The On-line Energy Measurement of Natural Gas
New Technologies

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Abstract

Since the early eighties, Process Gas Chromatographs have been the de facto standard for on-line energy measurement. Being a robust, accurate and widely accepted technology, it is however relatively slow and therefore not suited for control applications.
Instromet recently developed both a new generation of Process Gas Chromatographs, and a fast Correlative Energy Meter. This allows to serve the complete on-line energy market, from the accountable measurement systems requiring ultimate precision to control applications with the accent on speed of response.

The EnCal 3000 represents a new era in Process Gas Chromatography for natural gas. The combination of MEMS based analytical components with narrow-bore capillary columns improves analytical performance, analysis time, utility consumption and overall dimensions with a factor 3 to 5 compared to systems based on conventional technology.
The EnSonic is a Correlative Energy Meter, calculating the on-line gas properties based on only 3 input parameters using a patented correlative algorithm. The continuous input of the Velocity of Sound at elevated pressure (VoS_H) and at near-atmospheric conditions (VoS_L), together with the measurement of the CO_2 concentration, provides the base for the on-line assessment of all gas properties within seconds, at an accuracy level comparable to conventional Process Gas Chromatographs.

The paper explains the 2 technologies in detail with extensive field test results, and gives examples of typical applications for both devices.

Introduction

During the last 30 years, variety and quantity of natural gas supply has increased exponentially all over the world. The figures below show clearly this trend for Europe.
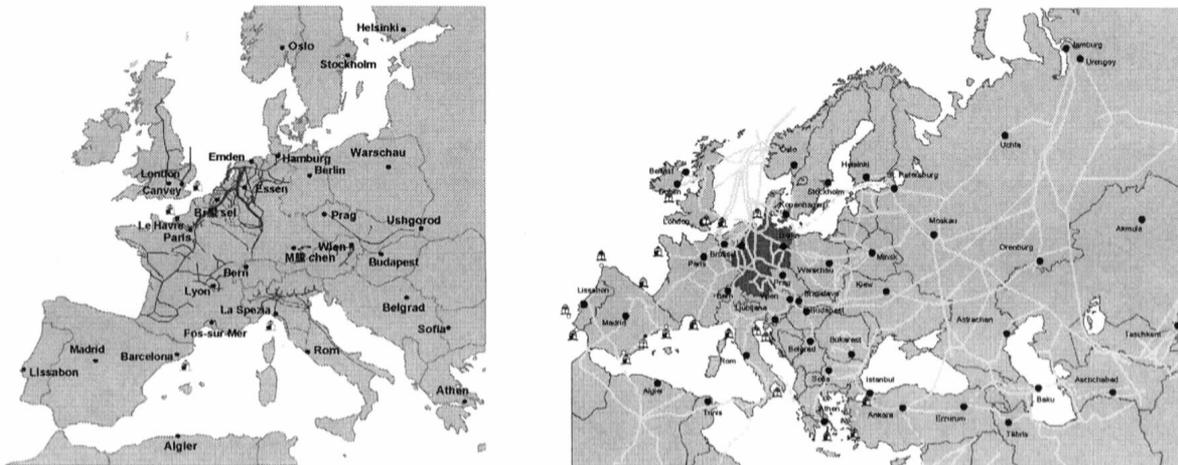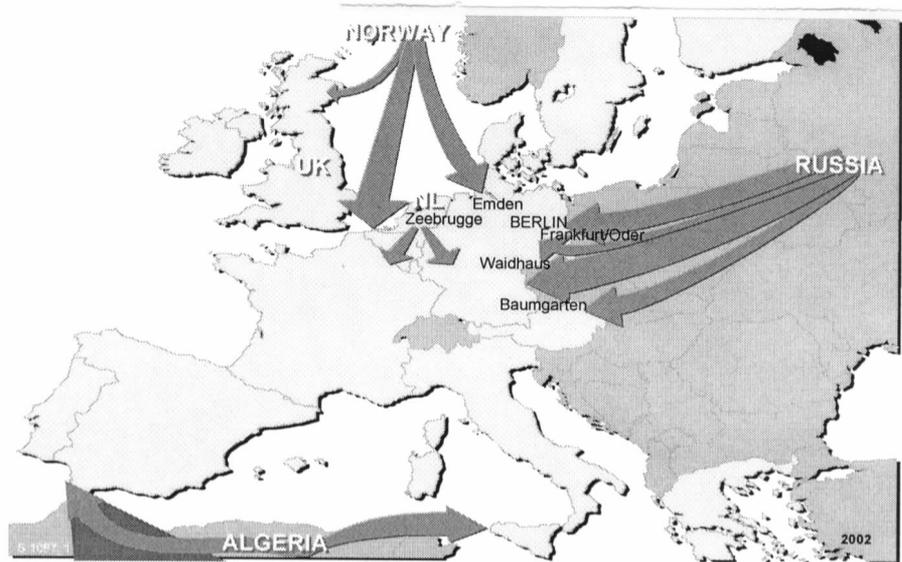

