Eliza Dyakowska, Magdalena Pęgielska, Paweł Szufleński - ***GAZ-SYSTEM S.A.***
Jean-Luc Fabre, Dairo Balestas - ***GDF SUEZ***
Susana Ávila Calzada - ***ENAGÁS***
Tamsin Kashap - ***NATIONAL GRID***
Luciano Occhio - ***SNAM***

Comparison of results obtained with different approaches to natural gas emissions measurements - GERG project no 2.73

1. Introduction

In 2010 a GERG project „*Inventory of Natural Gas Emissions Measurement Method"* was concluded. Partners to the project were Eni Power & Gas Division, E. ON Ruhrgas AG, FLUXYS, GAZ-SYSTEM S.A., GDF SUEZ, NV Nederlandse Gasunie, Snam Rete Gas).

It was found, that the most useful method to measure emissions is Air Flow Method and the most popular device based on this method is Hi Flow Sampler (HFS). Partners to the project decided, that it is justified to compare two emissions measurement methods - Air Flow Method and method described in EN 15446:2008 standard, to find out which is more reliable for natural gas industry and develop a reference method to be applied across Europe. Reference method to be developed should be tested and verified in a laboratory and in the field conditions and shall be standardized

The aim of the present project was to compare the accuracy of two methods of methane fugitive emissions measurements – one according to EN 15446 standard and another using the Air Flow Method with a Hi Flow Sampler device.

Project is performed as The European Gas Research Group (GERG) project – Programme Committee Transmission&Storage. Five companies are participating: GAZ-SYSTEM S.A. (Poland) as a leader, GDF SUEZ (France), SNAM/Snam Rete Gas (Italy), ENAGAS (Spain) and NATIONAL GRID (United Kingdom).

2. Scope, installation and test procedure

Estimation of an accuracy of two measurement methods for natural gas leakages in a laboratory conditions were performed on six leaking elements of gas installations listed in Table 1. The test facility was constructed in CRIGEN, which is the GDF SUEZ Group research and operational expertise center dedicated to gas, new energy sources and emerging technologies.

Table 1 Number of measurements for all elements tested

	Leaking element					
	Open ended pipe 6 mm	**Threaded connect-ions**	**Flange on spool DN 100**	**Flange on reduction DN 150**	**Valve SRI**	**Valve MAPEGAZ**
No. of measurements with EN 15546 method	9	15	9	9	9	9
No. of measurements with Air Flow Method	9	15	9	9	9	9

Pressure of gas – methane was used – was in the range 1 – 60 bar.

A scheme of the test facility, which was designed and constructed by CRIGEN is shown on Fig.1.

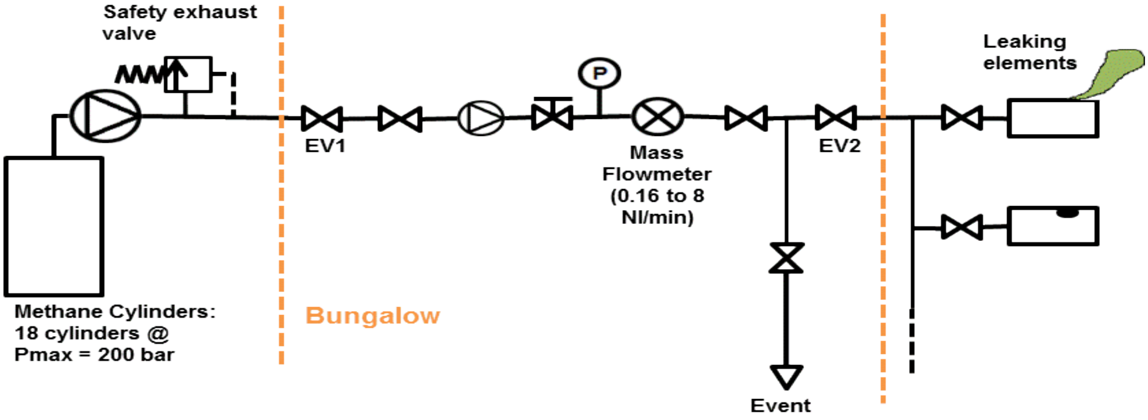

Fig.1 Scheme of the test facility

The installation comprises of two parts: a first one where the gas rate is “generated” at a known flow-rate (measured by a flowmeter) and the second one where several leaking elements are filled with gas through a valves manifold.

