical household consumptions.

The testing protocol consisted in the comparison of the gas meter readings with a standardised device using a water displacement principle. Between two and three gas meters to be tested were connected in series with the water displacement device, and a volume of approximately 20l of gas was circulated through the circuit. For each set of devices, 8 to 10 such tests were performed at different flows and gas pressures. The tested flows varied between 0.04 m^3/h and 0.63 m^3/h. The tested pressures were comprised between 0 and 6.4 kPa. Typical household biogas consumption flows vary between 0.07 m^3/h (gas lamp) and 0.45 m^3/h (stove at maximum power).

Three models of diaphragm meter **SZ-G1.6T** from Zhejiang Sanzhan Gas Meter Co., Ltd. were tested. Performances were very poor below 0.1 m^3/h, for all three gas meters. One gas meter performed poorly for flows up to 0.35 m^3/h, showing errors of at least -40%. Above 0.1 m^3/h, the other two gas meters showed errors of no more than (in absolute value) -16% and -4% respectively.

Four models of impeller meters **TYG-Y-4** from Jilin Changchun Tianyi were tested. These meters have been marketed especially for the measurement of domestic biogas consumptions. One meter performed very poorly, with errors between -40% and -100% over the whole range of flows. For the three other meters, the performance was overall good above 0.35 m^3/h, with errors within +/- 10%. Below 0.35 m^3/h however, the behaviour of the device was very random, with many instances in which the impeller failed to move at all. When the impeller started, the results were however generally precise.

The results were mainly flow dependant, and no correlation could be drawn between the performances of the gas meters and the relative pressure at which they were operating. All results were pressure-corrected.

In the light of ID China's requirements for future uses of gas meters, none of the devices perform to a satisfactory standard, neither respected the manufacturer's specification. However, during the research, a relatively efficient and cost-effective approach has been developed for testing gas meters on the field. This method could be used again for the future testing of other models.

法国发起发展组织 Initiative Développement (以下简称 ID)为 2500 余户农村家庭建设了户用沼气池，为了向受益者提供持续的项目后期维护，ID 进行了为期一年的“沼气池优化管理”研究。

为对沼气池运行进行长期监测，ID 中国对比了一些气体流量计，并选择了其中两种更具竞争力的流

量计进行了测试。在将来，ID 可能使用气体流量计跟踪每户家庭沼气的使用量，测试不同原料以及不同沼气池的管理方法对产气量的影响等。除此之外，二氧化碳减排量的认证标准可能在将来需要检测特定家庭沼气的使用量。

测试原则是利用排水原理的装置的读数来对比气体流量计读数的准确度。将排水装置与需要被测试的两种气体流量计连接，并使约 20 升的沼气流通。用不同的气体流量和气压来测试每组装置 8 至 10 次。测试的气体流量从 0.04 立方米/小时至 0.63 立方米/小时不等。测试的气压从 0 至 6.4kPa 不等。典型户用沼气的流量从 0.07 立方米/小时（沼气灯）至 0.45 立方米/小时（沼气灶的最大功率）不等。

在对浙江出产的三个型号的膜式流量计 SZ-G1.6T 的测试中，当气体流量值低于 0.1 立方米/小时，三个流量计的性能都不理想。当气体流量达到 0.35 立方米/小时，其中一个流量计的错误率至少为-40%。当气体流量超过 0.1 立方米/小时，其余两个流量计错误率的绝对值分别为-16%和-4%。

我们又对吉林长春出产的四个型号的叶轮式流量计 TYG-Y-4 进行了测试。这几个流量计的标签上注释了其专门为户用沼气池沼气使用量检测而设计。其中一个流量计的性能糟糕，在所有流量测试中错误率在-40%至-100%之间。其余三个流量计的性能较好，当气体流量在 0.35 立方米/小时，其错误率在+/-10%之间。当气体流量低于 0.35 立方米/小时，这组流量计的性能波动较大，在几次测试中，叶轮甚至停止了运转。当叶轮正常运转时，测试结果普遍准确。

流量计的测试结果取决于测试时气体流量的大小。流量计的功效与其运行时的相对气压无关，因为在所有测试前都做过压力校正。

根据 ID 中国未来对气体流量计使用的需求，被测试的流量计中没有任何一个达到我们满意的标准，也与生产商所保证的质量不符。然而，研究发明了一套测试气体流量计领域的经济有效的测试途径。这一测试途径可以在将来用于测试其他装置。

2 TESTED MODELS

Illustration 1: Diaphragm meter (above) and impeller meter (below)

2.1 DIAPHRAGM METER

Three devices **SZ-G1.6T** from Zhejiang Sanzhan Gas Meter Co., Ltd. were tested.

At the time of testing, two of the meters (D1 and D2) had been in service for 3 months for measuring the consumption of a household equipped with a 10m^3 digester. During this time of use, the gas flow was purified with a sulphur filter. The third meter (D3) was new.

The specifications of this gas meter model are reported below.

Name of parameters	Unit	Type		
		SZ-G1.6T	SZ-G2.5T	SZ-G4.0T
Maximum flow-rate Qmax	m^3/h	2.5	4	6
Minimum flow-rate Qmin	m^3/h	0.016	0.025	0.04
Maximum pressure	kPa	50		
Basic error	%	Qmin≤Q<Qt ±3		
		Qt≤Q≤Qmax ±1.5		
Connection screw worm		M30×2orG¾orG1¼		
Distance between connection centers	mm	110 or130		
Working temperature	°C	—10~+40		
Pressure loss	Pa	≤200		

产品概述：

SZ-GT 系列钢壳燃气表适用于天然气、人工煤气、液化石油气、沼气等燃气流量的计量。现有的产品分家用和工业用两种。其中 G1.6T 、 G2.5T 、 G4.0T 为家用膜式燃气表， G6T 、 G10T 、 G16T 、 G25T 为工业用膜式燃气表。

主要性能特点：

1. 容积式计量器具，采用膜式结构，设计先进、结构合理、计量准确、灵敏度高，性能稳定。

2. 机芯为聚甲醛塑料整体计量室，外壳采用优质钢板拉深成形后压封而成。

3. 机芯与计数器之间采用磁耦合传动，保证小阻力和良好的密封性。

4. 使用维修方便，采用特殊的表面处理技术，防腐能力强，使用寿命长。

主要技术指标：

名称 型号规格	家用膜式燃气表			工业用膜式燃气表			
	G1.6T	G2.5T	G4.0T	G6T	G10T	G16T	G25T
公称流量（m3/h）	1.6	2.5	4.0	6	10	16	25
最大工作压力（kPa）	10			15			

2.2 IMPELLER METER

Four devices **TYG-Y-4** from Jilin Changchun Tianyi 吉林长春天意 were tested. All devices T1, T2, T4 and T5 were new and had not been used for gas measurements before.

