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Experimental evaluation of the performance of humidity analyzers in natural gas under industrial conditions

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ABSTRACT

The work reported is the continuation of the extensive comparison performed in controlled laboratory conditions using natural gas from the Spanish grid, as part of the European Metrology Research Project (EMRP) "Characterisation of Energy Gases" (ENG01-Gas, 2009). One of the outcomes of the project was the good performance of a laser absorption spectrometer with respect to other measurement technologies, in particular the absence of appreciable drift effects, exhibited by aluminium oxide (Al_2O_3) sensors that are traditionally used in the natural gas industry. The investigation was performed over a wide range of humidity content (13 ppm_v to 250 ppm_v) in ambient conditions of 23 °C ± 3 °C, at Enagás central laboratory in Zaragoza, Spain (Gallegos et al., 2015).

We report the subsequent comparison of two laser absorption analyzers, from different manufacturers, and a conventional Al_2O_3 installed on site in real industrial conditions, at an underground gas storage (UGS) and drying plant of Enagás in Serrablo, Spain. The performance of sensors is reported and discussed for all production stages of the plant (extraction, injection and shutdown), during which extreme ambient temperature values took place (from −15 °C up to 40 °C) and at line pressures up to 6.7 MPa. A purpose built sampling system was designed and constructed to accommodate the different instrumentation requirements and ensure an optimum metrological analysis.

The new results are compared with those previously obtained under more ideal laboratory conditions in the context assuring compliance with the contractual specifications that are to be met in Europe (EASEE-gas, 2005).

1. Introduction

The condensation behaviour of natural gas (NG) is one of the most important features to ensure its efficient and safe use. When water molecules are present together with other trace contaminants in the gas stream, namely H_2S and CO_2, these may react resulting in potentially corrosive acids in the pipeline (Carroll, 2009). On the other hand, one of the biggest problems in handling high pressure NG with a high water molar fraction is that, when the gas temperature decreases too, it can lead to hydrate formation. This phenomenon must be avoided not just for safety reasons, but also to minimise pumping costs due to load losses in the national supply grids and to avoid drastic decreases in the life expectancy of the pipeline and its components (Sloan, 1998; Avila, 1999; Mychajliw, 2002; Sloan et al., 2011).

There are not only compelling safety or economic efficiency reasons to consider humidity as a key parameter that must be monitored with high accuracy during the most important operations in any gas processing activity (Mokhatab et al., 2006). In addition to this there is the need to fulfil contractual obligations to control gas quality in international exchanges. In the case of the water dew point (WDP), the current specifications that have to be met in the transmission of natural gas within Europe have been defined by the European Association for the Streamlining of Energy Exchange - gas (EASEE-gas). According to this regulating body, WDP must be lower than −8 °C at 7 MPa or at the maximum pressure line (EASEE-gas, 2005).

Therefore, accurate humidity measurement and control is

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essential in the NG industry in order to maximise the performance of its processes. Metrology can play an important role in providing the necessary support to overcome some of the current challenges of this energy sector. Indeed, the need for research in this field has been identified by some of the most important international bodies in the field of metrology (BIPM, 2007; EURAMET, 2008). The target to offer support to achieve the actual industrial challenges is also outlined in the European roadmap for humidity and moisture measurement (Bell et al., 2008). This is further justification for the cooperation between Instituto Nacional de Técnica Aeroespacial (INTA) and Enagás, as the Designated Institute (DI) responsible for the Spanish National Humidity Standards and as the technical manager of the Spanish gas system and main transmission system operator of natural gas in Spain, respectively. This collaboration initially was focused in an extensive comparative performance of diverse humidity sensing techniques in natural gas under semi industrial conditions (Gallegos et al., 2015). This activity was part of Joint Research Project (JRP) “Characterisation of Energy Gases” running under the EMRP (ENG01-Gas, 2009). The comparative study of humidity sensing techniques has shown to be of increasing relevance to the NG community, as shown by the work of other researchers, such as Løkken (Løkken, 2012a).

The work reported in this paper, extends the results obtained in laboratory conditions to those obtained in the field, consistent with the further work suggested at the conclusion of the EMRP project in view of to the good results shown by one of the newest humidity sensing techniques, absorption spectroscopy (Gallegos et al., 2015). Nowadays, this technology is acquiring great importance not only as a laboratory analytical technique, but also at industrial level, including the energy sector. Thus, it is of interest to the gas industry and manufacturers of humidity analyzers to have direct independent information on the behaviour of the technique under real industrial conditions compared to the most commonly used, Al_2O_3 sensors. The main differences between the initial investigation carried out in the EMRP project and the new work described in this paper have been summarized in Table 1.

