

CRUDE BIOGAS FLOWMETERING

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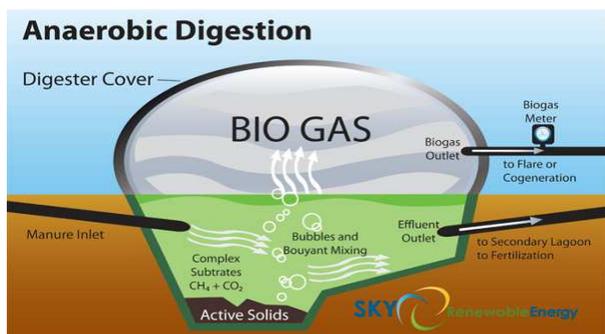
Abstract:

The Biogas, also known as digester gas, is the gaseous product of anaerobic digestion (decomposition without oxygen) of organic matter. It is considered as a renewable energy source. GDF SUEZ is working actively on the development and recovery of this energy, drawing on synergies with the natural gas industry.

In this context the CRIGEN had realized, for the first time in Europe, a complete study on a metering system for crud biogas (without any treatment). This study is carried out for ADEME¹ and for three of the principal actors of treatment of waste in France (SITA, VEOLIA and COVED), and this, within the framework of the new lawful requirements relating to the valorization of the biogases produced in their decheterie.

Introduction

Biogas is produced by anaerobic digestion or fermentation. Which means that biomass is converted by microorganisms to biogas without oxygen. It is a mixture of methane, carbon dioxide, nitrogen, hydrogen, oxygen and hydrogen sulphide. The chemical composition of biogas varies depending upon the feedstock material and different parameters like temperature and acidity of the substrate.



It is considered as a renewable energy source and can substitute for natural gas as an alternative fuel to providing electricity. It capitation is a legal requirement.

Since several years, GDF SUEZ is working actively on the development and recovery of this energy, drawing on synergies with the natural gas industry. In this context the CRIGEN had realized a wide study on flowmetering for crude biogas (without any treatment). This study had been carried out for the ADEME and three of the principal

actors of the waste treatment in France, and this, within the framework of the new lawful requirements relating to the valorization of the biogases produced in their decheterie.

This law permits to the waste reception centers a large tax reduction (tax relative to polluting activities). To take advantage of this reduction, the law requires the valorization of more than 75% of the produced biogas. To prove this valorization, the operator of these centers has to install an adapted fiscal metering system.

This study consists of 3 parts:

- **First part:** A wide state of the art on the fiscal and non-conventional gas metering technologies adapted to crud biogas, as well as a benchmark, near the decheteries fitters and operators in Europe. This led to identify the “adapted” technologies of flowmeters: differential pressure flowmeter, mass flowmeter, averaged pitot, a thermal-mass flowmeter and a vortex flowmeter.
- **Second part:** An important experimental study on test benches (with natural gas and dry air) in order to metrologically check the selected flowmeters. To complete these tests, flowmeters had been installed and tested on three biogas production sites lasting more than for months. As a result, numerous parameters had been identified to be impacting the flowmetering such as the biogas composition, the biogas temperature...
- **Third part:** The analysis of all these experimental results allowed the CRIGEN to identify:
 - The impact of each parameter: gas composition, pressure, temperature...
 - The “actual” adapted flowmeter to each type of biogases.

Also to define recommendations for installation and operating these metering station.

State of the art on biogas flowmetering

A wide benchmark near the decheteries fitters and operators in Europe and the flowmeters manufacturers permits to define 2 big families for the biogas flowmeters:

- Adapted to crud biogas family,
- Not adapted to crud biogas family.

Adapted to crud biogas family

For a gas flowmeter, to can be considered as “adapted” to crud biogas, it must:

¹ ADEME: the French environment protection and energy managing agency.

- resists to high hydrogen sulphide concentration (>50 ppm),
- resists to water presence,
- support high composition variability (>5% for the CH4) without impacting the flowrate measurement error.
- Have few or no mobile parts.

This first family is composed by two anemometers and three differential pressure flowmeters:

- An averaging Pitot,
- A venturi flowmeter,
- The V-cone flowmeter,
- An oscillations flowmeter,
- A vortex flowmeter,
- A thermal-mass flowmeter.

Non-adapted to crud biogas family

All the others flowmeters are considered as not adapted to crud biogas fiscal flowmetering. Essentially because of presence of moving parts and high sensitivity to water presence, to high hydrogen sulphide concentration (>50 ppm) and to high variability composition (>5% for the CH4).

Laboratories test

For the laboratories tests, two gases had been chosen: natural gas and dry air. This choice of this two gases and not biogas is due to the fact that it is very difficult technically to provide big volume of reconstructed biogas for the laboratories tests. In the other hand, the natural gas and dry air have physical properties very close to those of the biogas (see table below).

	μ [Pa.s]	ρ [kg/m ³]
Natural gas	110.55 10 ⁻⁷	0.73 → 0.849
Biogas	140 → 160	1 → 1.2
Dry air	170.8 10 ⁻⁷	1.97 → 1.229

Natural gas setup (GDF SUEZ – CRIGEN)

The natural gas flow metering test facilities “PLAT” is a part of GDF SUEZ Research Division. It is supplied with natural gas from GRTgaz transmission network. The gas is filtered and its temperature controlled.

