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Innovative MEMS gas property sensor (GPS) for advanced natural gas identification

White paper

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Determination of viscosity and density of natural gas mixtures

Introduction

Energy efficiency legislation has forced the conversion to intelligent electronic metering systems and smart grids. Increasing, classic volume-based gas meters are being replaced by smart gas meters. These often utilize thermal flow sensors, which allow for a more cost-effective and accurate measurement of gas consumption.

The increasing diversification of gas supply sources will lead to stronger fluctuations of gas composition. New gas fields with differing compositions of ingredients are being exploited (Figure 1). Natural gas contains a variety of calorific gases, primarily methane, and other varying amounts of alkanes, and sometimes a small percentage of hydrogen sulfide along with non-calorific gases such as carbon dioxide and nitrogen. The most important gas, methane, typically shows a proportion of 70 – 95 %, but this can go down to 25 %. The high fluctuations of natural gas compositions have a large impact on the accuracy of thermal flow sensors.

Component	Field Gas Source				Dry, Sweet Pipeline Gas
	Well Head A	Well Head B	Well Head C	Well Head D	
Methane	27.52	88.00	71.01	89.78	92.20
Ethane	16.34	6.40	13.09	4.61	5.90
Propane	29.16	8.50	7.91	2.04	0.30
i-Butane	5.37	0.67	1.68	0.89	0.00
n-Butane	17.18	0.00	2.09	0.00	0.00
i-Pentane	2.18	0.30	1.17	0.26	0.00
n-Pentane	1.72	0.00	1.22	0.00	0.00
Hexane	0.47	0.00	1.02	0.21	0.00
Heptanes and Heavier	0.04	0.00	0.81	0.00	0.00
Carbon Dioxide	0.00	0.04	0.00	0.00	0.00
Hydrogen Sulfide	0.00	5.40	0.00	0.08	0.00
Nitrogene	0.00	12.33	0.00	2.13	0.00

Figure 1: Examples of gas source compositions

Source: www.machinerylubrication.com/Read/344/natural-gas-compressors-lubrication

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The accuracy of thermal flow sensors depends on the thermal properties of this gas composition. To compensate for these variations, it is necessary to know the properties of the composition. Most gas fields show a certain signature of the mixed gases (Figure 2).

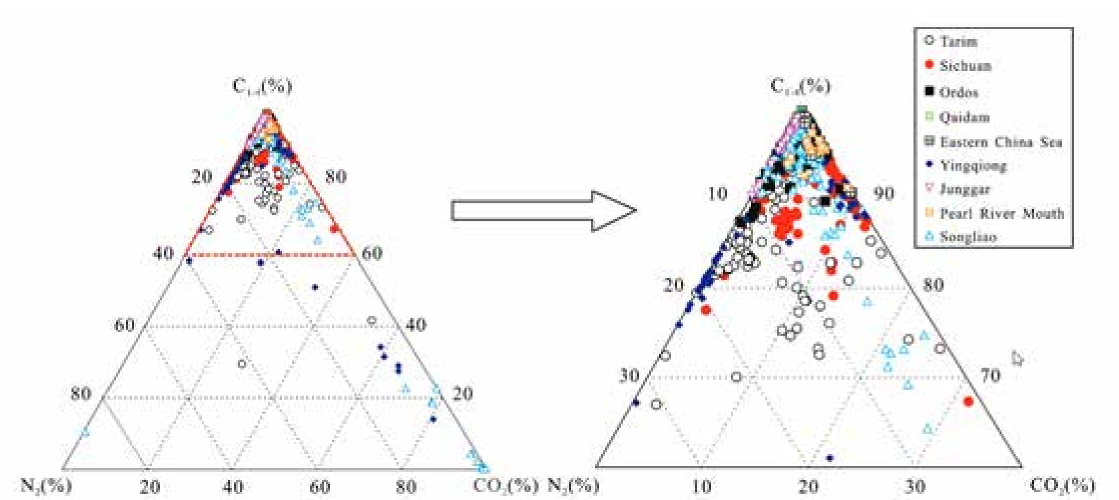

Figure 2: Clustering of gas fields

Source: journals.sagepub.com/doi/pdf/10.1260/0144-5987.32.4.635

Innovative gas property sensor (GPS) – Features and benefits

Thermal conductivity and thermal capacity are typically used to obtain information about the gas, but this is often not sufficient to provide adequate compensation. By measuring additional parameters, such as viscosity and density, it is possible to better identify the gas field of a given sample and to apply the appropriate compensation factors.