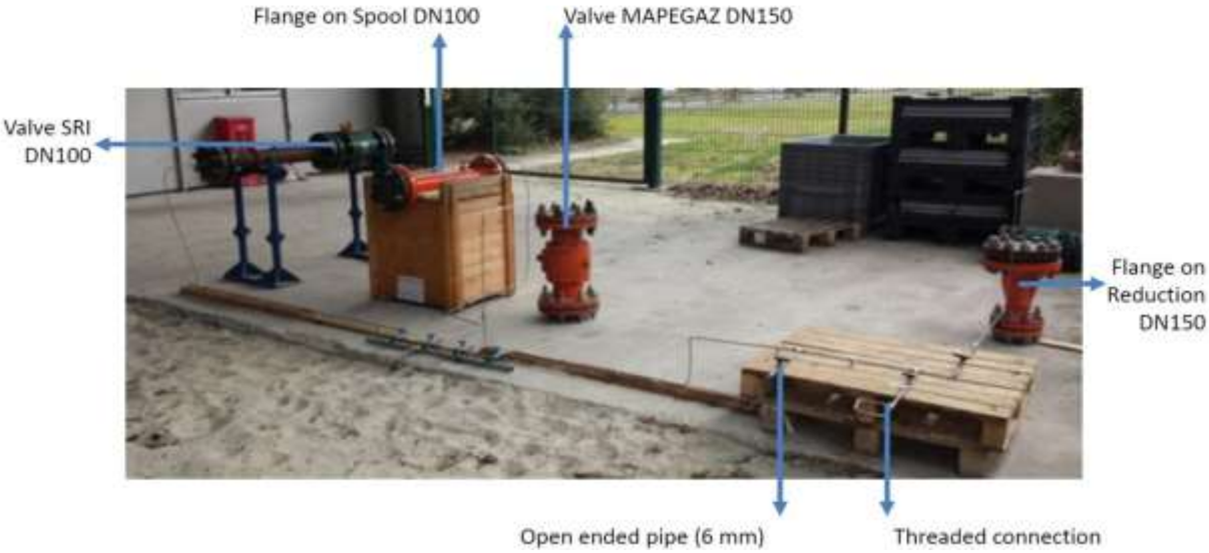

Fig.2 Picture of the second part of the test facility

The range of fugitive gas emission rates in which standard EN 15446 may be applied is not described in this document, but from correlations presented in the standard it is justified to assume, that this method may be applied to small or medium leaks only. In case of SOCMI (Synthetic Organic Chemical Manufacturing Industry) correlation the biggest gas emissions, which may be calculated on the basis of concentration measurements or taken from the table in Annex C, are of about 14.47 l/min. With the use of EPA PETROLEUM INDUSTRY correlations, maximum calculated gas leak will be only 1.77 l/min for flange, and maximum value taken from the table is 3.25 l/min for valve.

Hi Flow Sampler device has a measuring range 0.09 to 13.5 m^3/h, i.e.1.42 l/min to 226 l/min.

It was decided, that flowrate from the leakages will be in the range 0.1 m^3/h ÷ 0.5 m^3/h, i.e. 1,67 l/min to 8,33 l/min, so it will be possible to compare both methods.

Total number of independent measurements, taken by external contractors, when using EN 15446 method and Air Flow Method was 120.

Following test procedure was established for different flow/pressure combinations:

1) The CRIGEN operator sets a leaking rate on a leaking element;
2) The CRIGEN operator makes a measurement with an RLMD instrument;
3) The Contractor measures the leaking rate following the EPA-21 method;
4) Step 1 to 3 are repeated to measures following the tests program until completion of the measurements with the EPA-21;
5) When step 4 is completed, step 1 to 3 are repeated following the tests programme until completion of the measurements with the HFS.

It was decided, that measurements shall be taken by a company, which is experienced in emission measurements using different methods. To avoid the possibility of making systematic errors, which are not due to the methods used, partners to the project agreed that two different companies from different EU countries will make measurements.

3. Leaks creation

Except for the open tube, leaks were created by damaging a tight element (valve, flange, connection) at specific points. Initial tightness tests at 9 barg were performed to ensure that it would not leak at undesired points. Example of creating the leak is given on fig. 3.