The test method is based upon the assessment of the mass flow rate using Venturi nozzles operated in sonic conditions. The mass flow through the set of nozzles in use is determined from the upstream stagnation pressure and the upstream density. The flow coefficients of each nozzle are determined beforehand by an individual calibration on the French primary bench "PISC" (CESAME-EXADEBIT). This mass flow indicated by the tested device is determined from the pressure and temperature measured at its location, the raw flow indicated by it and the density measured upstream of the nozzles [eq. 1]. Real

gas effects are taken into account by applying compressibility factor corrections for the thermodynamic conditions at the measurements locations. These various measurements and calculations allow a comparison between the reference and the tested device mass flows, thus, to determine the device deviation.

$$Q_m = A \cdot C_d \cdot C^* \cdot \frac{P_0}{\sqrt{r \cdot T_0}} \tag{Eq. 1}$$

Where:

- Po, To: the gas absolute stagnation pressure and temperature,
- A: the cross section of the nozzle,
- Cd: discharge coefficient (ISO 9300)
- C*: critical flow function (ISO 9300)
- r: ratio of the Universal gas constant on the molar mass

This bench is working at the conditions below:

Flowrate Q [SQMPH]	10 → 11000
Pipe diameters	DN50 → DN200.
P [bar]	1.0 bar → 50 bar
Error	±0.32%

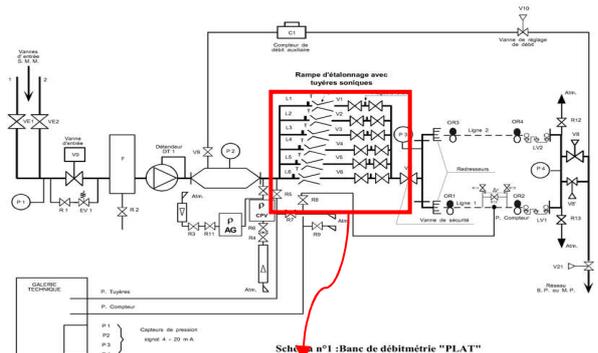


FIG. 1 – Scheme of the GDF SUEZ natural gas flowmetering bench “PLAT”

Dry air setup (CESAME EXADEBIT)

The dry air flow metering test facilities is a part of CESAME Exadebit. It is supplied with dry air from a storage vessel 110 m³ at 200 bar. The air goes through the valves and the heating control system. This adjusts the suitable temperature and pressure upstream the nozzles automatically.

The test method is identical to natural gas bench.

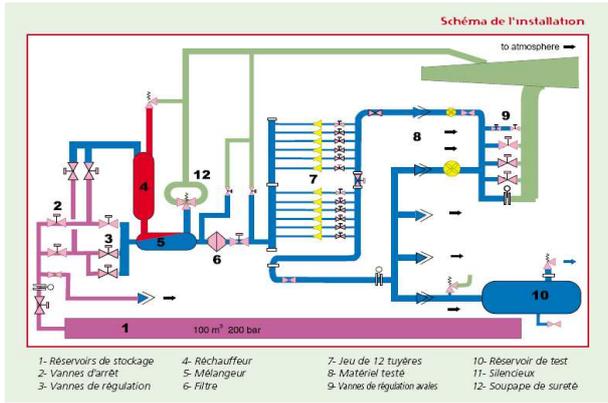


FIG. 2 – Scheme of the CESAME dry air flowmetering bench

This bench is working at the conditions below:

Flowrate Q [SQMPH]	8 → 90000
Pipe diameters	DN25 → DN300.
P [bar]	1.0 bar → 50 bar (it can be extended to 100 bar)
Error	±0.2%

Laboratories results

Four flowmeters, identified in the part 1, had been selected to be tested at a laboratories and installed after that in three different biogas productions sites. These tests had been done to verify the metrological performance of these flowmeters at a laboratory conditions with two different gases: natural gas and dry air. These two gases permit to test the flowmeters in conditions close to the biogas properties (density and viscosity). These flowmeters are:

- 03 x averaging Pitot (2x4”+1x3”),
- 01 x venturi (3”),
- 01 x V-cone (4”),
- 01 x oscillations (4”).

The flowmeters had been tested two at a time, with an averaging Pitot at each time. The same configurations had been conserved and tested on the biogas production sites. On the field, the APT is considered as a flowmetering reference. The test configurations are described below.

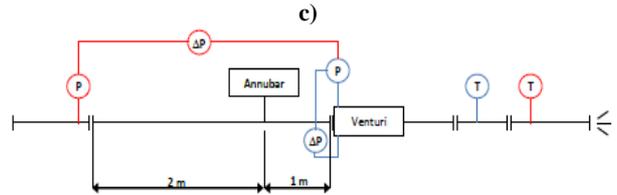
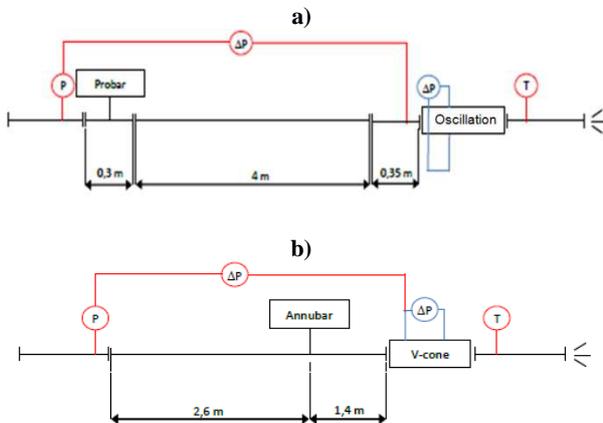