Fig. 1   Increase in natural gas pipelines and LNG terminals from 1970 to 2004 in Europe
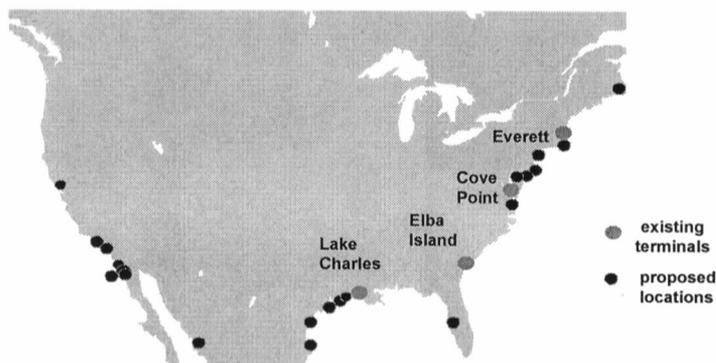
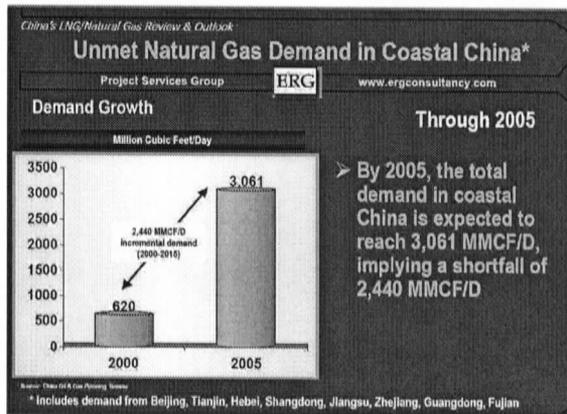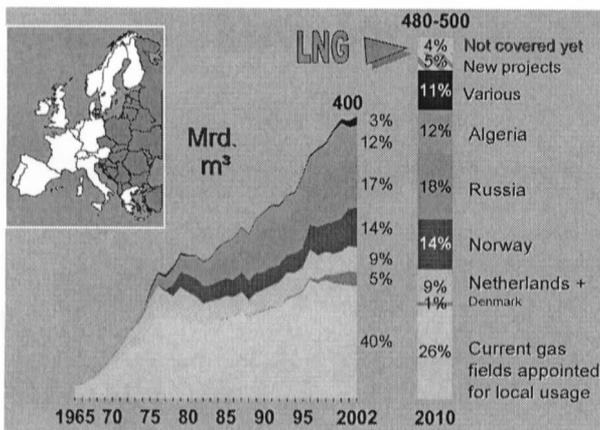Fig. 2   Gas Sources in Europe

Fig. 3   Growth of Natural Gas and LNG in Europe, China and USA

The above pictures show the following trends in natural gas supply :

- Growing demand of natural gas in the world
- Increased variety of natural gas supplies
- Increased supply of LNG

Together with the technological progress, they form the driving force for an exponential growth in on-line energy flow measurement in the natural gas industry.

Three major application fields can be defined :

- High precision accountable measurement, typically for the gas transportation market
- Control measurement, with the accent on fast response (within seconds). Typical application fields are blending stations and the Wobbe metering market.
- Off-shore market, with accent on robustness and reliability.

Instromet has developed for these field applications 2 new devices. The paper explains their technological concept, and gives detailed field test reports.

II The EnCal 3000 : Application of MEMS technology to On-line Gas Chromatography

II 1   Introduction

Process Gas Chromatographs (PGC) are the de facto standard for on-line analysis of natural gas because of their accuracy, suitability for automation and reliability. The analytical heart of current PGC's for natural gas typically consist of :

- Micro-packed columns
- Analytical components made with fine-mechanical tools, and interconnected with 1/16" tubing
- Standard Thermal Conductivity Detector with a internal volume of app. 5 µl

This results in a the following analytical performance :

- Analysis time 4 to 12 minutes
- Accuracy 0.20 % for a fairly large range of gases with single-point calibration
- Repeatability 0.05 % (acc. to ISO 6976)

However, the coming of age of MEMS technology allows for a new generation of gas chromatographs, with strong impact not only on the analytical performance, but also on the overall design of this type of devices.

II 2   MEMS technology used in natural gas analysis

MEMS (Micro Electro Mechanical Systems) technology combines mechanical and electronical techniques on a micro-scale. Using micro-machining processing steps developed by the IC industry, chip-level devices are created which not only allow for a significant improvement of the interaction between these 2 disciplines, but also provides a much better control of the processes which occur on this micro-scale.

MEMS applications have been growing exponentially during the last 5 years. Important application areas are the automotive industry (for example airbag sensors), IT and the medical sector.

Fig. 4   MEMS electrically driven motor with a diameter of a human hair

Gas chromatography is almost a natural bride for MEMS technology. Besides the obvious size reduction (with the associated decrease in manufacturing and installation costs) and the reduction in consumables (both power and gas consumption), MEMS technology has a major impact on the analytical performance :

- Miniaturisation of the Thermal Conductivity Detector (TCD), which drives its performance up to levels previously only attainable with FID's, and which indirectly enables the use of capillary columns for on-line C_{6+} analysis.
- Ultra precise integration of columns, detectors and sample injection system – the core analytical components – with the channel system of the base silicon wafer, leading to a significant reduction of the internal dead volume, which is crucial for the analytical performance of a GC.
- Reduction of the analytical module size, which allows for a much tighter temperature control of the analytical components, essential for the repeatability of the analysis results.

II 2.1 The use of capillary columns in process natural gas chromatography

Capillary columns is the popular name for open-tubular columns, referring to the small diameter sizes commonly used for this type of columns*.
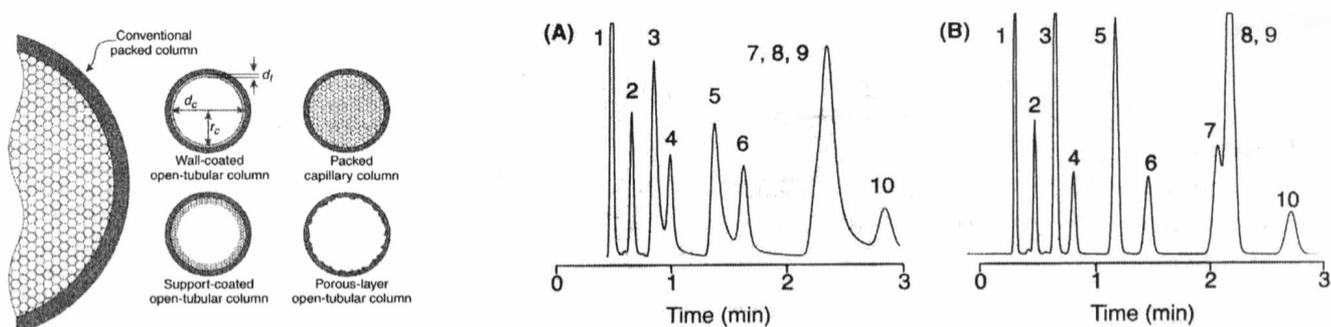

Fig 5   Different types of capillary columns, and difference in separation quality between packed and capillary column for identical velocity and temperature settings.

The most used capillary columns are of type WCOT (wall coated open-tubular) and PLOT (porous layer open-tubular), which offers a better film stability in case a higher loading of the column wall is required. The advantage over a packed column lies in the reduction in pressure drop (typically a factor 25 lower). This allows for much longer lengths and therefore much higher separation power. Nowadays they have replaced the traditional (micro)-packed columns in almost all gas chromatographic fields.