Fig.3 Creation of a leakage - damaged metallic gasket and graphite packing, two bolts bad fitted on the same flange

When leaks were created, validation tests were made to confirm, that it is possible to obtain desired flowrates at the desired pressure range (leakage tests at pressures from 4 to 30 barg).

It was necessary to modify created leaks several times to get the desired flowrates.

4. Results of test facility checking

When the facility was ready, the tightness of the feeding line (circuit before the manifold letting the gas go to the leaking elements) was checked. Pressure of 3 to 60 bar was applied, and tightness was verified.

To ensure that the leaks are produced only at the intended points, i.e., where the leak sources were created, leaks localization tests were performed on the elements at pressure of gas from 3 up to 60 bar. As was expected, all leaking elements leaked only at the intended points. Also time needed to perform all 120 measurements was estimated – about ten working days - and later on confirmed by contractors making measurements.

According to the test programme, operator was obliged to repeat the same flowrate, for each element, three times, so it was necessary to test if it is easily achievable. For this purpose, CRIGEN tested repeatability of generating a desired flowrate as a function of pressure.

Examples of test results are shown on fig. 4 and 5.

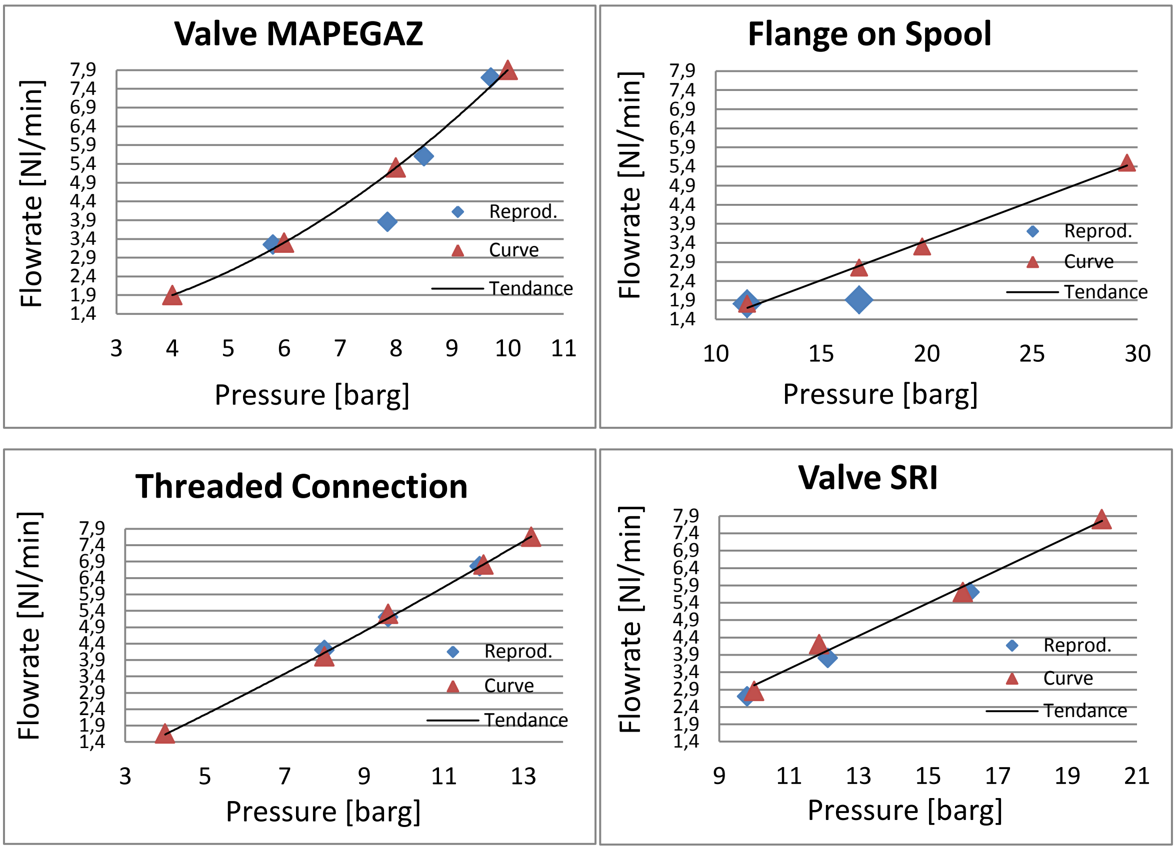

Fig. 4 Flow as the function of the pressure for valve MAPEGAZ, valve SRI, Flange on spool and threaded connection – dispersion of results

As can be seen, in case of all elements, dispersion of results was quite good, in most cases below 10%. Also correlations between flowrates and pressures were as expected.