FIG. 3 – Installation diagram of the 3 tested couples of biogas flowmeters

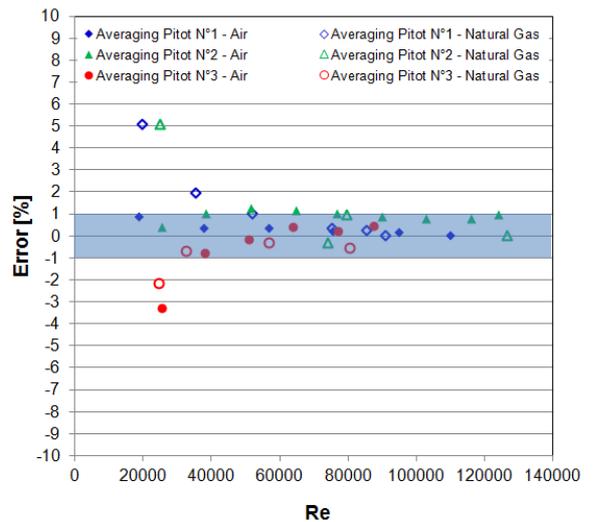
The tests with the two gases had been done with the same configuration, at the same temperature (20°C), the same pressure (1050 mbar) and the same Reynolds number.

Every flowmeter was equipped with its own flow-computer. For the lab tests, the gas composition was fixed to a standard natural gas and dry air composition. For the infield tests, every site define it standard biogas composition.

Only the three averaged pitot was able to adjust the standard flowrate with pressure and temperature measurement. For all the other flowmeters, this adjustment had been done “a posteriori”. For the gas composition it was done for all meters “a posteriori”.

The results are analyzed in terms of standard flowrate error to the bench flowrate reference (sonic nozzle) according to the Reynolds number.

On the figure 4 are plotted the flowrate error of three different averaging pitot (2x4”+1x3”) according to the standard flow rate and to the Reynolds number. The gas flowrate Q_v varied from 30 Nm³/h to 400 Nm³/h and the gas velocity from 0.7 to 18 m/s. The first observation is that the three averaging Pitot have an error less than ±1% on all there rangeability range: 100 to 400 Nm³/h (as specified by the manufacturer). In the other hand, the error increase to 5% when the flowrate is less or equal to Q_{min} . The gas composition has a little impact.



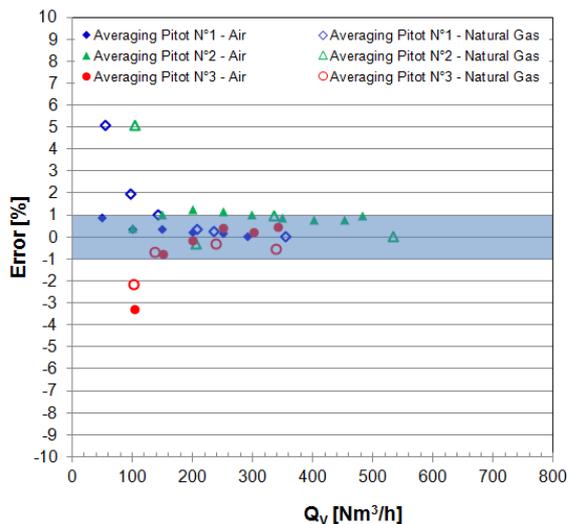


FIG. 4 – Flowrate error of three different averaging pitot according to standard flowrate and to the Reynolds number.

On the figure 5 are plotted the flowrate error of three different differential pressure flowmeters: venturi (3”), V-cone (4”) and oscillations (4”) according to the standard flow rate and to the Reynolds number. The gas flowrate varied from 30 Nm³/h to 800 Nm³/h and the gas velocity from 1 to 30 m/s. The first observations are that the three flowmeters have an error less than $\pm 5\%$ for Q_v up to 100 Nm³/h and they are low impacted by the gas composition. The venturi as well as the oscillations has an average error less respectively to, 0, 5 % and 5 %, which respect them specifications. In the other hand, the V-cone flowmeter over-meter in every case and its average error is higher to its specifications: 1 % instead of 0,5 %.

To summarize, the averaging Pitot, the venturi and the V-cone are more precise than the oscillations with an error about 1%. The oscillations error is about 5%. This error increases when the flowrate Q_v is less than 100 Nm³/h. Also, laboratories results show that for the density and dynamic viscosity tested ranges, all the tested flowmeters are almost insensitive to the variation of the physical properties of the gas.

For the tested flowmeters, 3 technologies stand out: the APT and the V-cone because of their low error (1 %) and their high stability; the venturi because of its very low error (0,5 %) and its low small installation size (see the table at the end of the paper).

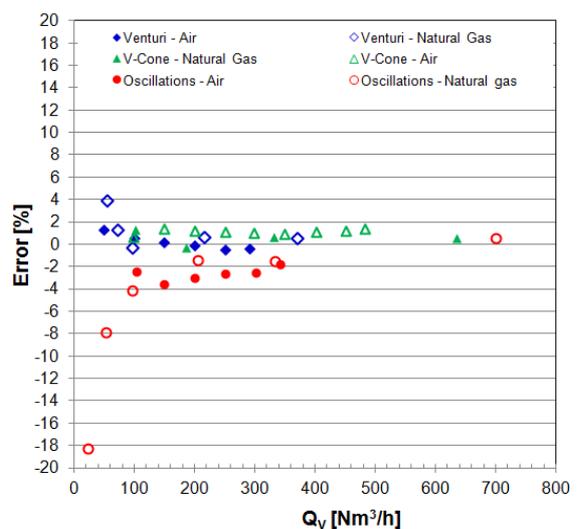
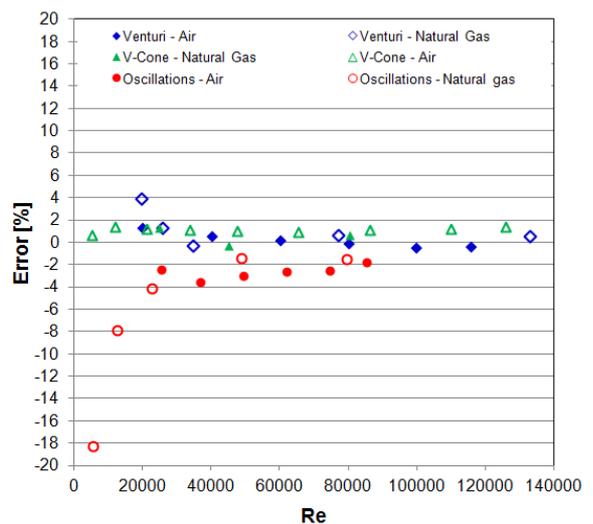