The efficiency of a capillary column increases with decreasing internal diameter. A 10 µm capillary column with a length of 10 m has the same separation characteristics as a 25 µm column of 25 m length.
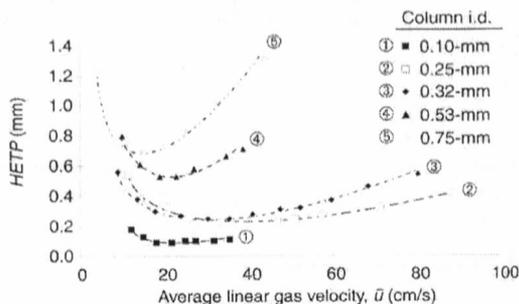

Fig 6   Separation efficiency as function of the average linear gas velocity for different column diameters

The film thickness of the stationary phase is proportional to the internal diameter to maintain the optimal phase ratio for component separation. Efficiency increase therefore results in a strong limitation of the sample size which can be injected onto the column, to prevent saturation of the stationary phase.

In the past TCD's were not sensitive enough to accurately detect the small sample sizes associated with capillary columns. Analytical designers were forced to integrate FID's (Flame Ionisation Detectors), which have a fast response time and low detection limit. Because these detectors require H_2 for the ionisation process, their use is not trivial in hazardous areas. Process analyzers for the natural gas industry therefore were limited to the use of TCD's in combination with (micro-)packed columns.

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*   This is misleading since open-tubular columns could in theory be manufactured at diameters larger than packed columns. However, because of its wide spread use, in this document the term "capillary" will be used.

TCD's based on MEMS technology can compete with conventional FID's for 2 reasons :

- MEMS technology allows for much smaller internal volumes (both the size of the detector chamber and the connections between capillary tubing and detector) which increases the sensitivity of TCD to levels at which they are compatible with the low sample volumes associated with capillary systems.
- The extreme reduction of the sensor size leads to a heat capacity low enough to reach thermal time constants around 5 ms. In general this constant should be a factor 5 smaller than the standard deviation of the most narrow peak. Capillary columns easily produce peak widths less than 1 s, which explains the absolute necessity of MEMS technology for TCD's used in combination with narrow-bore capillary columns.

However it has to be noted that even for MEMS TCD's the detection limit is still significantly higher than for FID's . The TCD's have to be put directly in the gas flow to assure fast response times necessary for narrow bore peaks. The inevitable flow variations lead to a relative high noise level. A typical detection limits for a MEMS TCD is 1 ppm for C_5, where FID's can go as low as ppb levels. MEMS TCD's are therefore not (yet ?) appropriate for trace analyses.
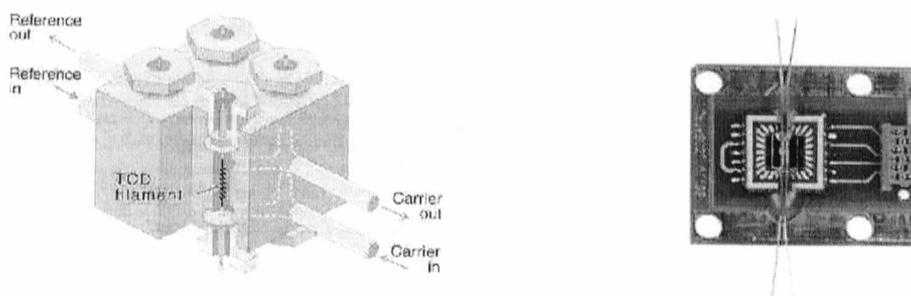

Fig 7   TCD manufactured with conventional fine-mechanical tools (left) and with MEMS technology (right). The internal volume is reduced with a factor 1000.

II 2.2   Reduction of dead volumes

The second fundamental advantage of MEMS technology for on-line natural gas analysis comes from the level of control it offers on dimensioning of the interconnecting flow paths.

Absolutely crucial for the analytical performance of gas chromatograph system is the number of dead volume spots, and their size, especially between column outlet and detector chamber. Any dead volume will allow the separated components to recombine after the column and therefore destroy the separation performance of the system.
MEMS technology allows to provide a smooth transition between capillary columns and detector inlet port.
Commonly used sizes for both internal diameter of the capillary column and the channel width are 100 and 250 µm.

II 2.3   Analytical module size reduction

One of the more obvious advantages and major driving force for MEMS applications in general is the intrinsic size reduction of the complete system, which allows for reduction of foot print, overall dimensions and weight, and therefore production and installation costs. For gas chromatography this size reduction allows for a much tighter temperature control of the analytical compartment of the GC, leading to a significant improvement of the repeatability of the analysis data.

II 3   Practical implementation
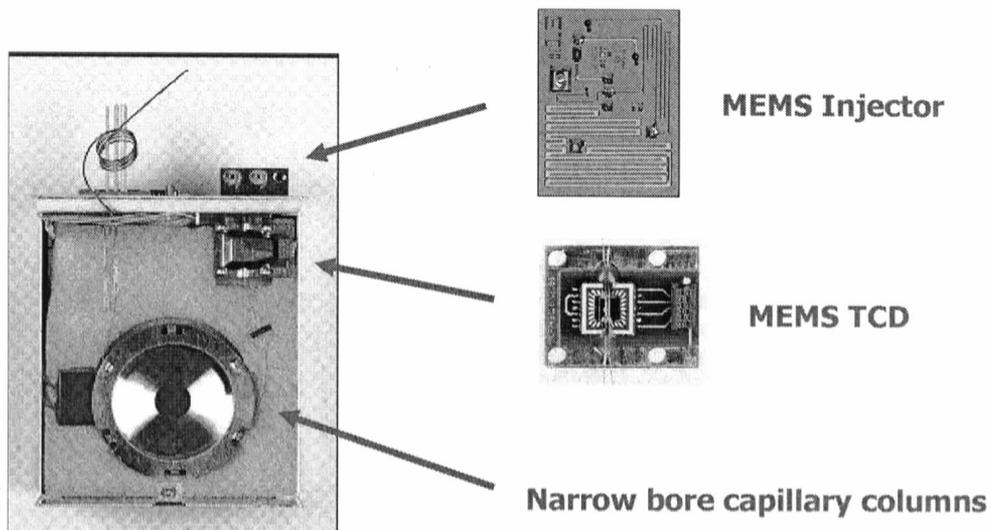
II 3.1   Analytical Modules

Fig 8   Major analytical components of the MEMS based analytical module

Analysis time

The combination of narrow-bore capillary columns with MEMS based components allows for C_{6+} analysis in less than 90 seconds if backflush configuration is used.