5. Measurements according to method presented in EN 15446

5.1 General description of the method

Method considered is presented in EN 15446:2008 „Fugitive and diffuse emissions of common concern to industry sectors - Measurement of fugitive emission of vapours generating from equipment and piping leaks” [1].

This standard applies to the measurement of fugitive emissions of volatile organic compounds (VOCs) from process equipment. The leak sources include, but are not limited to, valves, flanges and other connections, pressure relief devices, process drains, open-ended valves, pump and compressor seal systems, agitator seals, and access door seals. It does not apply to instrument tubing connections.

The standard is based on the measurement of the gas concentration at the interface of a leak. This concentration is measured with a portable instrument and is converted to a mass emission rate by use of a set of correlations.

Basic requirements related to equipment, the standard screening procedure and correlations, which may be applied, are given in the standard.

For screening values exceeding the range of a detector, a fixed emission factor (so-called "pegged" factor) is used. If measurements are made to a maximum that is higher 100 000 ppm, the correlation shall be used for all data that are within the measurement range of the equipment, and pegged values at 100 000 ppm shall be used for values beyond the data range of the equipment.

5.2 Measurements made by Company A

The detector used in this project was the Toxic Vapor Analyzer (TVA) 1000 B (Thermo Instruments), with Flame Ionization Detection. The instrument was calibrated with methane at concentrations of 500 and 10 000 ppm.

The probe inlet of the instrument was placed at the surface of the component interface where leakage could occur. The probe was moved along the interface periphery while observing the instrument readout. If an increased meter reading was observed, the interface where leakage was indicated was sampled slowly until the maximum meter reading was observed. The probe inlet was left at this maximum reading location for approximately two times of the instrument response time.

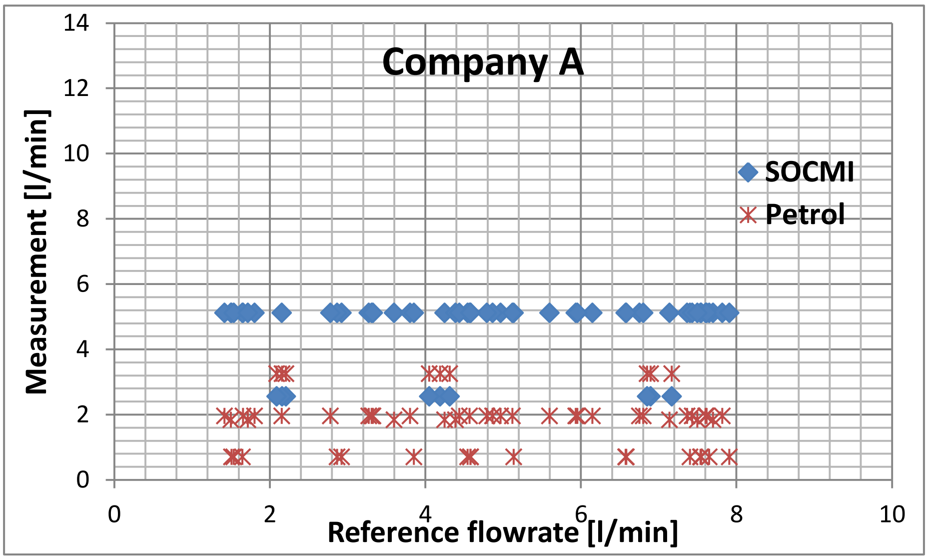

Fig.5 Results obtained by Company A corresponding to reference values

Both correlation – EPA SOCMI and EPA Petroleum Industry were used to obtain emission rates.

It can be seen, that there is no correlation between reference values and results obtained by Company A.

5.3 Measurements made by Company B

Company B made their measurements using Sigi Ex2 methane detector produced by ESDERS GmbH. The range of the measurements of that detector is from 1 ppm (vol) up to 100 % (vol). Detailed information on SIGI Ex2 are presented in a manual for this device [2].