FIG. 5 – Flowrate error of three different differential pressure flowmeters according to the standard flowrate and to the Reynolds number (biogas site n°1).

Infield tests

After the laboratories tests, all the flowmeters had been tested infield. Three different biogas production sites had been chosen, all in France. These sites had a production about 150 to 500 Nm³/h of crude biogas and hadn't valorization systems. The same flowmeters couples had been installed on every site (see figure 3). For two of these three sites, two supplementary insertion flowmeters had been installed: a Thermal-Mass flowmeter and a vortex flowmeter.

The infield tests had lasted 3 to 5 months. As for the laboratories tests, only the averaged pitot standard flowrate is automatically adjusted, in it flowcomputer, with the actual biogas pressure and temperature.

Different parameters had been acquired with different frequencies:

- The standard flowrate of each flowmeter every 5 minutes,
- The gas temperature and pressure every 5 minutes,

- The gas composition every two weeks for 2 sites,
- The CH₄ concentration every 5 minutes for 1site,
- The meteorological data (atmospheric pressure, ambient temperature, humidity), every 1 hour.

In this part, the analysis is made by site.

The first analyzed site is the one equipped with a CH₄ analyzer. For this site, the averaged pitot was installed with the venturi and in series with a Thermal-Mass flowmeter. All parameters had been acquired, even the CH₄ concentration, every 5 minutes.

On the figure 6 are plotted the flowrate shifts between the averaged pitot, the venturi and the Mass-thermal flowrates. The venturi flowrate is adjusted a posteriori only with the actual pressure. What we see on this figure is that the flowrate shifts vary from -4% to +10%. It is less than 1% for the couple averaged-pitot/venturi, which completely acceptable in view of the fact that the specified errors of these are, respectively, $\pm 1\%$ and $\pm 0,5\%$. The shift is much higher with the Thermal-Mass meter. This means that the Mass-Thermal flowrate is much impacted by the operatory conditions such as the biogaz pressure, temperature and composition.

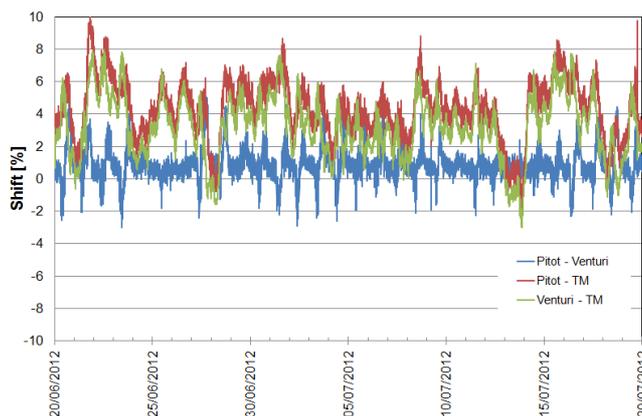


FIG. 6 – Infield flowrate shift of three different flowmeters: and averaged pitot, a venturi and a Thermal-Mass (biogaz site n°1).

To analyze the effect of each of these operatory conditions, we study each parameter impact separately.

For the study of the pressure effect, the flowrate shifts are plotted and compared to the absolute biogaz pressure variation (figure 7 - a & b). It is easy to conclude that the pressure variation is low: less than 50 mbar and there is no correlation with the flowrates shifts.

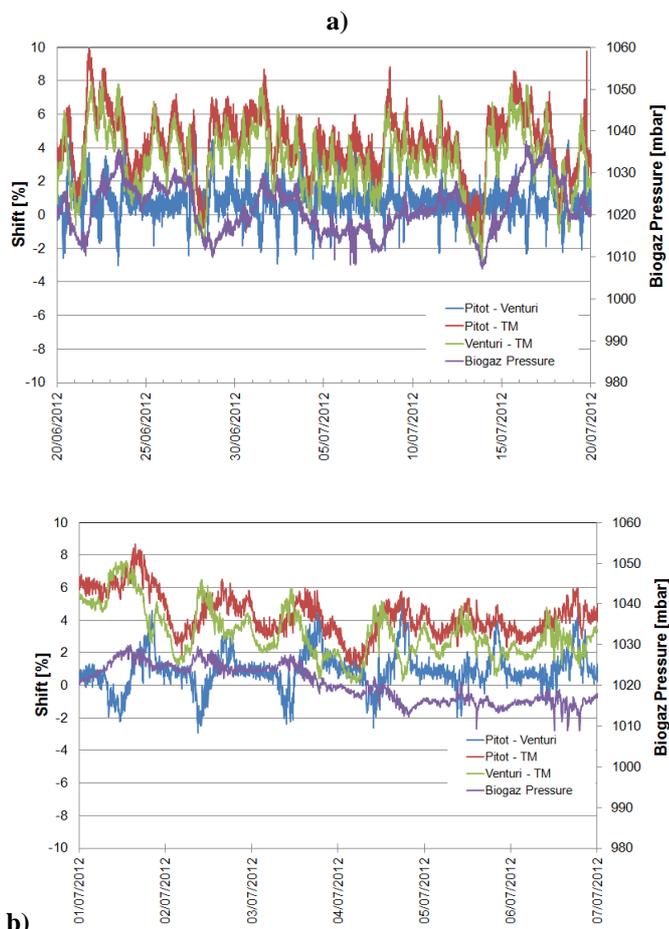


FIG. 7 – a) Infield flowrate shift of three different flowmeters: and averaged pitot, a venturi and a Thermal-Mass compared to the absolute biogaz pressure variation for all the period. b) Zoom on 7 days (biogaz site n°1).