The specifications of this model are reported below.

一、产品简介：

TYG—Y—4 B级叶轮式燃气表是当今世界最先进的气体流量计量精密仪表，它利用气体运动原理推动机械运动实现计量气体消耗量之目的。

本仪表由壳体、射流盘、喷嘴、叶轮、传动系统和计数器等组成，射流盘采用分流式气道设计，经过上万次流量试验，选定了最佳组合方案精心设计而成。该表由四个喷气嘴控制气流导向，当流量很小时(0.025m^3/h 和 0.4m^3/h 时) 气流除主流道进入内气室外，外来气体从锥型进气道进入斜角气道，开启分流小阀盖，喷射到外气室内，并分配到各喷嘴中使叶轮旋转，带动传动系统运行；当气流 加大时，部分气体仍从斜角气道进入，此时小阀盖闭合，大阀盖开启，由外气室从喷嘴射向内气室，顺气室切线方向射到叶轮上，使叶轮旋转，流量的大小控制叶轮 旋转的快慢，从而实现计量之目的。

射流盘采用工程塑料一次成型，流道光滑通畅，流动阻力小，叶轮采用铝合金冲压成型，各转动轴均采用合金钢淬火制成，轴承采用烧结刚玉材料，光滑、坚硬、耐磨。因此机心具有高强度、耐磨、耐温、防锈、性能稳定、可靠，耐久性好等特性。是当前国内外最先进的燃气计量仪表。

本设计经可靠验证，气体流动在室内运行顺畅，气室内不会存有任何杂质，因此在长时间使用中不影响计量精度，是当前各国燃气公司首选的计量仪表。

二、产品特点：

叶轮式燃气表经上万次测试和多年实践精心研制而成，它克服了膜式燃气表的一切缺陷，是国内外首创，其工作原理和产品结构是当今世界最先进，最新型的，其工作可靠性是对燃气表质量的全面提升。

它具有体积小、重量轻、精度高、应用范围广、使用时间长、安装方便、工作稳定、并具有防盗气和防计量失真等功能。是当前最适用的产品。

三、应用范围：

叶轮式燃气表适用于人工煤气、天然气、液化石油气、空气及其它多种气体流量的累积计量。

四、主要技术性能参数：

本表执行本公司制定的Q/JTY 叶轮式燃气表企业标准，主要技术性能参数

型号规格：TYG—Y—4

最大流量：Qmax(m^3/h)：4

最小流量：Qmin(m^3/h)：0.025

最大工作压力(Kpa)：5

最大压力损失(pa)：200

准确度(级)：B

计量精度：Qmin≤Q＜0.1Qmax 时 ±3%

0.1Qmax≤Q≤Qmax 时 ±1.5%

介质温度(℃)：－30 ~ +60

最小分度值：0.0001

适用介质：人工煤气、天然气、液化气等多种气体介质

连接形式：M30×2

重量(kg)：1.3

外形尺寸(mm)长×宽×高　215×130×140

五、包装、存放、使用说明：

1、燃气表应装入牢固的箱内，不允许燃气表在箱内自由窜动，搬运时小心轻放。

2、燃气表应存放在防雨防潮、不受机械振动或冲击，温度范围－30℃ ~ +60℃，相对湿度≤80%的环境中。

3、燃气表安装应进行外观检查，检查燃气表在运输中是否有损坏。

4、安装前应进行密封性能检查，输入 1.5 倍最大工作压力的压缩空气，关闭出口，检查有无漏气现象。严禁明火检查。

5、燃气表应保持水平安装，不得倾斜、倒置、不适用于强烈震动，安装时燃气表的方向与气流方向保持一致。

6、未经管理部门同意，用户不得随意拆装或启封调试，以确保燃气表的精度及用户的安全。

3 METHODOLOGY

Three separate series of tests were conducted on the field. In each test, a volume of biogas was circulated through the meters to be tested, which were connected in series. The gas was collected in a water displacement tube, which is described in the next section. The gas volume was measured by displacement of the water, which was itself weighed with a precision scale. Pressure gauges were inserted between the two gas meters as well as downstream of the second meter. A valve located before the water tube was used to adjust the flow. The installation is shown below in illustration 2.

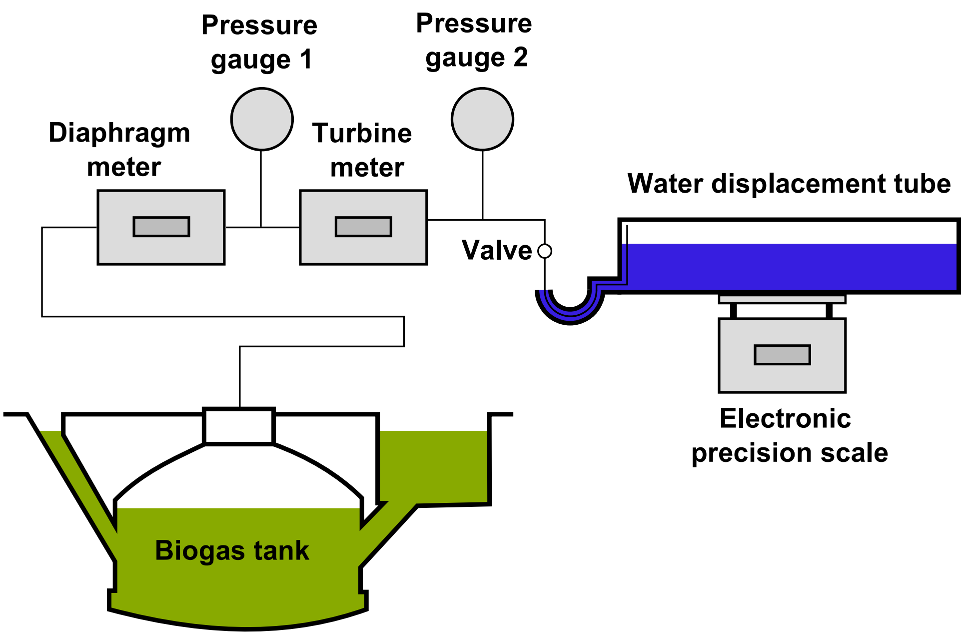


Illustration 2: Schematic installation (not to scale)

For each test, the following sequence was observed:

1. The tube was filled with water.
2. The scale was reinitialised to 0.
3. The starting indexes of the two meters were written down.
4. The valve was opened while the chronometer was started.
5. While the tube was filling with gas and simultaneously expelling the water, the pressures on the two gauges were monitored.
6. When the tube was nearly empty of water, the valve was closed and the chronometer was stopped.
7. The weight displayed on the scale was written down, as well as the end indexes of the two gas meters and the duration of the test.