1. Propane
2. i-Butane
3. n-Butane
4. neo-Pentane
5. i-Pentane
6. n-Pentane
7. Hexane
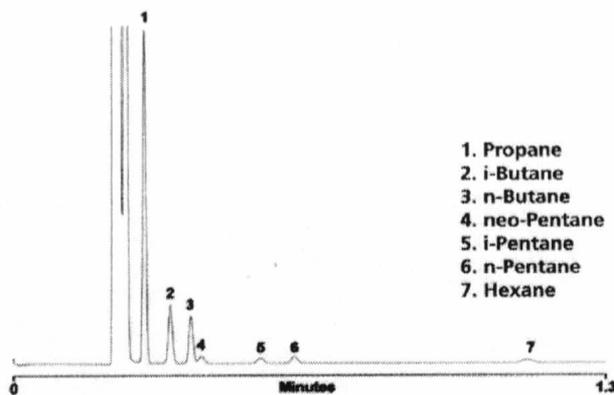
Fig 9   Analysis of the higher hydrocarbons on a MEMS based capillary system. C_8 can easily be detected in a straight-forward configuration in less than 3′

Since the Van Deemter curve (see fig. 7) becomes relatively flat for narrow-bore capillary columns, the linear velocity through these type of columns can be increased significantly without sacrificing much of the separation quality. This allows to increase the analysis speed further more, depending on the accuracy requirement setting.

Accuracy

Table I shows the analytical results for a dual-channel MEMS system, calibrated with the so-called 11D gas (standard calibration gas of the PTB). Three gases are analysed, with a deviation of -/+ 10 % in Calorific Value.

Table I   Accuracy results for a MEMS bases C_{6+} analysis

| | Cal. gas | Test gas #1 | | | Test gas #2 | | | Test gas #3 | |
		Certificate	Analysis		Certificate	Analysis		Certificate	Analysis
C6+	0.0500	0.0500	0.0499		0.0298	0.0307		0.0500	0.0504
N2	4.0700	13.0000	13.0381		0.7120	0.7637		0.8400	0.8220
CH4	88.8510	81.6870	81.6404		83.5310	83.5374		98.5390	98.5714
CO2	1.5400	1.4200	1.4368		1.8600	1.8639		0.0200	0.0200
C2H6	3.9900	3.1300	3.1268		10.2000	10.1659		0.2660	0.2523
C3H8	1.0000	0.5020	0.5073		2.8100	2.7499		0.0770	0.0815
iC4	0.2020	0.0810	0.0741		0.2370	0.2448		0.0530	0.0505
nC4	0.1990	0.0800	0.0775		0.4740	0.5020		0.0520	0.0527
neoC5	0.0000	0.0000	0.0000		0.0000	0.0000		0.0000	0.0000
iC5	0.0490	0.0250	0.0245		0.0735	0.0713		0.0530	0.0497
nC5	0.0490	0.0250	0.0245		0.0727	0.0704		0.0500	0.0495
HV [MJ/Nm3]	39.952	35.605	35.576		44.432	44.391		39.912	39.912
Diff [%]		-10.9			11.2			-0.1	
Error [%]			-0.08			-0.09			0.00

It has to be noted that the uncertainty on the calibration gases cannot be guaranteed to be better than 0.10 % on the Calorific Value.
In general MEMS based GC systems can easily deliver an uncertainty better than 0.10 % for a broad range of gases, based on a single point calibration. This a factor 2 to 3 better than what is achievable with conventional GC technology.
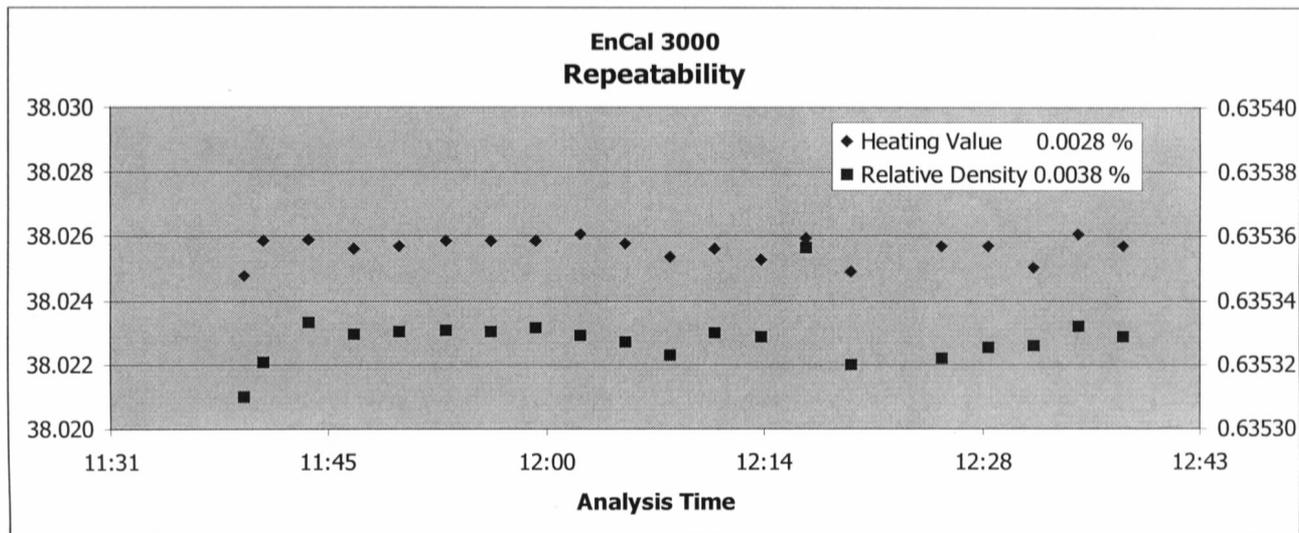
Repeatability