In the calculation of methane emission rates with use of correlation equation no pegged values or average additional emission factors were used, because methane concentration at the source of the leak was measured in full range, form 0 % to 100 % (vol).

Both correlation – SOCMI and EPA Petrol were used to obtain emission rates.

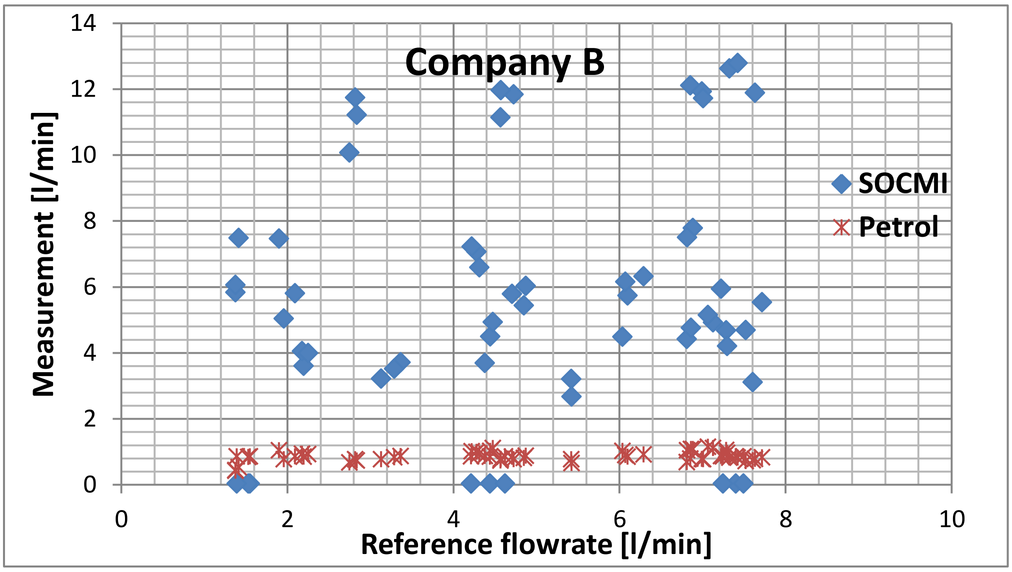

Fig.6 Results obtained by Company B corresponding to reference values

As can be seen on the Fig.6, there is no correlation between reference values and results obtained by Company B. The Company's B results for SOCMI were more varied than Company's A results.

6. Measurements according to Air Flow Method

6.1 General description of the method

When using this method, measurements are made with a Hi Flow Sampler (HFS) device, which is a portable, intrinsically safe, battery-powered instrument designed to determine the rate of gas leakage around various pipe fittings, valve packing, and compressor seals found in natural gas transmission, storage, and compressor facilities.

Leak rate from investigated equipment is measured by sampling at a high flow rate (generated by HFS) so as to capture all the gas leaking from the equipment along with a certain amount of surrounding air. By accurately measuring the flow rate of the sampling stream and the natural gas concentration within that stream, the gas leak rate is calculated as follows:

$$\text{Leak rate} = \text{Flow} \times (\text{Gas sample} - \text{Gas background}) \times 10^{-2} \quad (1)$$

where:

Leak - rate of gas leakage from source (l/min)
Flow - sample flow rate (l/min)
Gas sample - concentration of gas from leak source (%)
Gas background - background gas concentration (%)

The instrument automatically compensates for the different specific gravity values of air and natural gas, thus assuring accurate flow rate calculations. The main unit consists of an intrinsically safe, high-flow blower that pulls air from around the component being tested through a flexible hose and into a gas manifold located inside the unit.

To ensure that the instrument is capturing all the gas escaping from the equipment tested, usually two measurements are performed at two different sample flow rates. The first measurement is taken at the highest possible flow rate, followed by a second that is approximately 70–80% of the first one. If the two calculated leak rates are within 10% of each other, then it can be assumed that all gas has been captured during the test.

6.2 Measurements made by Company A

The equipment tested was bagged by wrapping it with the bag of the HFS. The end of the bag was closed. Air was allowed to flow into the bag to reduce the vacuum in the enclosure. A slight vacuum in the bag was maintained, and no gas should be leaking from the bag. The HFS main sampling hose was attached to the bag.