Illustration 3: The water displacement tube

The households chosen for the tests draw their gas from two $10m^3$ biogas tanks. A week prior to the test, the households were asked to stop using the gas to leave the pressure build up to around 6.5 kPa. Measurements were then made first at that maximal pressure, then the pressure was lowered in steps to around 4.5 kPa, 3 kPa and 1 kPa by consuming gas, while further measurements were made at these pressures.

In addition to making measurements at different pressures, a variety of flows were tested. The flow was adjusted at the entrance of the water displacement tube by using the valve. Since the valve was a simple on/off valve, it was not possible to know precisely the flow beforehand. Instead, the duration of the experiment was timed, and the mean flow was calculated afterwards by dividing the volume (as calculated in the water displacement tube) by the duration of the experiment.

However, the pressure at the gas meters was not independent from the flow. Firstly, at high flows the pressure drop was significant through the 20m pipe leading from the biogas tank to the kitchen where the experiment was held. At full flow (all valves fully opened) for example, although the biogas tank was at a pressure of 6.5 kPa, the recorded pressure at the two gas meters had dropped to 2.8 kPa. The combinations of high flow and high pressure were therefore not accessible to the test.

Secondly, at very low pressures the flow was slow, even with all valves fully open, so that the combinations of high flow and low pressure were not accessible to the test either.

Despite these limitations, a combination of different flows and different pressures could be tested. These combinations could only be attained empirically, through playing with the valves, and are thus not evenly spaced. As far as possible, pressures and flows were chosen all over the typical range of a household biogas digester's conditions of operation.

3.1 Water displacement tube

The device was custom-made with a 20cm diameter PVC tube. An extremity was sealed while the other one was fitted with a flexible siphon traversed by the biogas feeding pipe. The latter extremity, which was later glued in place, is pictured beside.

The length of the tube is 80cm, its empty weight 7kg. The water capacity is 23l.

The siphon at the end of the tube was made of flexible pipe, so that its discharge height can be adjusted to match the level of the water in the tube. By doing so, it can be made sure that the gas inside the water tube is at atmospheric pressure.

By moving the level of the siphon lower than the water level in the tube, the gas pressure inside the tube can be pulled below the atmospheric pressure. This extra pressure gradient can help to draw more flow in the device, in particular for the tests at very low pressure (this also explains why pressure readings indicate “0” for some tests).

Illustration 4: View of the inside of the water tube

3.2 Safety

During the course of the tests, special attention should be paid to avoid any risk of explosion. Every naked flame or spark should be avoided. Fortunately, according to the protocol, air and biogas are never mixed together, since the tube is first filled with water prior to the first test. Very special attention is needed in two cases:

- When refilling the tube with water between the tests (a bucket or a hose can be used for this purpose). During this step, the biogas is forced out of the tube towards the operator.
- At the end of the series of tests. The tube is then filled with biogas, which might remain during storage and progressively mix with air. It is therefore advised to fill the tube one last time with water to flush the biogas out.

Illustration 5: Water is forced out while the tube is filling with gas

4 ERROR ANALYSIS

The following errors can potentially affect the measurement:

- leaks on the gas line between the gas meters and the water displacement tube
- dissolution of some of the biogas into the water
- precision of the electronic scale
- differences between the pressure in the tube and the atmospheric pressure
- overflows/underflows of water

These factors are examined below.

4.1 Leaks

All leaks were carefully checked with water and soap, so it is assumed that potential remaining leaks are negligible in comparison to the flow to be measured.

4.2 Solubility of biogas in water

Of the different gases making biogas, carbon dioxide is the one most likely to dissolve in water and interfere with the experiment. The solubility of carbon dioxide is temperature dependant as shown in illustration 6. A simple calculation shows that at 5°C, the 25 litres of water used for the experiment could dissolve a theoretical maximum of 47.6 l of carbon dioxide (at the local atmospheric pressure). Since the same water was reused throughout the experiment, the maximal theoretical error on a single test would be 47.6l/190l (total volume measured through all tests) = 25%.

However, this theoretical error does not take into account the kinetics of the reaction, which does proceed much slower. The error of 25% stated above is therefore an upper theoretical limit.

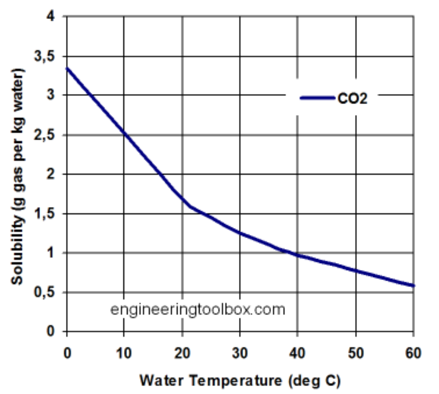


Illustration 6: Solubility of carbon dioxide in water

In practice, a tests was performed to measure the actual dissolution of biogas in the water:

- the water tube was half filled with gas, half with water, and the scale was initialised to 0
- in the next 15 minutes, the tube was left to rest. During this time, the slow absorption of gas resulted in a light decrease in water level in the siphon.
- the siphon was refilled with water to compensate for the absorbed volume of gas, and the weight of the water was recorded on the scale.

This test was performed twice, and showed that the maximal dissolution rate is about 0.15% per minute. It can therefore be assumed that the error is limited to 2.25 %, since the longest test lasted for not more than 15 minutes. In most tests (3 minutes typical duration), the maximal error will be closer to 0.45%.