The same work is done with the temperature (figure 8). From the zoom plots (2 days), we notice that the temperature variation is directly correlated to the shifts between the couples averaged-pitot/TM and venturi/TM. It is inversely proportional to the averaged-pitot and venturi flowrates and it proportional to the thermal-mass flowrate. These can be explained by the temperature-dependence, respectively, of the biogaz density and calorific value.

To can confirm this last point, we use specific industrial software (“GASPACK - V2.3”) to calculate the actual density and specific heat of biogaz at different temperature. This allows adjusting some points of the figure 9. A new plot is given with these adjusted points (figure 10). As it can be seen on figure 10, the adjustment of the standard flowrate of both averaged-pitot and venturi with the actual density and temperature (at the actual temperature) gives new values very close to the adjusted Thermal-mass flowrate, which is adjusted with the actual specific heat. This result is observed each time when the right adjustment is done.

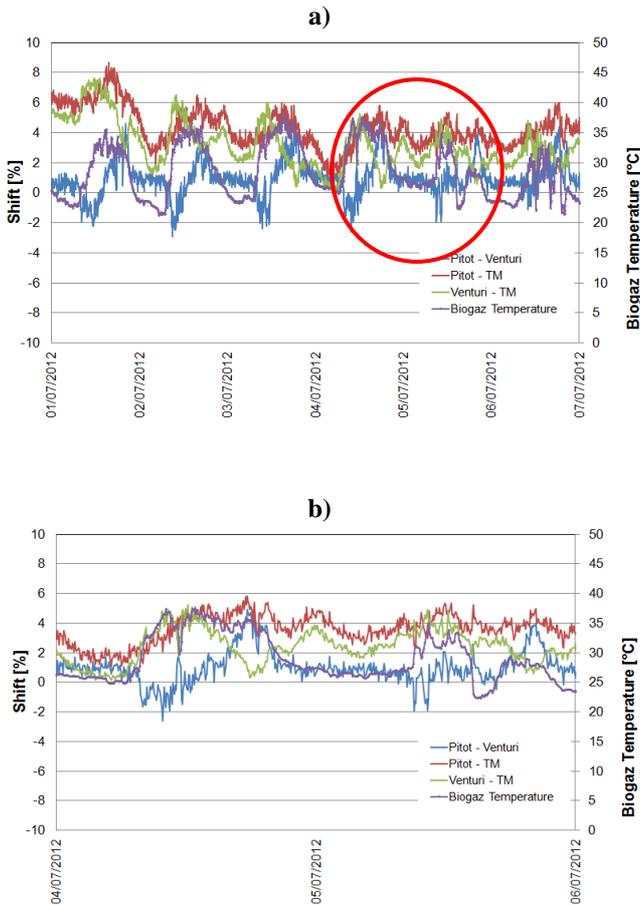


FIG. 8 – a) Infield flowrate shift of three different flowmeters: and averaged pitot, a venturi and a Thermal-Mass compared to the biogas temperature variation for 7 days. b) Zoom on 2 days (biogas site n°1).

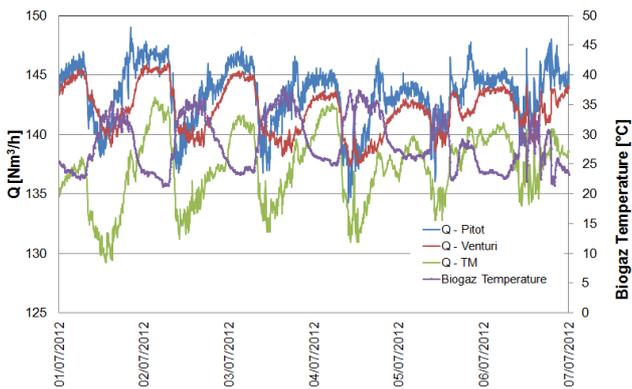


FIG. 9 – Infield flowrates of three different flowmeters: and averaged pitot, a venturi and a Thermal-Mass compared to the biogas temperature variation for 7 days (biogas site n°1).

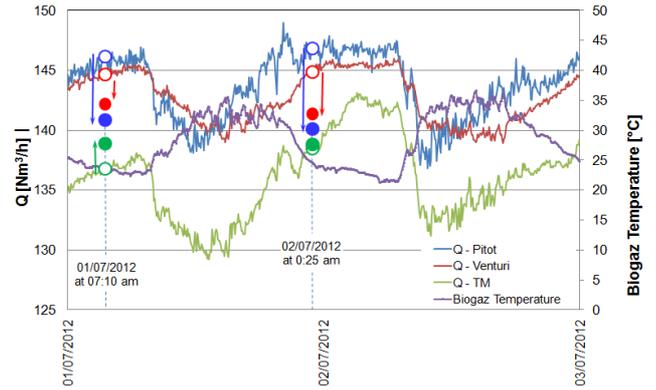


FIG. 10 – Infield flowrates of three different flowmeters: and averaged pitot, a venturi and a Thermal-Mass with some points adjusted with temperature dependency (biogas site n°1).