A TVA 1000B was placed at the exhaust of the High Flow Sampler to log the concentration in ppm during a couple of minutes. Using this log, the average values were calculated. These ppm-values in combination with the flowrate measured on HFS were used to calculate the loss according to the following equation:

$$Loss = \frac{Concentration \cdot MW \cdot Flow \cdot P}{R \cdot T} \cdot 10^{-3} \tag{2}$$

where:

Loss - Average loss (g/h)
Concentration - Actual Concentration (ppm) (average of the concentration log on the TVA 1000 B)
MW - Molecular Weight (g/mol)
Flow – Flowrate measured on HFS (m^3/h)
R - Gas Constant (0,0820578 L*atm*K-1*mol-1)
T - Temperature (K)
P - Pressure (atmospheric pressure of 1 atm)

The concentration was measured at two different aspiration flows. Results were averaged to present the total loss per test point.

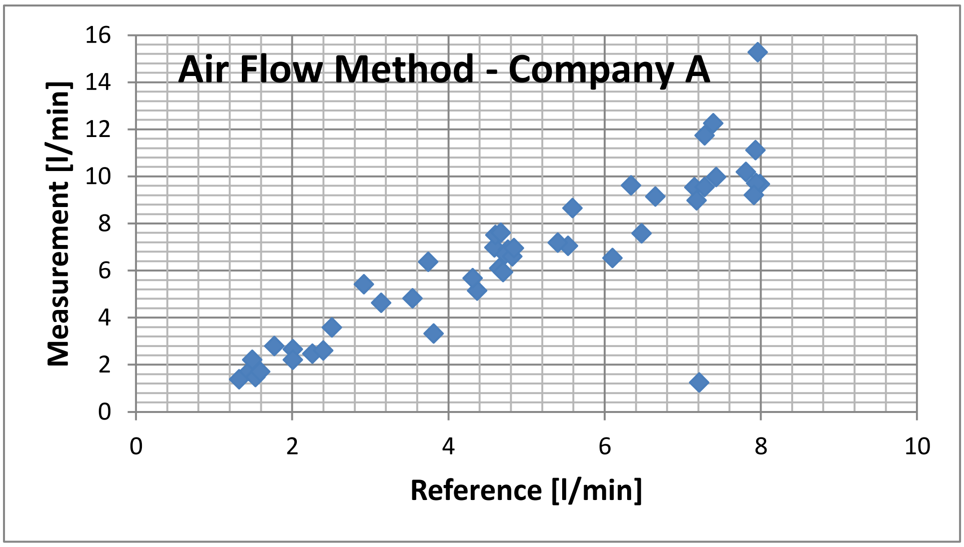

Fig.7 Company A - results from elements tested

As can be seen on the Fig.7, there is a correlation between reference values and results obtained by Company A, however these results are overestimated by about 50%.

6.3 Measurements made by Company B

For the open ended tube flexible hose was used as a probe, for other elements capture bag was used. When using capture bag it is not allowed to completely close off the bag – it is necessary to allow air to flow into the bag.

Measuring at the first higher flow rate was carried out until a stable leak measurement was achieved. Once a stable leak measurement was obtained, *Save* button was pressed and the flow rate was automatically lowered. Sampling at the reduced flow rate was continued until once again a stable leak measurement was achieved. Once again *Save* button was pressed and HFS was moved to clean air area.

When all measurements were completed, all records of experiments from HFS were transferred to a personal computer and methane emissions were calculated with use of Microsoft Excel program. Obtained results were recalculated to get methane emission rates at normal conditions.