This error will always lead to an overestimation of the errors on the counters. Indeed, if the gas volume has been underestimated in the water displacement tube because of the dissolution of a part of the biogas, then the reference to which to compare is underestimated.

4.3 Errors of the electronic scale

The scale was tested at 1kg, and gave a reading of 998g. Testing at 30kg was not done. A precision of ±1% will be assumed.

4.4 Pressure in the water tube

Other errors could be due to the gas in the water displacement tube not being at atmospheric pressure at the end of the experiment.

Prior to the start of the experiment, the level of discharge in the siphon was adjusted to fit the final level of water in the tube, but it was difficult to ensure that the levels would correspond by better than 1cm. Any difference levels would lead to the gas volume being under- or over-pressured.

A 1cm difference would lead to a mistake of estimating the gas volume of ±0.1% (0.1 kPa of overpressure on an absolute pressure of 80 kPa).

4.5 Overflows/underflows of water

Controlling the flow of water pouring down from the tube while it is filling with gas cannot be done perfectly. Some errors occur when excessive water has flown out, or when too little has been drawn out, or if the level of the siphon changes during the experiment. In practise, the precision is limited to about $50 cm^3$, corresponding to a relative error of ±0.2%.

4.6 Summary of errors

	Overestimation	*Underestimation*
Leaks	Neglected	
Solubility of CO2	+2.25%	0 %
Errors of the electronic scale	+1 %	-1 %
Errors of pressure in the tube	+0.1 %	-0.1%
Overflows/underflows of water	+0.2 %	-0.2%
Total	**+3.55%**	**-1.3%**

5 RESULTS AND ANALYSIS

5.1 Relative errors

The error for each test is calculated as follows, by comparing the volumes recorded by the meter and by the water displacement tube:

$$error = \frac{V_{gasMeter} - V_{waterTube}}{V_{waterTube}}$$

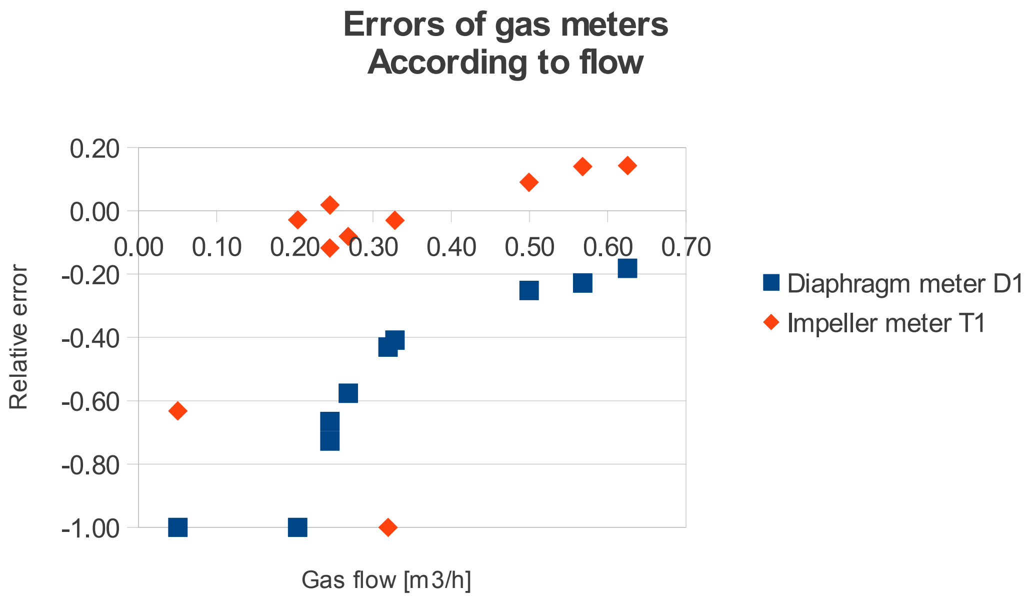
The relative error will be positive if the gas meter has over-evaluated the volume compared to the water displacement tube. It will be negative if the gas meter has under-evaluated the volume.

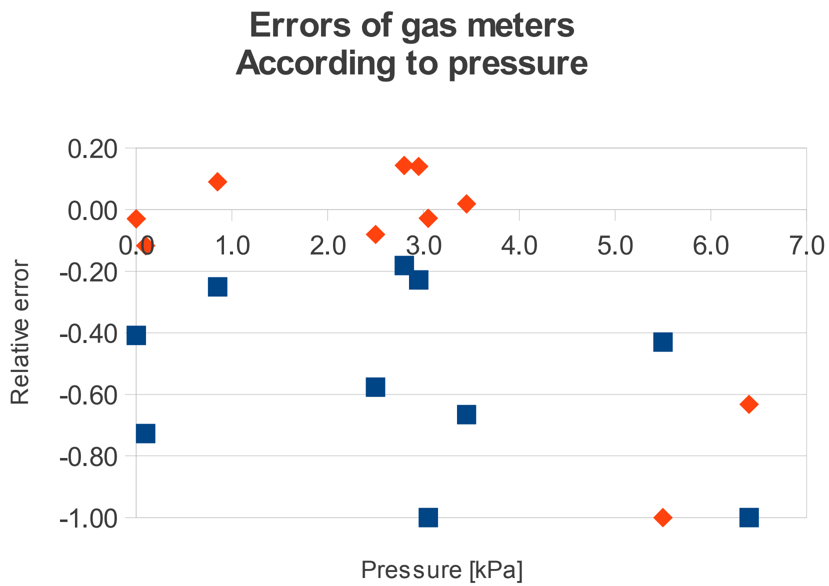
The illustrations below plot the error for the three series of tests that were performed, according to the gas flow and to the operating pressure.

All gas volumes were corrected to local atmospheric pressure of 80 kPa (the tests were performed at 2000m altitude). Indeed, at the meter the biogas was pressurised (up to 6.4 kPa), while the water displacement tube, to which the volume is compared, was held at local atmospheric pressure.

