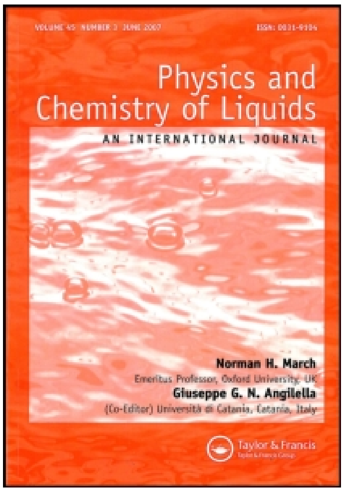

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DEW POINTS OF BINARY NITROGEN+WATER MIXTURES

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Experimental measurements of dew point for binary nitrogen + water were carried out between $5.0\,10^5$ Pa and $100.2\,10^5$ Pa and temperatures from 263.0 K to 283.7 K. The experimental method is based on the generation of wet gases by water condensation in two temperature-controlled condensers with continuous gas flow at specified pressures.

Keywords: Vapour-liquid equilibrium; Dew point; Nitrogen + water; Condensation; Natural gas

1. INTRODUCTION

Nowadays, there are several supplies of natural gas in Europe, one of them direct imports from Algeria through the Magreb–Europe gas pipeline. Previously, most imports were carried out as liquefied natural gas (L. N. G.). L. N. G. contains nitrogen, methane and other light hydrocarbons, which rarely have more than six carbon atoms. The natural gases import through gas pipeline however can reach a content of heavier hydrocarbons of 0.3% and water contents of $65\,10^{-6}\,\mathrm{kg\,m^{-3}}$(n). This fact introduces, on the one hand, risks of

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condensation in pipes, and on the other, the undesired formation of ice or hydrates and the corrosion of the pipes or blockages during the transport.

In order to know the behaviour of vapour-liquid equilibrium of the natural gas, an experimental device was built up and tested in a previous work [1]. In the present work, it is studied the binary nitrogen + water system in the usual temperature and pressure ranges in natural gas transmission pipelines.

Experimental dew points of several binary nitrogen + water mixtures between 5.0 10^5 Pa and 100.2 10^5 Pa and temperatures from 263.0 K to 283.7 K are presented here.

2. EXPERIMENTAL

2.1. Gases

Air Liquide supplied the gas, nitrogen with a purity of 99.999%, which was verified by chromatographic analysis.

2.2. Apparatus

The experimental method used for this work is based on the generation of wet gases by water condensation in two temperature-controlled condensers with continuous gas flow at specified pressures. The dew point generation apparatus used for our experimental data generation (Fig. 1), was built up and tested in a previous work [1]. The water concentration in the gas is measured at the outlet of the moisture generation system, using a Karl Fischer titration [2] that is carried out at atmospheric pressure, according to the standard method ISO 10101/3 [3]. By doing so, a water content reference value of the gaseous phase is obtained. The dew point values are measured by means of a chilled mirror instrument [4]. The chilled mirror instrument input pressure is the same as in the moisture generation system, when the apparatus reaches a stable value of dew temperature, both pressure and temperature are recorded. In this way the values of the pressure and temperature of the dew points of wet gas generated are obtained.

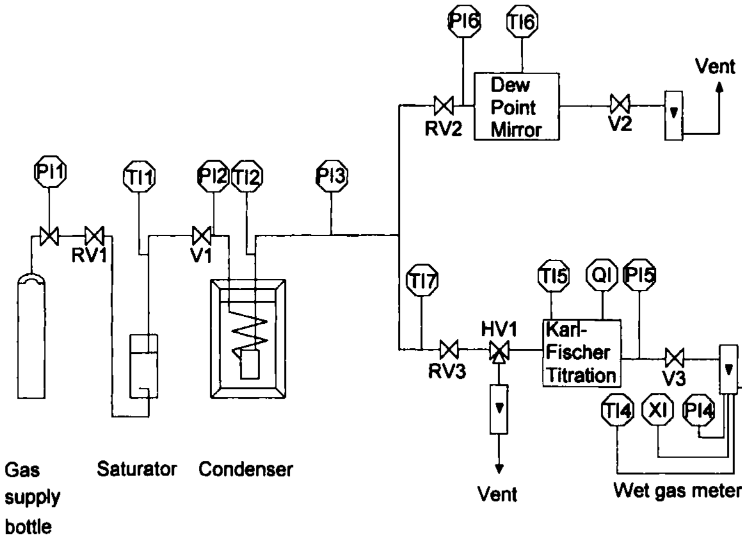

FIGURE 1 Scheme of the experimental apparatus used in this work. RV: Control valve; V: Ball valve; HV: three ways valve; TI: Temperature measurement; PI: Pressure measurement; QI: Coulometric measurement; XI: Volume measurement.

The instrumentation used for water content and dew point measurements is the following:

- Mitsubishi CA 06 Karl Fischer Titrator, coupled with an Elster wet gasmeter Type Gr. 00, E51, 0.2% accuracy.
- MBW dew point instrument Mod. DP3-D. A Peltier-cooling unit achieves the cooling of the mirror with automatic mirror check device. The uncertainty on the dew temperature is better than ± 0.4 K.
- Pressure transmitter with a maximum error of 0.2% in the calibrated range.