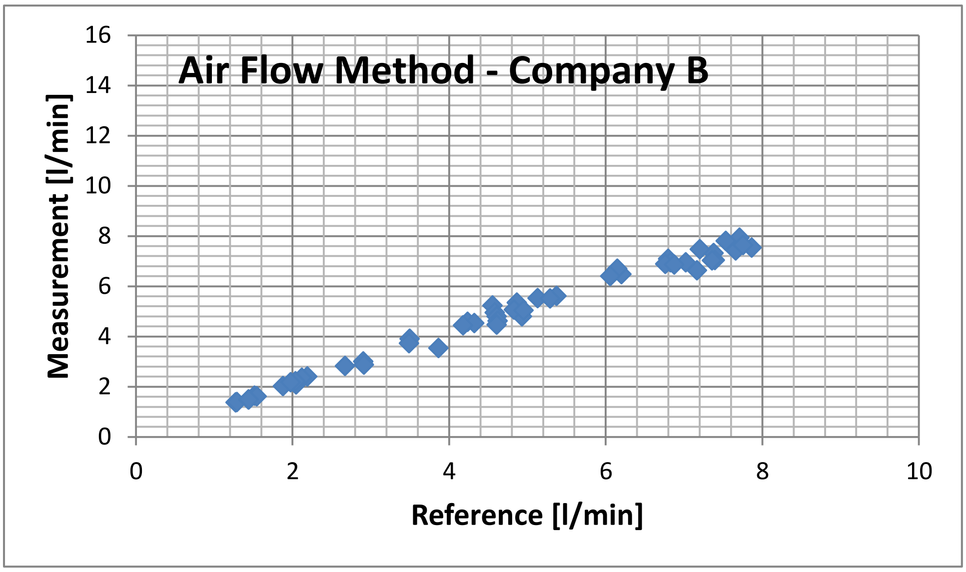

Fig.8 Company B - results from elements tested

As can be seen on the Fig.8, there is a very good correlation between reference values and results obtained by Company B.

7. Comparison of results for EN 15446 method

Measurements were made with different equipment – in case of Company A, a device used for concentration measurements was the Toxic Vapor Analyzer (TVA) 1000 B (Thermo Instruments), with Flame Ionization Detection. The instrument was calibrated with methane at concentrations of 500 and 10 000 ppm.

The device used by the Company B was SIGI Ex2, produced by ESDERS GmbH. The range of the measurements is from 1 ppm (vol) up to 100 % (vol) (without any dilution of the sample).

The instrument was checked every day twice (before and after measurements) with two calibrations gases (1000 ppm and 2.2 % of methane).

As can be seen on fig. 5 and 6, when using EPA Petrol correlation, all results are underestimated. SOCMI correlation gives results closer to reference values and in that case it can be seen, that crucial is the range of a detector used, however there is no correlation between reference values and results obtained by any of the two companies.

Differences between reference values and values obtained by using SOCMI correlations were in the range from -240% to 65% (Company A) and from -430% to 100% (Company B).

8. Comparison of results for Air Flow Method

Although in a manufacturers Instruction 0055-9017Operation & Maintenance, Rev. 5 – June 2010 [2] a detailed procedure of taking measurements with the HFS is specified, the companies did measurements differently. Company A used additionally TVA 1000B device, and calculated the emission rate from eq. (2), while Company B used records of experiments from HFS and calculated methane emissions from eq. (1); results were also recalculated to get methane emission rates at normal conditions. Temperature during measurements was recorded by HFS, pressure registered separately.

As can be seen on fig. 7 and 8, there is a very good correlation between reference values and results obtained by both companies, although Company A results are overestimated by about 50 %, in case of Company B results were overestimated by about 3,5%.

In case of Flange on Reduction element a leak was much higher than indicated by a reference flowmeter, what have been identified by both companies. However that leak was not correlated with reference values.

Differences between reference values and values obtained by contractors were in the range from -10% to 90% (Company A) and from -11,5% to 4,5% (Company B).

9. Conclusions

The range of leak rates tested was only a small part of HFS range, but included a whole range for EPA Petroleum Industry correlation and about half of the range for EPA SOCMI correlation.

Flowrate leakages investigated was in the range 0.1 m3/h ÷ 0.5 m3/h, i.e. 1,67 l/min to 8,33 l/min, in order to compare both methods.

Results of measurements made by two external companies showed that:

a) Use of EN 15446 standard allows to use detectors of different range, what gives different results for existing correlations, but there is no specific correlation for natural gas industry in that standard;

b) Use of a method described in EN 15446 standard didn't allow to identify much higher leaks;

c) Measurements made with the use of HFS have a good correlation with reference values;

d) In case of HFS device, compliance with the manufacturers procedure gives better results;

e) Difference between reference values and measurements results in case of a standardized method are much greater than in case of measurements made with HFS.

Bibliography/ References

1. EN 15446:2008 „Fugitive and diffuse emissions of common concern to industry sectors - Measurement of fugitive emission of vapours generating from equipment and piping leaks".

2. HI FLOW Sampler, Natural Gas Leak Rate Measurement, Instruction 0055-9017 Operation & Maintenance, Rev. 5 – June 2010