Test of two models of gas meters, 22 January 2012

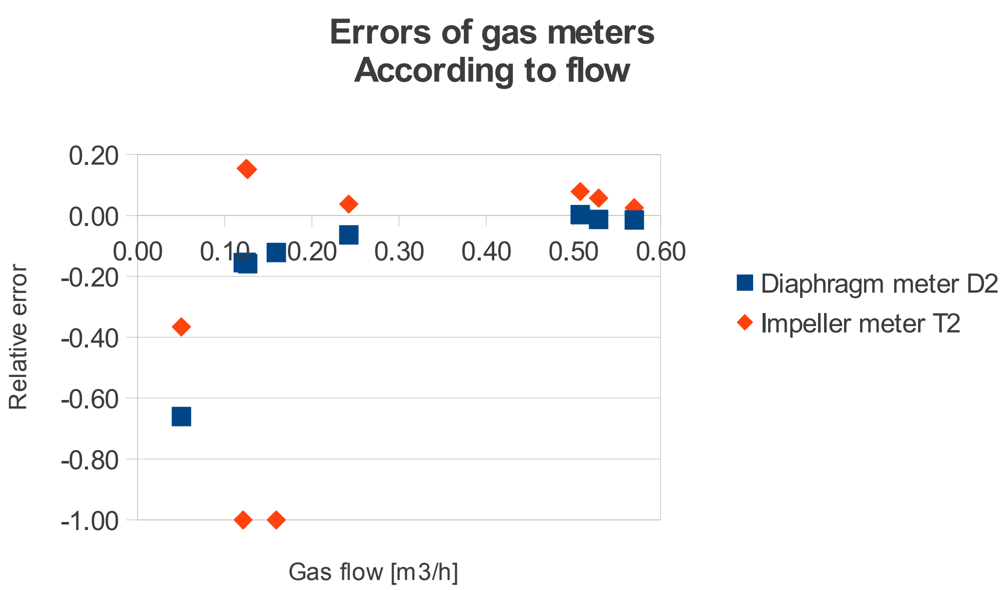
Test No	Pressure gauge 1 [kPa]	Pressure gauge 2 [kPa]	Mean pressure [kPa]	Duration of sampling [s]	Diaphragm meter D1				Impeller meter T1				Water displacement test			Flow [l/s]	Flow [l/min]	Flow [m3/h]	Errors	
					Start index	End index	Difference (l)	Pressure corrected (l)	Start index	End index	Difference (l)	Pressure corrected (l)	Start index	End index	Net volume [l]				Diaphragm meter D1	Impeller meter T1
1	2.8	2.8	2.8	99	9876	0012	13.6	14.1	5320	5510	19.0	19.7	130	-17070	17.2	0.17	10.4	0.63	-0.18	0.14
2	6.2	6.6	6.4	756	0012	0012	0.0	0.0	5510	5546	3.6	3.9	130	-10445	10.6	0.01	0.8	0.05	-1.00	-0.63
3	5.2	5.8	5.5	220	0012	0116	10.4	11.1	5546	5546	0.0	0.0	130	-19380	19.5	0.09	5.3	0.32	-0.43	-1.00
4	2.9	3.0	3.0	132	0118	0273	15.5	16.1	5558	5787	22.9	23.7	130	-20697	20.8	0.16	9.5	0.57	-0.23	0.14
5	2.8	3.3	3.1	355	0278	0278	0.0	0.0	5788	5976	18.8	19.5	130	-19955	20.1	0.06	3.4	0.20	-1.00	-0.03
6	2.5	2.5	2.5	268	0278	0360	8.2	8.5	5976	6154	17.8	18.4	130	-19840	20.0	0.07	4.5	0.27	-0.58	-0.08
7	3.2	3.7	3.5	298	0362	0427	6.5	6.8	6156	6354	19.8	20.7	130	-20145	20.3	0.07	4.1	0.24	-0.67	0.02
8	0.7	1.0	0.9	143	0427	0574	14.7	14.9	6354	6568	21.4	21.6	0	-19838	19.8	0.14	8.3	0.50	-0.25	0.09
9	0.0	0.2	0.1	297	0575	0630	5.5	5.5	6572	6750	17.8	17.8	0	-20191	20.2	0.07	4.1	0.24	-0.73	-0.12
10	0.0	0.0	0.0	232	0630	0755	12.5	12.5	6752	6957	20.5	20.5	0	-21132	21.1	0.09	5.5	0.33	-0.41	-0.03