The dehydration method used by the facility chosen uses triethylene glycol (TEG). This system has gained nearly universal acceptance as the most cost effective of the glycols due to many factors as: superior dew point depression, lower operating cost and reliability (Polák, 2009); TEG exhibits ease of regeneration and operation, minimal losses of drying agent during operation, high affinity for water, chemical stability, high hygroscopicity and low vapour pressure at the contact temperature (Anyadiegwu et al., 2014). For these and many other reasons, TEG dehydration is the most used worldwide compared to other methods such as activated alumina, silica gel or zeolite molecular sieves (Mohamad, 2009).

In this paper we present the results obtained using two humidity sensing technologies in NG and compare their performance in all production phases of the drying plant in an annual production cycle.

2. Experimental set-up

Natural gas dehydration is closely linked to storage of natural gas for two basic reasons: firstly, from a point of view national strategic reserves to reduce dependency on NG supply; and secondly, to deal with increases in energy demand in short-term peaks, and during winter periods to satisfy heating demand. The most advantageous option for storing large volumes of gas are the underground gas storages (UGS) (Netušil and Ditl, 2012). In this particular case, the industrial facility chosen to carry out this work was the Enagás UGS of Serrablo (Spain), close to the Pyrenees, which is equipped with a TEG NG dehydration plant with a daily treatment capacity up to 7.5 $NMm^3\ d^{-1}$. It was the first gas field reconverted to UGS in Spain at the end of its exploitation in 1989, so the ground properties were ideal for reuse as a strategic storage. Today, there are six productive wells connected to two independent reservoirs with a total volume of 1.1 NGm^3 (Enagás, 2010).

The pressure inside the storages increases as the gas is being injected, up to values close to 19 MPa, however the usual pressure values inside of the main lines of the national distribution grid are around to 7 MPa. Thus, this kind of facility must be also associated with a pumping system to inject the gas into the wells, and an expansion system when the gas is extracted. Another reason for which this facility was chosen, was that it receives NG from regasification plants of liquefied natural gas (LNG) and from international exchanges via the national grid. Thus, the water content of NG must be very closely controlled at these points to be able to reduce the humidity locally in the case of a problem being detected at any point of the grid.

2.1. Description of measurement instruments

As it has been already mentioned, in this work we compare the performance of instruments using two humidity sensing techniques: Al_2O_3 capacitive transmitters and absorption spectroscopy analyzers. The first is used globally in the natural gas industry, and the latter is an extension of a promising technology used in countless sensing applications in other gases.

The Al_2O_3 capacitive sensor evaluated was a Panametrics-MIS II, manufactured and sold by General Electric (GE), already installed in the plant and used by Enagás after the last drying stage before delivery of NG to the national grid when the facility is operating in extraction mode. This sensor has a heated sampling box that includes the simple glass bead filter. The sensor has a built-in pressure sensor to express the humidity in WDP directly. Enagás' logging system records one value every hour throughout the year. Another instrument, provided by GE, was an Aurora spectroscopic analyzer, of the same model as an instrument whose performance had already been evaluated successfully in semi-industrial conditions in the previous work (Gallegos et al., 2015). The third instrument was a spectroscopic analyzer, OptiPEAK TDL600,

Table 1
Differences between the comparative study previously performed under semi-industrial conditions (Gallegos et al., 2015) and the study reported here in industrial conditions.

	Semi-industrial conditions[a]	Industrial conditions
Ambient temperature, °C	23 ± 3	−15 to 40
Relative humidity, %rh	25–63	Up to saturation
Pressure line, MPa	0.45; 2.8; 5.8	3.4–6.7
Water vapour fraction, ppm_v	13–250 (at 11 levels)	4–350
Instruments compared	11	3
Humidity sensing techniques studied	Absorption spectroscopy, polymeric, electrolytic P_2O_5, Al_2O_3 capacitive, condensation, microwave resonator[b]	Absorption spectroscopy Al_2O_3 capacitive
Properties analyzed	Response time, drift, hysteresis, response to pressure changes.	Relative dynamic performance, drift and influence of contaminants.

[a] Process variables controlled using humidity generator and heated pressure regulator.
[b] Reported by Gavioso et al. (Gavioso et al., 2014).