Fig 10   Typical repeatability results for a MEMS based C_{6+} analysis

II 3.2   Explosion proof design

For use in the natural gas industry, the MEMS based unit should be suitable for outdoor installation, close to the sample point. The complete analytical system (analytical module, electronic boards, sample handling and stream selection) has to be mounted in a explosion proof enclosure (ATEX or CSA/FM approved) and IP 65 classification for environmental impact (water and dust). The unit must have an internal heating module to prevent freezing of the sample gas.
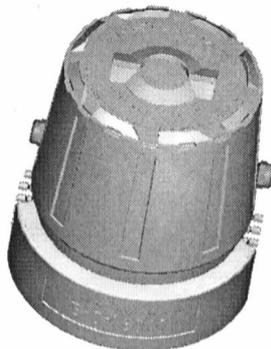

Fig 11   Explosion-proof enclosure for a MEMS on-line analyzer for natural gas

In general a MEMS based analyzer will have following specifications :

- Natural gas analysis according to ISO 6974 in less than 3 minutes
- Uncertainty < 0.1 % for a wide range of gases, based on a single point calibration
- Repeatability < 0.005 % (acc. to ISO 6976)
- Compact explosion proof enclosure (ATEX and FM certified) suitable for hydrogen applications
- IP 65 environmental protection
- Low utility consumption (less than 10 ml/min for supply gases, less than 30 W for normal operation)
- Operational ambient temperatures between −20 and 50 °C
- 24 VDC power supply
- Direct ModBus output (both serial and TCP/IP)
- Internal data storage of at least 35 days
- Sample system integrated in EX enclosure
- Different applications (C_{6+}, C_{9+}, sulphur, odorants) with the same hardware

II.4   Conclusion

MEMS technology enables a new generation of on-line analyzers for natural gas :

- Analytical performance is increased with a factor 3 to 5 :
  - Chip-level TCD's allow for the use of capillary columns
  - Integration of the analytical components on chip-level scale eliminate dead volumes between column outlet and detector, and enable very precise sample volume control
  - Size reduction of the analytical module facilitates the temperature control of the analytical module.
- Overall size and weight reduction with a factor 2 to 5 compared to conventional analyzers.
- Reduction of power and utility gas consumption with a factor 2 to 5.

III   The EnSonic : Correlative Energy Measurement of Natural Gas

III.1   Introduction

To fulfil the latest requirements of the natural gas energy market Instromet has expanded its range of natural gas analysis equipment with a newly developed, low OPEX energy meter based on ultrasonic technology : the EnSonic. Based on the combination of the measurement of the carbon dioxide content and the velocity of sound at both high (approx. 40 bar / 580 psi) and low (approx. 3 bar / 43 psi) pressure and a new, patented correlative algorithm, an accurate, fast and direct measurement of natural gas parameters like calorific value, density, Wobbe index and compressibility has been realized. The EnSonic has been developed in close cooperation with Gasunie Research, which is part of the N.V. Nederlandse Gasunie.

Tests undertaken so far indicate that the uncertainty ($\pm$ 0.3%) and reproducibility ($\pm$ 0.05%) are fully comparable with highly accurate field GC's used in custody transfer applications nowadays. The short response time of approximately 4 s and its inherent insensitivity for fouling make the method ideally suited for 'real time' energy measurement in high pressure control applications like gas blending, exploration and off-shore platforms.

Since the EnSonic is installed directly near the gas line, does not require an analyzer building and auto-calibrations are performed using a single multi-component calibration gas on significantly lower intervals compared to current systems, the costs of ownership are kept to a minimum.

This paper explains the operational principle of the EnSonic and the correlative method used and presents results obtained during field tests.

III.2   Principle of operation

The correlative model used for the EnSonic is based on the GERG database of natural gases (equivalent to the AGA8-DC92 and ISO 12213), developed by Prof. J. Schouten ad Dr. J. Michels of the Van De Waals – Zeeman laboratory of the University of Amsterdam. The model is based on the fact that for natural gases the ratio between the individual hydrocarbons depends on the heating value of the gas. For a given heating value a certain 'decay rate' exists for the hydrocarbons. By applying this model the number of components in the gas can be reduced to the following 4: N_2, CO_2, CH_4 and the rest of the hydrocarbons C_{2+}.

Since the correlative model links the C_1 to the C_{2+} only three input parameters are required to fully characterize this 4-component gas mixture. The model itself and the derived applications are subject to patents ([11], [12] and [13]).

The choice of input parameters is mainly determined by the following requirements :
     1) naturally, the input parameters must be mutually independent
     2) in order to realize a 'real time' energy meter the measurements should be as fast as possible
     3) the technology applied should be proven, reliable and accurate
     4) the technology should be certified according to the latest standards (ATEX, FM, CSA).

Since the ultrasonic measurement principle fulfils the above requirements and Instromet has been one of the main manufactures of ultrasonic flow meters for natural gas for more than a decade, the choice for using the measurement of the velocity of sound as input parameters is a logical one. The independence of the measurements is guaranteed by performing the velocity of sound measurements and both high (approx. 40 bar abs, **VOS_H**) and low (approx. 3 bar abs, **VOS_L**) pressure.

The third input parameter is the carbon dioxide content of the gas $\mathbf{X_{CO2}}$ which is measured using commercially available, dual wavelength, near-infrared technology.

III.3   Calculation method

The iterative procedure to calculate the calorific value from the input parameters is shown in figure 12. First, the velocities of sound at high (**VOS_H**) and low (**VOS_L**) pressure are measured together with the corresponding pressures (**P_H, P_L**) and temperatures (**T_H, T_L**). At the same instant the carbon dioxide content of the gas ($\mathbf{X_{CO2}}$) is determined.

The next step is the assumption of an initial composition with a known CO_2 content. This composition is used to calculate the velocity of sound at both high and low pressure using the AGA-10 equations and the measured conditions **P_H, P_L, T_H** and **T_L**. The calculated results are compared with the measured velocities of sound and as long as there is no match the composition of the gas mixture is adapted using the correlative set of rules and the calculations are repeated. Finally, when the numbers match the composition of gas mixture is determined. This so called

'intermediate composition' is used to calculate the overall gas parameters like the Wobbe index W_i, the heating value H_{SR}, the relative density d and the compressibility Z using the standard ISO 9676, AGA or S-GERG equations.