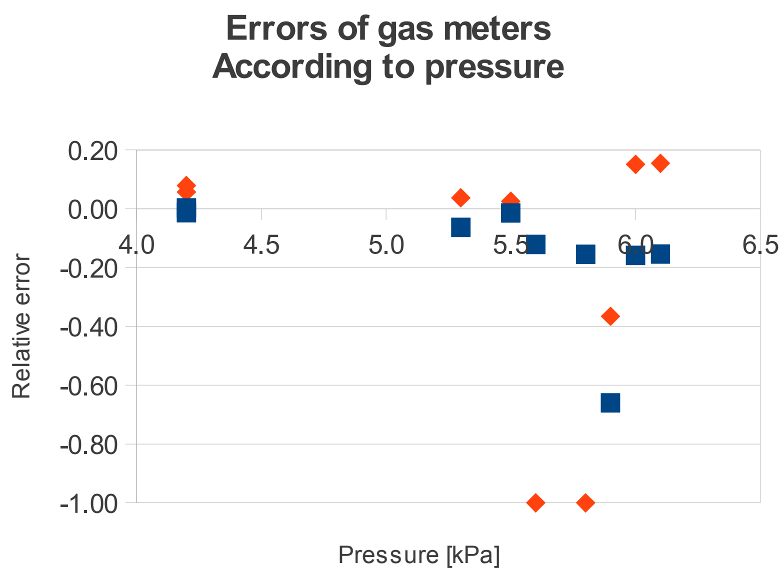




Test of two models of gas meters, 23 March 2013

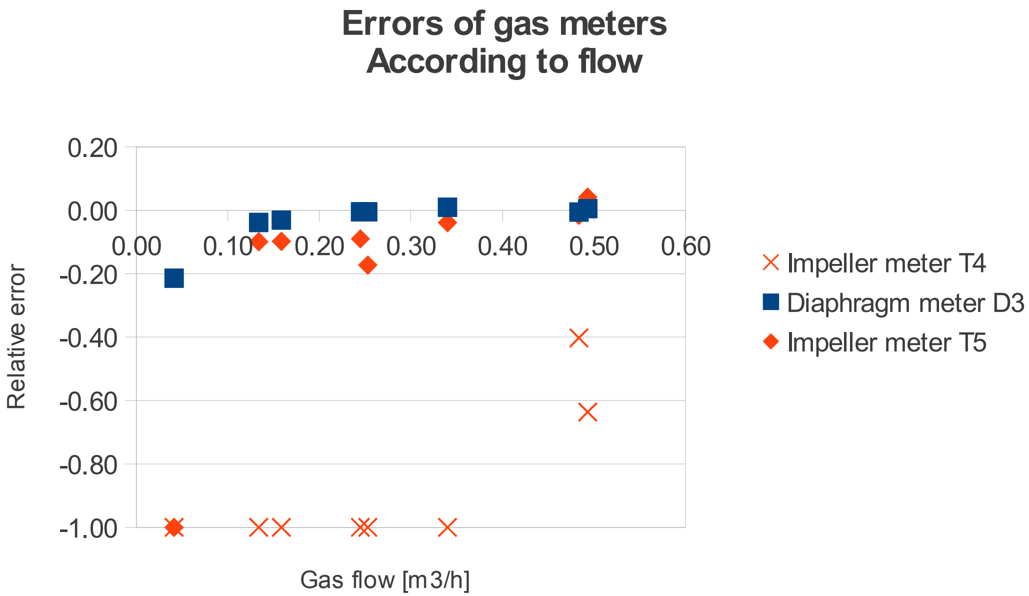
Test No	Pressure gauge 1 [kPa]	Pressure gauge 2 [kPa]	Mean pressure [kPa]	Duration of sampling [s]	Diaphragm meter D2				Impeller meter T2				Water displacement test			Flow [l/s]	Flow [l/min]	Flow [m3/h]	Errors	
					Start index	End index	Difference (l)	Pressure corrected (l)	Start index	End index	Difference (l)	Pressure corrected (l)	Start index	End index	Net volume [l]				Diaphragm meter D2	Impeller meter T2
1	4.2	4.2	4.2	148	6650	6849	19.9	20.9	2782	2996	21.4	22.5	0	-20880	20.9	0.14	8.5	0.51	0.00	0.08
2	5.5	5.5	5.5	135	6849	7046	19.7	21.1	2996	3201	20.5	21.9	0	-21366	21.4	0.16	9.5	0.57	-0.01	0.03
3	6.1	6.1	6.1	624	7046	7216	17.0	18.3	3201	3433	23.2	25.0	0	-21624	21.6	0.03	2.1	0.12	-0.15	0.15
4	6.0	6.0	6.0	564	7218	7373	15.5	16.7	3433	3645	21.2	22.8	0	-19802	19.8	0.04	2.1	0.13	-0.16	0.15
5	4.2	4.2	4.2	143	7413	7610	19.7	20.7	3702	3913	21.1	22.2	0	-21009	21.0	0.15	8.8	0.53	-0.01	0.06
6	5.3	5.3	5.3	313	7610	7795	18.5	19.7	3913	4118	20.5	21.9	0	-21070	21.1	0.07	4.0	0.24	-0.06	0.04
7	5.9	5.9	5.9	339	7795	7810	1.5	1.6	4118	4146	2.8	3.0	0	-4741	4.7	0.01	0.8	0.05	-0.66	-0.37
8	5.8	5.8	5.8	422	7812	7924	11.2	12.0	4146	4146	0.0	0.0	0	-14215	14.2	0.03	2.0	0.12	-0.15	-1.00
9	5.6	5.6	5.6	457	7925	8091	16.6	17.8	4146	4146	0.0	0.0	0	-20221	20.2	0.04	2.7	0.16	-0.12	-1.00