As for the pressure and temperature, the analyses of the impact of the methane (CH_4) concentration had been done. In the flow computers of these three flowmeters, the CH_4 concentration is fixed to 42%. But as we seen on figure 11, the CH_4 concentration is varying from 30% to 52%. This variation is too high to be considered as negligible for the standard flowrate calculation. On the figure 11 are plotted the flowrate shifts and compared to the CH_4 concentration variation. It is easy to note that there is no an evident correlation of the flowrates fluctuation with the CH_4 concentration variation. In the other hand, we can't assume that the biogas composition has no effect because all the thermodynamic parameters used for the flowrate calculation, such us density, specific heat, viscosity, are directly correlated to biogas composition and then to the CH_4 concentration. That why, it is necessary to monitor this parameter. But to can be correctly taken in account, simple equations must be developed and tested for the in-line calculation of the thermodynamic biogas properties from the CH_4 concentration, the temperature and the pressure.

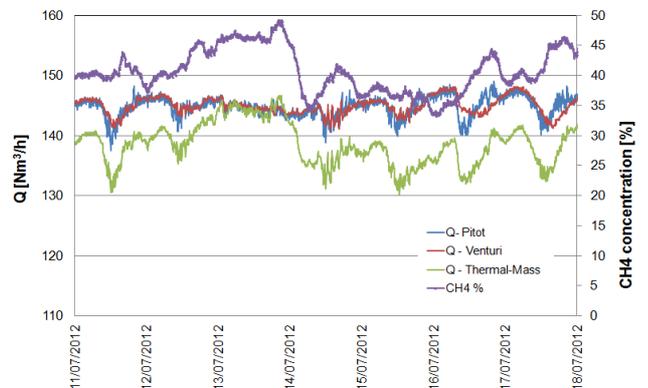


FIG. 11 – Infield flowrates of three different flowmeters: and averaged pitot, a venturi and a Thermal-Mass compared to the CH_4 variation for 10 days (biogas site n°1).

The same study of the impact of the temperature had been done for the two lasting sites. For the second site, it has been clearly identified that the biogas production flowrate is inversely proportional to the temperature (figure 12-a). This is due to the negative impact of the temperature on bacteria responsible of the methanation process. In the other hand, the averaged-pitot and the V-cone are less sensitive than the vortex to the temperature variation. The V-cone and the vortex flowrate are closer. The analysis of figure 12-b shows that the flowrates shifts is much higher than the first site. This can be explained by the metering technologies difference. Also, the fact that, the temperature variation is much higher, about 30°C against 15°C for the first site.

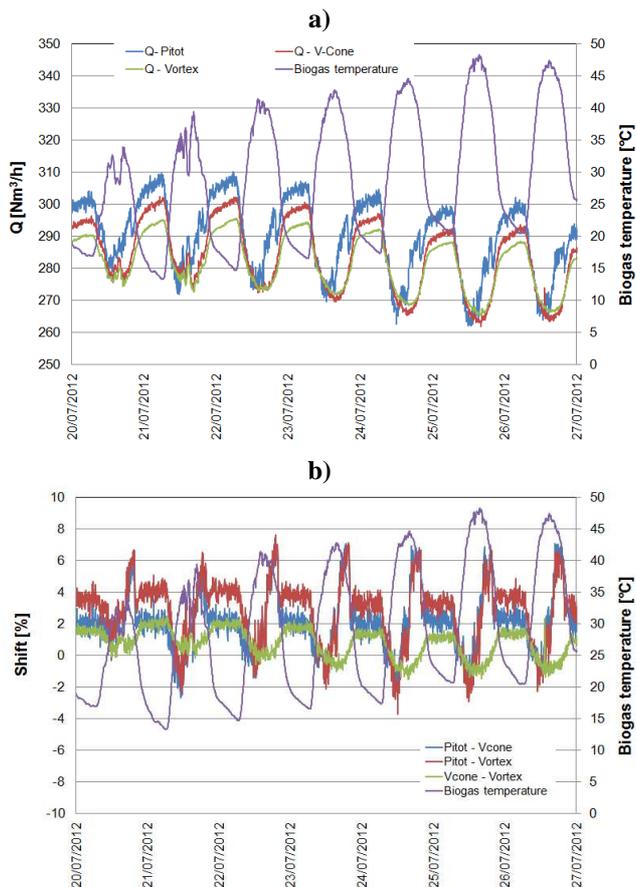


FIG. 12 – a) Infield flowrates of three different flowmeters: and averaged pitot, a V-cone and a vortex meters compared to the biogas temperature variation for 7 days. **b)** Infield flowrate shift of the three different flowmeters on 7 days (biogas site n°2).

On the figure 13 are plotted the flowrates evaluation measured at the site 3 where both an averaged-pitot meter is compared to an oscillations one. In this case, nothing can strictly be deduced from the comparison of these meters. In the other hand, these results show that the oscillations meter is much less sensitive to the flowrate variation than all the tested flowmeters. The same observation can be done from this last figure: the temperature variation monitoring is a key factor to improve the crud biogas flowrate, like for the biogas composition.