Since this intermediate composition is based on calculated values there may be minor differences with the actual composition. The intermediate composition is therefore not made available to the user of the system. However, the correlative model has been designed to calculate the overall parameters of the gas mixture with high accuracy, typically ± 0.3% for the Wobbe index and heating value and ± 0.1 % for the density.
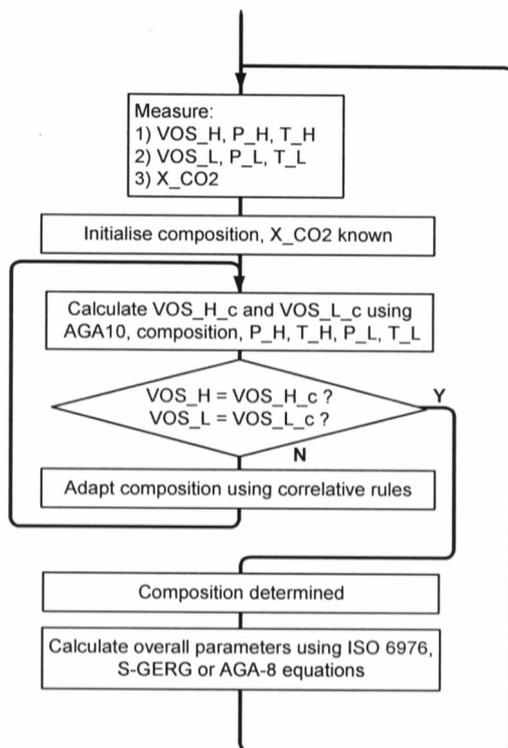

Fig 12   Calculation procedure

III.4   Sensitivity

The sensitivity of the correlation model with respect to the input parameters is illustrated using table 1 where the deviation on the heating value H_{SR} is given for a deviation on a specific input parameter. To illustrate the independence of the VOS measurements at high and low pressure the deviation is presented for pressure differences of 50, 35 and 20 bar (725, 510 and 290 psi) between the high and low pressure VOS measurements.

Table II   Sensitivity analysis

ΔP (bar/psi)		50 / 725	35 / 510	20 / 290
Input	Deviation (%)	ΔH_{SR} (%)	ΔH_{SR} (%)	ΔH_{SR} (%)
X_{CO2}	+3	-0.05	-0.047	-0.046
VOS_H	+0.1	-0.82	-1.15	-2.03
T_H	+0.1	+0.56	+0.73	+1.14
P_H	+0.1	-0.012	-0.026	-0.04
VOS_L	+0.1	+0.91	+1.24	+2.1
T_L	+0.1	-0.44	-0.60	-1.02
P_L	+0.1	+0.005	+0.005	+0.01
VOS_H + VOS_L	+0.1	+0.09	+0.10	+0.11
T_H + T_L	+0.1	+0.13	+0.13	+0.13
P_H + P_L	+0.1	-0.008	-0.019	-0.029

The table reveals that, in relation to the other parameters, an error in the CO_2 measurement doesn't contribute much to the overall error.

The largest contribution comes from the velocity of sound measurements **VOS_H** and **VOS_L** and the temperature measurements **T_H** and **T_L**. Important to notice are the opposite signs in the errors of both pairs of measurements. This implies that the influence of systematic errors in the VOS measurements due to calibration or offset is reduced significantly by performing both measurements with the same equipment, see **VOS_H + VOS_L**.

If the temperature measurements **T_H** and **T_L** are combined by keeping both the high and low pressure gas at the same temperature, the influence of systematic errors for this measurement is also reduced significantly, see **T_H + T_L**. Although the systematic errors in the pressure measurements **P_H** and **P_L** are at least an order of magnitude smaller their influence can be reduced as well by using the same calibration equipment and procedure for both pressure transmitters.

The table also shows that for smaller pressure differences between the velocity of sound measurements the error in the outcome increases. However, even for the lowest pressure difference of 20 bar / 490 psi the errors remain small for the combined measurements.

To eliminate errors due to analogue signal transmissions the internal communication between the different devices in the EnSonic is completely digital (RS232 or HART).

III.5   System setup

By taking the sensitivity of the input parameters into account the following optimal system setup has been realised, see fig 13. High pressure line gas, between 80 and 40 bar (1160 and 580 psi) is sampled from the main transport line and split in two separate flows of different pressure (40 and 3 bar / 580 and 43 psi). Both pressures are controlled by back-pressure regulators mounted downstream of the 'Double Velocity of Sound Cell' (2VOS cell) to reduce the upstream volume. The flows through the system are controlled by 3 metering valves of which 2 are mounted directly upstream of the 2VOS cell. Before the VOS measurements take place the high and low pressure gas flow through a heat exchanger integrated in the 2VOS cell to ensure that both gases reach the same temperature. The temperature of the body is measured using a Pt-100 temperature sensor and kept constant at 50 ± 0.005 °C (122 ± 0.009 °F) using a dedicated heating and control system. Part of the gas leaving the low pressure cell passes through the CO2 analyser via the third metering valve. Finally, the gas is vented into the atmosphere.
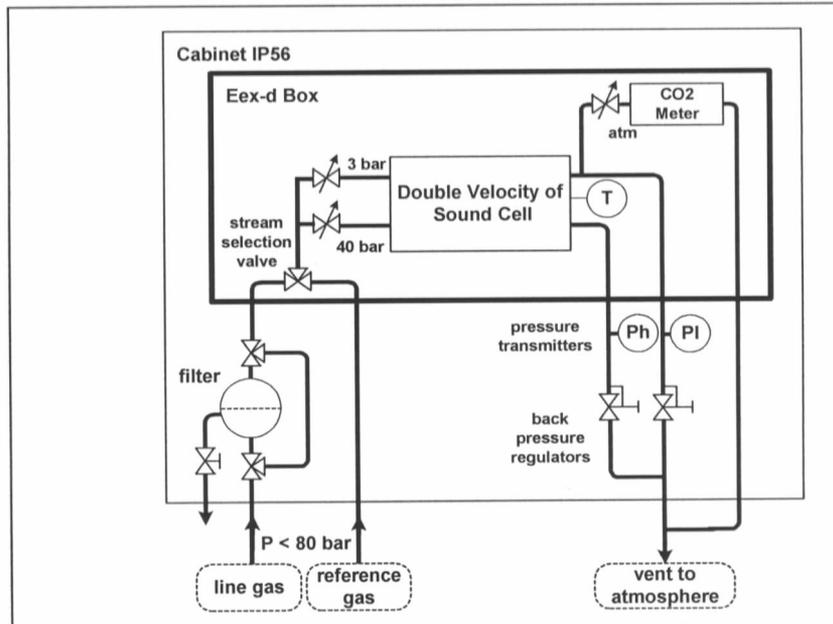