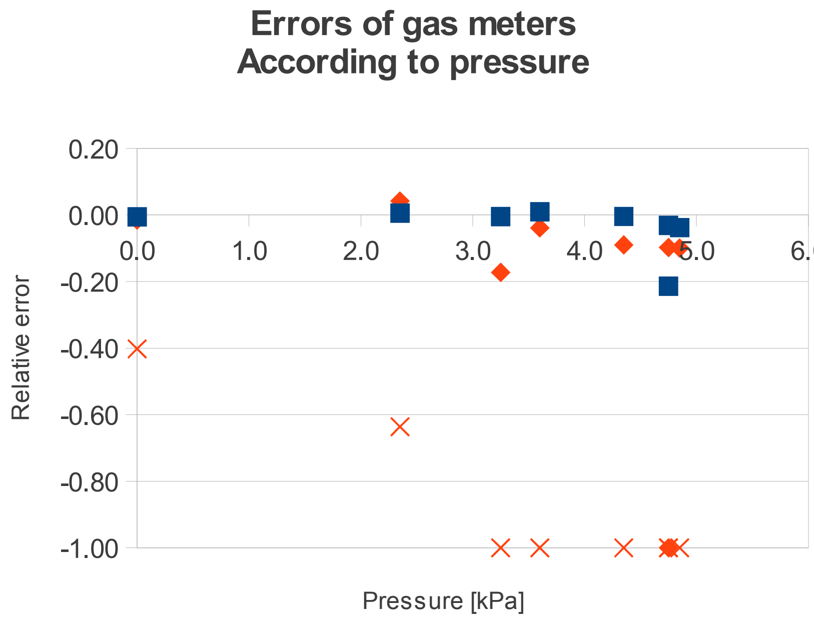


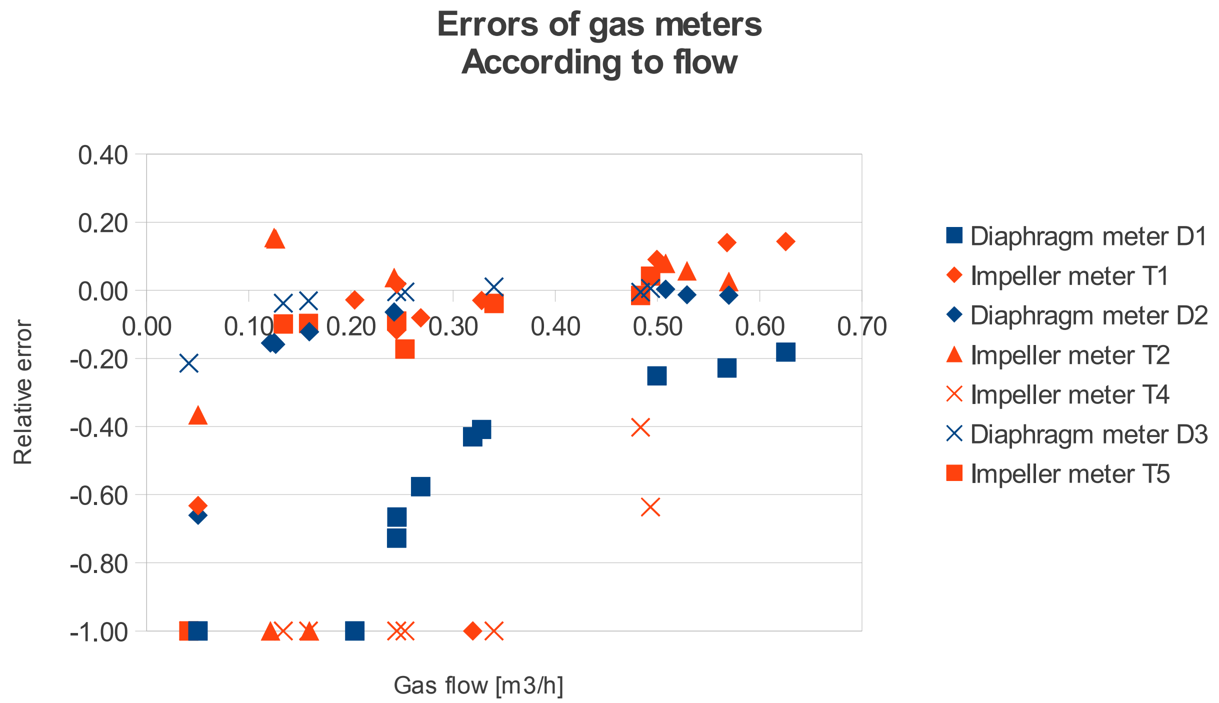


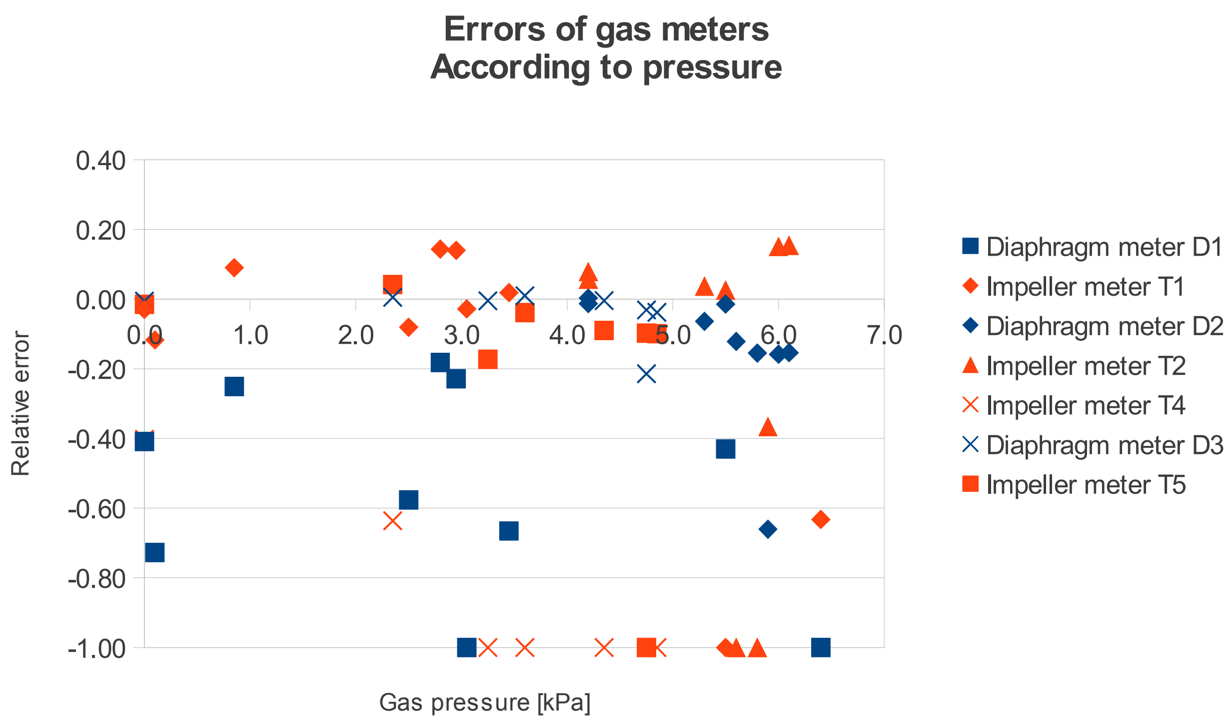
Test of two models of gas meters, 8 May 2013

Test No	Pressure gauge 1 [kPa]	Pressure gauge 2 [kPa]	Mean pressure [kPa]	Duration of sampling [s]	Impeller meter T4				Diaphragm meter D3				Impeller meter T5				Water displacement test			Flow [l/s]	Flow [l/min]	Flow [m3/h]	Errors		
					Start index	End index	Difference (l)	Pressure corrected (l)	Start index	End index	Difference (l)	Pressure corrected (l)	Start index	End index	Difference (l)	Pressure corrected (l)	Start index	End index	Net volume [l]				Impeller meter T4	Diaphragm meter D3	Impeller meter T5
1	2.5	2.2	2.4	157	332	408	7.6	7.8	4519	4729	21.0	21.6	4406	4630	22.4	22.4	0	-21505	21.5	0.14	8.2	0.49	-0.64	0.01	0.04
2	5.1	4.6	4.9	442	408	408	0.0	0.0	4729	4878	14.9	15.8	4630	4778	14.8	14.8	0	-16427	16.4	0.04	2.2	0.13	-1.00	-0.04	-0.10
3	5.0	4.5	4.8	375	408	408	0.0	0.0	4878	5029	15.1	16.0	4778	4927	14.9	14.9	0	-16511	16.5	0.04	2.6	0.16	-1.00	-0.03	-0.10
4	3.7	3.5	3.6	217	408	408	0.0	0.0	5029	5227	19.8	20.7	4927	5124	19.7	19.7	0	-20493	20.5	0.09	5.7	0.34	-1.00	0.01	-0.04
5	4.5	4.2	4.4	299	457	457	0.0	0.0	5229	5421	19.2	20.2	5124	5309	18.5	18.5	0	-20333	20.3	0.07	4.1	0.24	-1.00	0.00	-0.09
6	0.0	0.0	0.0	152	457	579	12.2	12.2	5425	5628	20.3	20.3	5311	5512	20.1	20.1	0	-20412	20.4	0.13	8.1	0.48	-0.40	-0.01	-0.02
7	3.4	3.1	3.3	265	579	579	0.0	0.0	5628	5806	17.8	18.5	5512	5666	15.4	15.4	0	-18612	18.6	0.07	4.2	0.25	-1.00	0.00	-0.17
8	4.9	4.6	4.8	880	579	579	0.0	0.0	5806	5881	7.5	7.9	5666	5666	0.0	0.0	0	-10111	10.1	0.01	0.7	0.04	-1.00	-0.21	-1.00