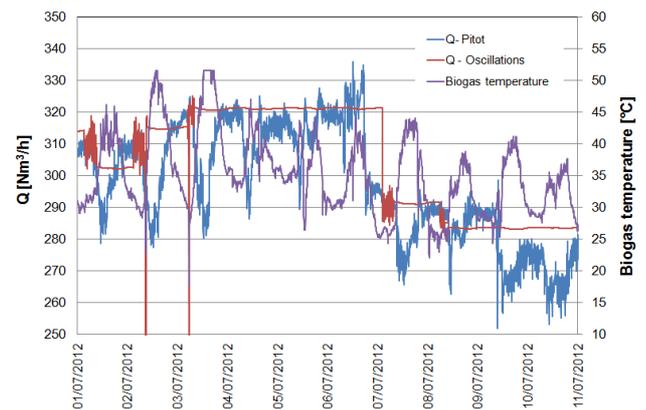


FIG. 13 – Infield flowrates of two different flowmeters: an averaged pitot and oscillations meters compared to the biogas temperature variation for 10 days (biogas site n°3).

Installation & operating recommendations

This wide experimental study permit to define some important recommendation to can ensure the reliability and accuracy of the crude biogas flowrate measurement:

- All the installation meter manufacturer must be respected and, we propose also, to go a little further like increasing by about 20% the straight lengths to ensure the absence of residual flow instabilities due to the installation configuration.
- The Thermal-Mass flow meter must be installed in inclined plan (about +45°) to avoid the liquid stagnation around the sensors.
- Every flowmeter must be connected to a temperature and pressure sensors. These to ensure the P & T volume correction.
- Every crude biogas metering station has to involve a gas composition analyzer or, in minimum, a methane CH₄ concentration sensor. This device has to be connected to the flowcomputer too. This to ensure the volume adjustment (gas density, heat capacity and compressibility).
- If this last recommendation is not respected, a daily composition has to be measured. Then, the volume correction can be done “a posteriori”.

Conclusions

All these results: laboratories and infield ones show that, even the crud biogas is a very wet gas with a high composition variation and important fluctuation of the temperature, it is possible to correctly measure it flowrate. They allow, also, comparing and studying the behaviour of the different tested flowmetering technologies. It is evident that the corrosive and wet characteristics of the crude

biogas ask for the use of a robust and without mobile parts flowmeters. But, even, all the tested flowmeters meet these requirements; they behaviours are very different considering the high fluctuations of the crud biogas properties, such as composition, liquid presence, pressure and temperature.

However, first, the averaged-pitot is the most adapted one, it is very robust and always high accurate. Secondly, the venturi and the V-cone are adapted and accurate in measuring crud biogas because of their high robustness (no mobile parts), their high accuracy and their simple principle and operating.

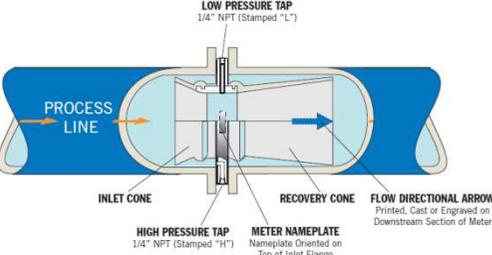
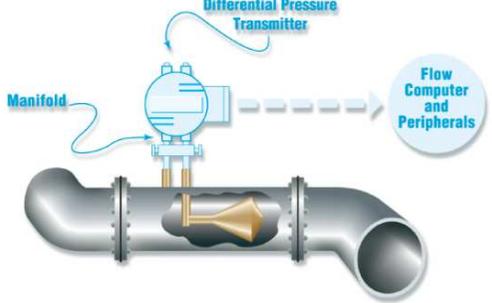
Other technologies can be used with the crud biogas, such as the Thermal-Mass and vortex meters. But these are more sensitive to the fluctuations of the biogas characteristics.

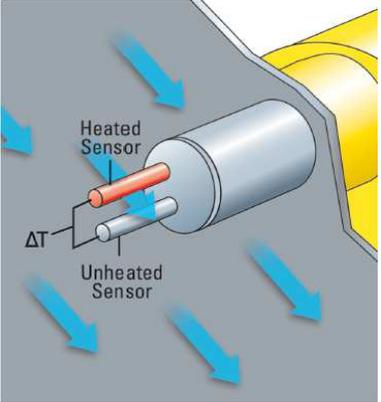
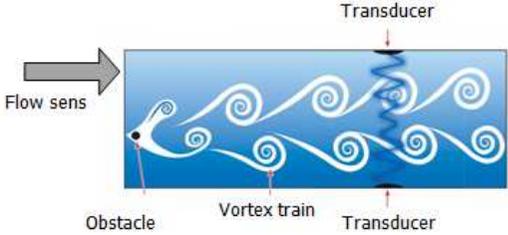
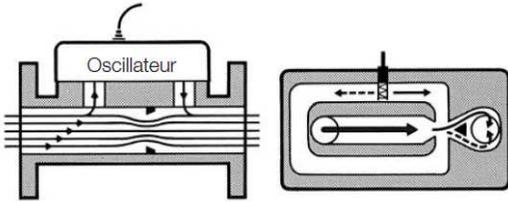
An important conclusion is obtained from these experiments: the flowmetering technology and robustness are not the only guarantee of the accuracy of the flowrate measurement. The temperature and the biogas composition are also key factors to improve the flow measurement. This because these factors are the most impacting the thermodynamic characteristics of biogas, such as density, heat capacity and viscosity; which are the key parameters for the flowrate calculation for both, pressure difference, vortex and thermal-mass metering technologies.

To summarise all these results for an operating use, in the above tableau, are given, the advantages and inconvenient and the useful characteristics (range, installation conditions, price...) of each tested technology.