Therefore, the published patent GPS can be used to measure these parameters simultaneously for each device and allows the in-field compensation of thermal flow sensors without the need of complex calibration for certain gas compositions.

The GPS is integrated directly on the thermal flow sensor die and can thus be easily implemented into the application. Due to its innovative design and non-consuming technology, the GPS provides very fast (~20 ms per measurement), reliable, and long-term stable results. The miniaturized and highly integrated GPS with its very low power consumption in the range of a few milliwatts makes it ideal for mobile applications and dynamic real time measurements.

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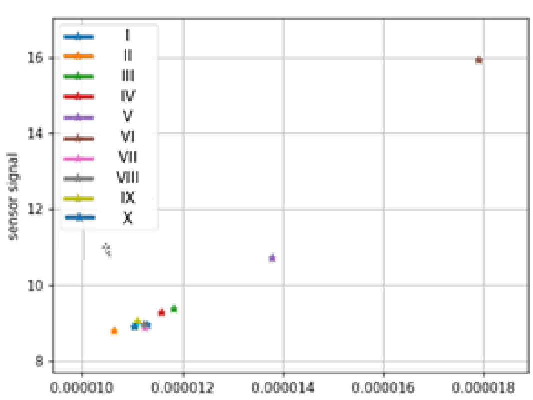
Gas sample analyses using GPS and their conclusions

To test the GPS for different natural gas compositions, 10 typical gas mixtures of up to seven components have been measured.

Figure 3 shows the composition of the gases and the calculated physical properties of density [kg/m3] and viscosity [µPa·s].

Gas	Component [%]							Density	Viscosity
	Methane	Propane	Isobutane	Butane	Hydrogen	CO2	Nitrogen	$[kg/m^3]$	[µPa· s]
I	100	0	0	0	0	0	0	0.68	10.75
II	87	0	13	0	0	0	0	0.83	10.26
III	80	0	6	0	0	14	0	0.92	11.39
IV	64	22	0	0	0	0	12	0.88	11.05
V	67	0	0	0	0	0	33	0.85	12.81
VI	0	0	0	0	0	0	100	1.18	17.34
VII	96	2	1	0	0	0.5	0.5	0.71	10.72
VIII	90.5	5	2	0	0	0.5	2	0.75	10.70
IX	87.5	9	2	0	0	1	0.5	0.77	10.56
X	90	5.5	2.5	0.5	0.5	0	1	0.75	10.57

Figure 3: Composition of sample gases



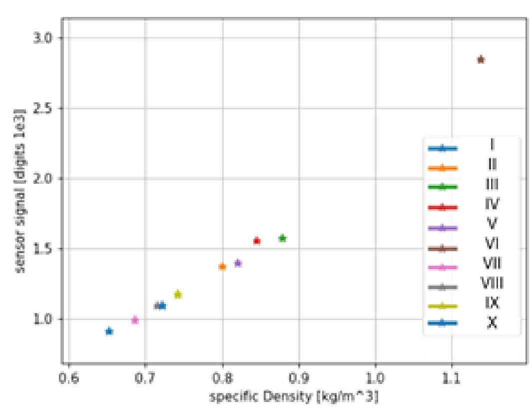


Figure 4: Measuring results of GPS

Figure 4 shows the measurement results of the published patent GPS. These results can be used to clearly identify gas sources and thus provide accurate flow measurement results. The GPS not only supports correct and reliable flow measurements, but it also supports determination of the heating value, i.e. the energy content of the gas mixture. The miniaturized GPS can be customized and is easy to implement in the application. It provides very fast, reliable, and long-term stable results and provides cost-effective alternatives to very complex gas analysis methods.

The advanced determination and distinction of combustion-relevant characteristics is important for many natural gas applications, such as advanced gas metering, improved regulation and operation of gas burners, motors and dual-fuel-engines, etc.