Errors of gas meters
According to flow
0.40
0.20
0.00
-0.20
-0.40
-0.60
-0.80
-1.00
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
Relative error
Gas flow [m3/h]
Diaphragm meter D1
Impeller meter T1
Diaphragm meter D2
Impeller meter T2
Impeller meter T4
Diaphragm meter D3
Impeller meter T5


Errors of gas meters
According to pressure
0.40
0.20
0.00
-0.20
-0.40
-0.60
-0.80
-1.00
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
Relative error
Gas pressure [kPa]
Diaphragm meter D1
Impeller meter T1
Diaphragm meter D2
Impeller meter T2
Impeller meter T4
Diaphragm meter D3
Impeller meter T5

5.2 ANALYSIS

From the results, a clearer pattern can be drawn according to the flow than according to the pressure.

The diaphragm meters are all three performing more precisely at higher flows, and their performance gradually decreases with the flow. Although the performance of D2 and D3 are satisfactory above 0.1 m3/h, D1 performs badly over the whole range of flows.

The impeller model suffers from random behaviour at start-up. At the start of the individual tests, especially at lower flows, the impeller often fails to start moving at all. However, if the impeller starts moving, it usually keeps on rotating until the end of the test, and the recorded flows are relatively precise. Although T1, T2 and T5 observed this pattern, the device T4 performed very badly over the whole range of flows with very frequent blocks.

The impeller meters can be “kick-started” with a higher flow, and the flow can then be decreased without interrupting the impeller's rotation. The impeller meters therefore seem to behave as though their static friction (on start-up) would be significantly higher than their dynamic friction (during movement).

When analysing the errors according to the pressure, no clear correlation does appear for neither of the two models of gas meters.

A particular interest that had initially motivated the tests on the gas meters was to establish whether the devices do compensate for pressure variations. As a reminder, due to the working principle of the fixed-dome type of bio-digesters, the biogas pressure is variable between typically 0 and 10 kPa, according to the amount that is stored in the digester. Therefore, if the gas flow is measured on a strict volume base, errors on the actual amount of gas (that is, once released at atmospheric pressure) can reach 10%. An accurate device should ideally take the gas pressure into account and compensate accordingly. Alternatively, the device can be built directly upon a mass flow measurement principle.

In these tests, it was not expected to observe pressure correction for the diaphragm meter, which is by principle based on strict volume measurement. The potential compensation of the impeller meter was unknown. Unfortunately, the overall performance of both models was far too imprecise to reach any definite conclusion in this area. It can only be observed that the absolute errors of D2 and D3 are reduced when the error is calculated based on pressure-compensated volumes.

5.3 TYPICAL BIOGAS CONSUMPTIONS RATES FOR RURAL HOUSEHOLD APPLIANCES

The following table shows typical gas consumption rates:

	According to http://www.eco-biogas.com	According to “Biogas Stove Design - A short course ” Dr David Fulford , 2006
Gas stove	0.45 m^3/h	0.3 to 1.2 m^3/h
Rice cooker	0.14 m^3/h	
Gas lamp	0.07 m^3/h	0.18m^3/h

Looking at the above values, we shall therefore ensure that the gas meters do measure with reasonable accuracy between 0.05 and 0.5 m^3/h, at least.

The precision under 0.05 m^3/h is not to be neglected, however. Indeed, if any gas leak occurs downstream of the counter, an accurate measurement of this leak is still important. For example, a 0.01 m^3/h leak would lead to a daily loss of 0.24 m^3 per day, which is about a quarter to half the daily typical production of a rural household biogas digester. If the counter fails to measure this leak at all, the production of the digester would be highly underestimated.

5.4 Manufacturer's error specifications

The table below summarises the manufacturer's error specifications against the results of the test.

	Specification	Test result	Specification	Test result
SZ-G1.6T (diaphragm)	0.016 – 1.6 m^3/h		1.6 – 2.5 m^3/h	
	± 3%	-100% ; +1%	± 1.5%	N/A
TYG-Y-4 (impeller)	0.025 – 0.4 m^3/h		0.4 – 4.0 m^3/h	
	± 3%	-100%; +15%	± 1.5%	-64%; +14%

6 CONCLUSIONS

Two models of household gas flow meters were tested on the field using an original methodology.

At typical flows spanning over the range equivalent to a biogas stove, a biogas rice cooker, or a biogas lamp, the performances measured in the test were not satisfactory. Besides, neither of the models respected their factory specifications for basic error.

In the scope of ID China's biogas projects, for experimentation purposes, or in the prospect of using gas meters as part of a emission reduction (ER) assessment method, these two models are therefore not considered reliable.

However, the original method that was developed for the tests has proven robust and relatively easy to deploy on the terrain, in the absence of proper laboratory facilities. This protocol could therefore be used in the future for low-cost, non systematic assessment of the performance of gas flow measuring devices, with particular interest in the field of rural development projects.

RECOMMENDATIONS

- To allow for long-term follow-up, all gas meters should be referenced by a unique code as soon as put in service.
- The testing protocol described above could be developed into a commissioning procedure: every new gas meter could be tested and selected to perform to a satisfactory standard.
- 10 gas meters or more could probably be tested simultaneously using the protocol (the devices can be connected in series with a reasonable loss of pressure).
- After a gas meter has been in service for measurements during a determined period, it could be tested again to determine whether its measurements can be validated.