Fig 11   System setup

In addition to the basic measurement setup the system is equipped with:
   a) a stream selection valve which enables the selection between line gas and reference gas used during the auto-calibration of the system
   b) a coalescing filter for the line gas, this item is optional and is used in situations where liquids in condensed form may be present
   c) an IP56 housing to enable field installation and an Eex-d proof housing for the non-Ex components in the system
   d) (not shown) an optional M2000 flow computer which enhances the system with a display, digital and analogue outputs and remote control via digital inputs.

III.6   Performance

Field tests with a prototype and an EnSonic were performed at the Gasunie blending station Beekse Bergen in the south of the Netherlands, see figure 14.
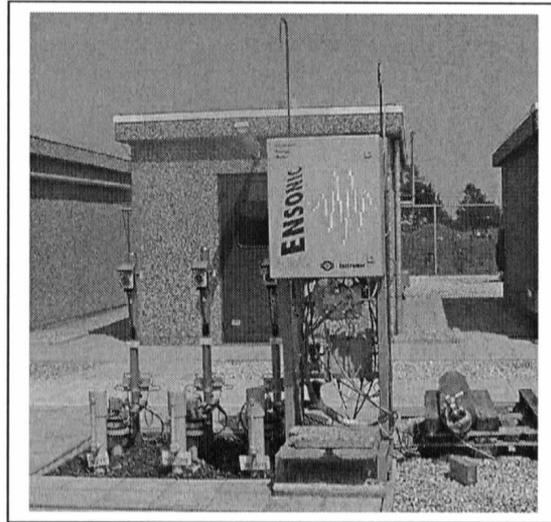

Fig 12   EnSonic at blending station Beekse Bergen

The EnSonic is installed directly on top of one of the main transport lines (burried) and gas is taken from the sample point directly to the left of the unit. On the right side of the unit a bottle with a single multi-component reference gas is visible which is used by the auto-calibration function of the system. The processed gas is vented to the atmosphere via the 2 pipes on top of the EnSonic.
The buildings in the background house the currently used Wobbe Index measuring systems requiring multiple reference gases, high purity compressed air and a climatic room. The reduction in operational costs when using EnSonics is obvious.

In table 2 the performance of the system during the field tests is presented. The numbers in this table were determined using 100 measurements during a short period (approx 100 sec) of almost constant gas composition.

Table II Performance of the EnSonic during field tests
at Beekse Bergen (Gasunie)

Parameter	Δ(Parameter) 2σ (%)	ΔH$_{SR}$ (%)
X$_{CO2}$	0.2	0.001
VOS_H	0.0015	0.02
T_H	0.003	0.003
P_H	0.01	0.001
VOS_L	0.001	0.015
T_L	= T_H	0
P_L	0.1	0.003
	ΔH$_{SR}$ (calculated)	**0.026 %**
	2σ of ΔH$_{SR}$ (measured)	**0.023 %**

The high accuracy and reproducibility of the results is obtained by using high quality transmitters with long calibration intervals. As shown by the data, the calculated and measured random error in the heating value **H$_{SR}$** are in good agreement with each other.

The resulting uncertainty in the calorific value is approximately ± 0.3% and the uncertainty in the density is less than 0.02%. To illustrate this a long and short term comparison between the EnSonic and the currently used Wobbe Index meter is presented in figure 15.
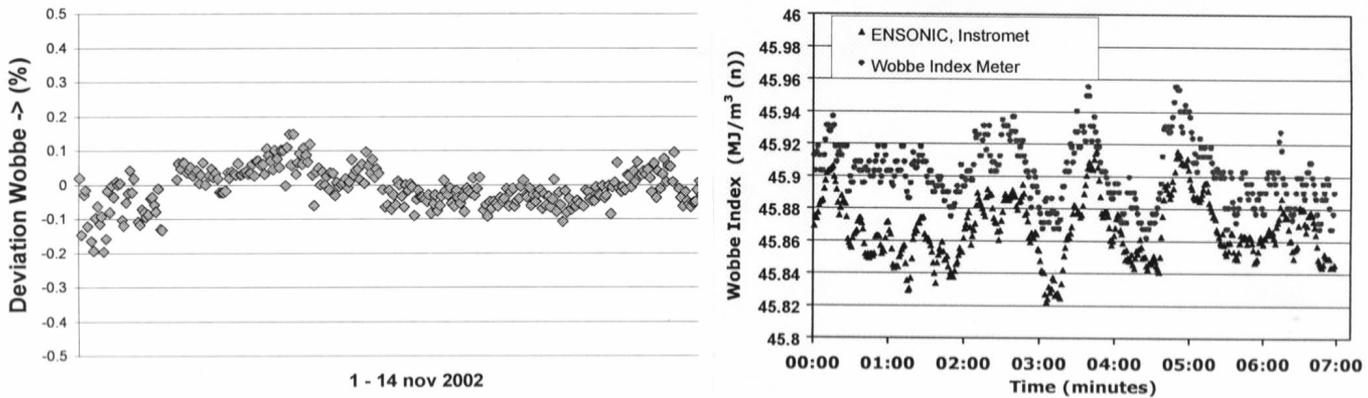

Figure 13 Long and short term comparison

While the long term comparison reveals a deviation of approx ± 0.1% over a period of 2 weeks, the short term comparison at the right illustrates that the EnSonic at least equals the currently used Wobbe Index meter in resolution and responsiveness.