References

- Circulaire du 6 avril 2010 : «Taxe générale sur les activités polluantes ». Ministère du budget, des comptes publics et de la réforme de l'Etat.
- DIRECTIVE 2004/22/CE DU PARLEMENT EUROPÉEN ET DU CONSEIL du 31 mars 2004 sur les instruments de mesure.
- CONTRAT D'ACHAT DE L'ENERGIE ELECTRIQUE PRODUITE PAR LES INSTALLATIONS VALORISANT LE BIOGAZ ET BENEFICIAINT DE L'OBLIGATION D'ACHAT D'ELECTRICITE : BGM6-V00. 11/12/2006.
- Arrêté du 21 octobre 2010 relatif aux compteurs de gaz combustible. Version consolidée du 11 novembre 2010
- Biogases injection - the German experience. Uwe Klaas. DVGW e.V., Bonn, Germany.
- Energy Sector Methane Recovery and Use. The Importance of Policy. INTERNATIONAL ENERGY AGENCY. 2009
- Débitmètres massiques. Claude GAILLEDREAU. Techniques de l'ingénieur.
- Bio-methane to Grid – European Injection Experience in Germany. Dr. Harald von Canstein, E.ON Bioerdgas.

Flowmeter	Principle	Advantages – Disadvantages	Illustrations
<p>1) The averaging Pitot tube (APT)</p>	<p>The APT is an anemometer. It produces an averaged differential pressure (ΔP) signal proportional to the square of the volumetric flowrate.</p>	<ul style="list-style-type: none"> ▪ Medium sensitivity to biogas composition, ▪ Low sensitivity to liquid presence ▪ medium straight lengths, ▪ medium rangeability (~20), ▪ Low pressure loss, ▪ No moving parts, ▪ Easy to install, ▪ Easy to maintain, ▪ Medium price, ▪ Unapproved model. 	
<p>2) The venturi</p>	<p>The Venturi measures a fluid's flowrate by reducing the cross sectional flow area in the flow path and generating a pressure difference.</p>	<ul style="list-style-type: none"> ▪ Medium sensitivity to biogas composition, ▪ Low sensitivity to liquid presence ▪ Low pressure loss, ▪ Low straight lengths, ▪ Medium rangeability (~20), ▪ No moving parts, ▪ Approved model, ▪ Easy to install, ▪ Easy to maintain, ▪ Expensive. 	
<p>3) The V-cone</p>	<p>The V-Cone is a differential pressure type flow meter with a unique design that conditions the flow prior to measurement. The Differential pressure is created by a cone placed in the center of the pipe. The flow rate is calculated by measuring the difference between the pressure upstream of the cone at the meter wall and the pressure downstream of the cone through its center.</p>	<ul style="list-style-type: none"> ▪ Medium sensitivity to biogas composition, ▪ Low sensitivity to liquid presence ▪ Low straight lengths, ▪ Medium rangeability (~20), ▪ No moving parts, ▪ Easy to install, ▪ Easy to maintain, ▪ High pressure loss, ▪ Unapproved model, ▪ Expensive. 	

<p>4) A mass flowmeter</p>	<p>Mass flow measurement. Thermal mass flow transmitters provide a measurement of the mass flow rate of the gas based upon heat transfer.</p> <p>The gas flows past a heated surface creating a cooling effect. Heat transfer is caused by the mass (or molecular) flow of the gas providing a mass flow measurement.</p>	<ul style="list-style-type: none"> ▪ High sensitivity to biogas composition, ▪ High sensitivity to liquid presence ▪ High straight lengths, ▪ High rangeability (>100), ▪ No moving parts, ▪ Easy to install, ▪ Easy to maintain, ▪ Medium price, ▪ High pressure loss, ▪ Unapproved model. 	 <p>The diagram shows a cross-section of a pipe with flow indicated by blue arrows. Two sensors are mounted on the pipe wall: a 'Heated Sensor' (orange) and an 'Unheated Sensor' (grey). A temperature difference ΔT is indicated between them.</p>
<p>5) A vortex flowmeter</p>	<p>The principle of operation is based upon the shedding or the creation of vortices from a blunt element. The instrument counts the number of vortices created; and, through a known relationship, converts this to the actual flow rate through the element.</p>	<ul style="list-style-type: none"> ▪ Low sensitivity to biogas composition, ▪ High sensitivity to liquid presence ▪ medium straight lengths, ▪ High rangeability (>100), ▪ No moving parts, ▪ Easy to install, ▪ Easy to maintain, ▪ Medium price, ▪ High pressure loss, ▪ Unapproved model. 	 <p>The diagram shows a pipe with flow from left to right. An 'Obstacle' is placed in the pipe, creating a 'Vortex train' of swirling flows. A 'Transducer' is positioned to detect these vortices.</p>
<p>6) An oscillations flowmeter</p>	<p>The oscillations flowmeter use the same principle as an orifice plate: the medium flows through an orifice in a tube. Bypass bores are located at the sides. The dynamic pressure at the orifice causes part of the gas volumetric flow to go into the bypass. The bypass channel contains the Oscillator and the oscillation frequency is proportional to the flow velocity and thus to the total volume flow.</p>	<ul style="list-style-type: none"> ▪ Medium sensitivity to biogas composition, ▪ Low sensitivity to liquid presence ▪ medium straight lengths, ▪ High rangeability (>100), ▪ No moving parts, ▪ Complicated to install (heavyness), ▪ No maintenance, ▪ Medium price, ▪ High pressure loss, ▪ Unapproved model. 	 <p>The diagram shows a pipe with flow from left to right. An 'Oscillateur' is mounted on top of the pipe, and a 'Transducer' is mounted on the side. The flow is shown being diverted into a bypass channel.</p>