Another example of an EnSonic application is the detection of the arrival of natural gas of different quality. To expand the natural gas distribution system in the main industrial area of the city of Rotterdam, part of the main transmission pipe line for high calorific gas had to be depressurized. A nearby pipe line for low calorific gas was temporary used for the transport of high calorific gas. An EnSonic was tested at the Gasunie station Rhoon and used to detect the arrival of high calorific natural gas during the displacement operation of low calorific gas. A fast and high resolution detection would eliminate the need for venting natural gas into the atmosphere during the transition from low to high calorific gas. Fig 16 perfectly shows the change in Wobbe Index during the arrival of the high calorific gas between 8:02 and 8:06.
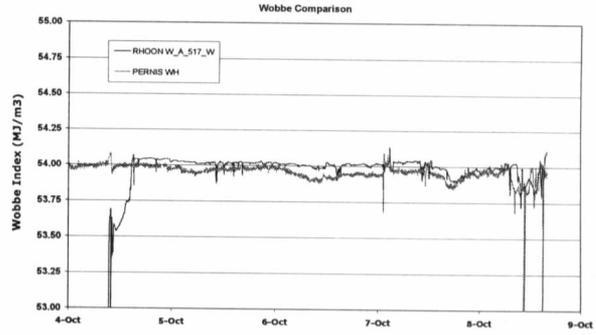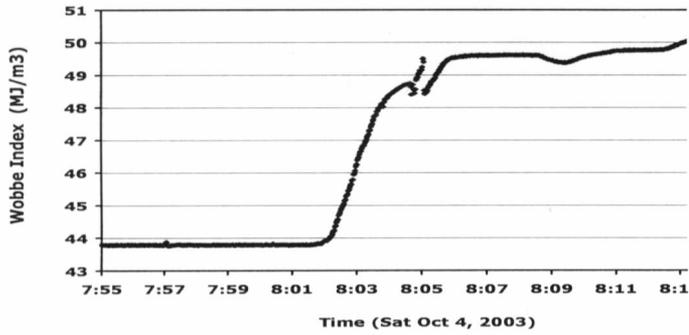
Fig 16   Measured Wobbe Index, station Rhoon

A longer term comparison of the measured Wobbe Index at Rhoon is given in the right figure, where a comparison is made with a Wobbe Index meter installed at Gasunie station Pernis nearby Rhoon. The arrival of the high caloric gas is still visible in the left part of the figure. The relative difference between the two meters is presented in figure 17.
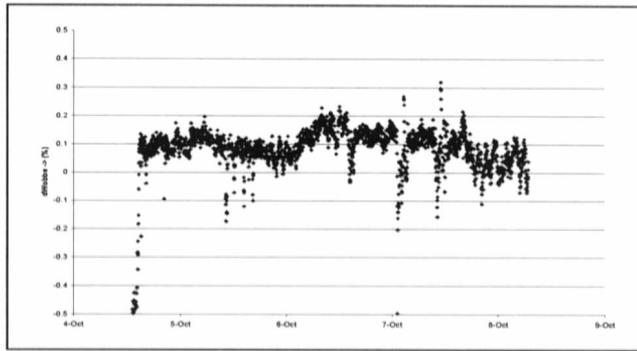

Fig 17   Wobbe deviation Rhoon - Pernis

Although the measurements were performed on different sites and possible time lags were not taken into account the difference between the Wobbe indices remains between 0.1% ~ 0.2%.
It should be mentioned that the complete installation of the EnSonic at Rhoon was completed within a few hours and that the unit has not been recalibrated since the start-up in the beginning of October.

III.7   Installation

The field installation of the EnSonic is illustrated using fig 18. The EnSonic cabinet and the bottle of reference gas are mounted as close as possible to the sample point where the high pressure gas is taken from the pipe. An optional skid can be used to facilitate the installation of the system.
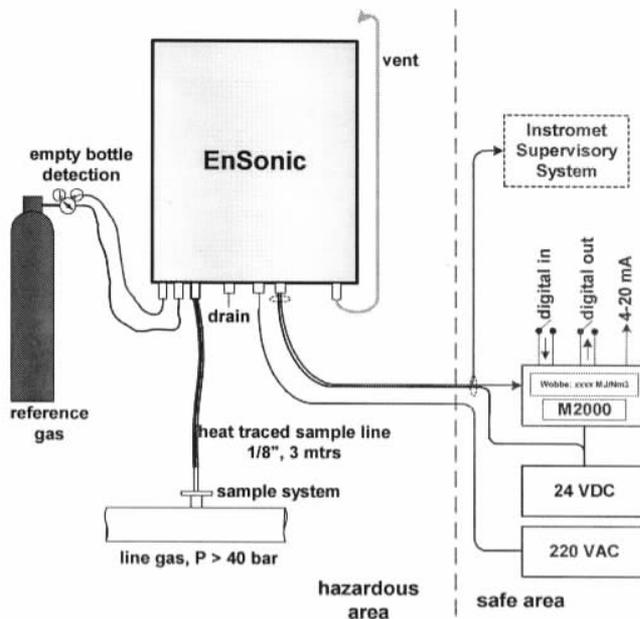
Fig 18   Field installation

Power for the main system (24 VDC) and the heated tracing (220/110 VAC) is coming from the power supplies mounted in the safe area. The measurement data from the EnSonic which is present on a MODBUS interface only can be handled in different ways. Conversion of the data is possible by installing an (optional) M2000 flow computer with a display, digital and analogue outputs and digital inputs. Other options are the use of an Instromet Supervisory System or a user supplied control system.

The calibration system capable of performing auto-calibrations at regular intervals is equipped with an empty bottle detection which prohibits auto-calibration of the system when no calibration gas is present. During operation the unit can externally be forced into calibration by writing to specific Modbus registers. When using an M2000 a digital input or a keyboard command can be used for this purpose.

4. Specifications

The following specifications are valid for the EnSonic system:
output update rate : approx. 1 sec

response time :	approx. 4 sec
input pressure :	40 – 80 bar (580 - 1160 psi)
output :	calorific value, compressibility, relative density, Wobbe Index
accuracy :	± 0.3% on calorific value and Wobbe index, ± 0.1% on density
gas consumption :	0.4 Nm3/h based on an update rate of 1 Hz (if the update rate is decreased the gas consumption decreases accordingly)
power supply :	24 VDC for the main unit; 220/110 VAC for the heated tracing
calibration :	remotely controlled or automatic with a programmable interval, one single bottle of a generic natural gas is required
remote diagnostics : and storage	all the data relevant to the measurements is available via the MODBUS interface for trending
ATEX certification :	pending

Acknowledgements

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