Prior to this study of nitrogen + water dew points, the performance of both analysis methods and experimental procedures was determined [1]. Repeated analysis of water content of one standard nitrogen + water mixture prepared by Air Liquide were carried out in order to evaluate the experimental error of the analysis of water content. The measured values were equal to the standard water content within a rejecting percentage of 0.05% [5]. Repeatability and reproducibility of Karl Fischer titration of this standard nitrogen + water mixture were calculated according to ISO 5725 [6]. The values obtained were 0.76

10^{-6} kg m^{-3}(n) and 1.68 10^{-6} kg m^{-3} (n), respectively. These values are much better than those allowed by ISO 10101 [3].

Repeatability and reproducibility of water dew point generation were calculated according to ISO 5725 [6] after repetitive measurements. The results obtained in the performance evaluation were 3.64 10^{-6} kg m^{-3} (n) and 8.90 10^{-6} kg m^{-3} (n) respectively. These values are much better than those permitted by ISO 10101 [3]. Reference conditions for volume are 273.15 K and 1.01325 10^5 Pa. The test was achieved on a water dew point of 263.15 K and 60 10^5 Pa in pure nitrogen.

The reliability tests results are taken as consistency criteria: the maximum acceptable standard deviation of measurements is derived from the repeatability value, and the maximum acceptable discrepancy with measurements from external laboratories is derived from the reproducibility value.

2.3. Results and Comparison with Literature Data

The water content in the vapour phase and the dew points of the mixtures generated at the moisture generation system were determined and the results of the experiments are collected on Table I.

In Figure 2 the experimental values of water content are represented. As it can be seen in Figure 2, an increase of water content

TABLE I Experimental dew point temperatures and pressures and water contents (ρ) for binary mixtures nitrogen + water

TI K	*PI* 10^5*Pa*	ρI 10^{-6} $kg\,m^{-3}(n)$	*TI* K	*PI* 10^5 *Pa*	ρI 10^{-6} $kg\,m^{-3}(n)$
263.1	99.8	32.1	263.3	40.0	55.3
268.0	100.2	37.0	268.5	40.1	68.7
272.9	99.8	41.2	273.0	40.0	117.6
278.1	100.0	58.3	278.3	40.0	188.4
283.5	100.0	110.6	283.3	40.0	244.9
262.3	80.0	33.9	263.0	14.9	129.7
268.2	80.0	41.7	268.0	15.0	205.5
273.1	79.9	48.9	273.1	15.0	269.6
278.2	80.1	102.8	278.3	15.0	391.2
283.8	80.0	120.8	283.1	15.0	575.3
263.1	60.0	42.0	263.2	5.0	324.4
268.5	60.0	50.1	268.1	5.0	507.3
272.9	60.0	78.2	273.6	5.0	745.7
278.3	59.9	141.2	278.7	5.0	1072.9
283.7	60.0	159.2	283.4	5.0	1632.0

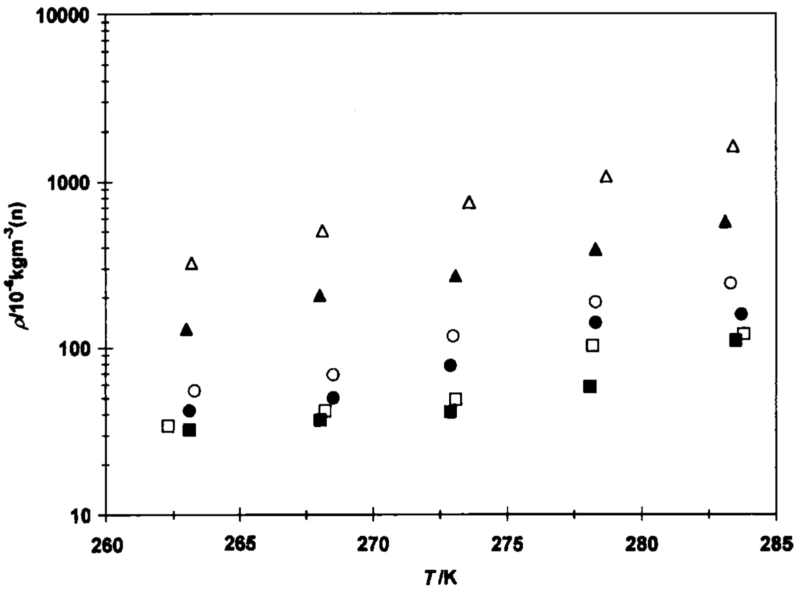

FIGURE 2 Experimental water contents (ρ) for the system nitrogen + water: ■, $P=100\ 10^5$ Pa; □, $P=80\ 10^5$ Pa; •, $P=60\ 10^5$ Pa; ○, $P=40\ 10^5$ Pa; ▲, $P=15\ 10^5$ Pa; △, $P=5\ 10^5$ Pa.

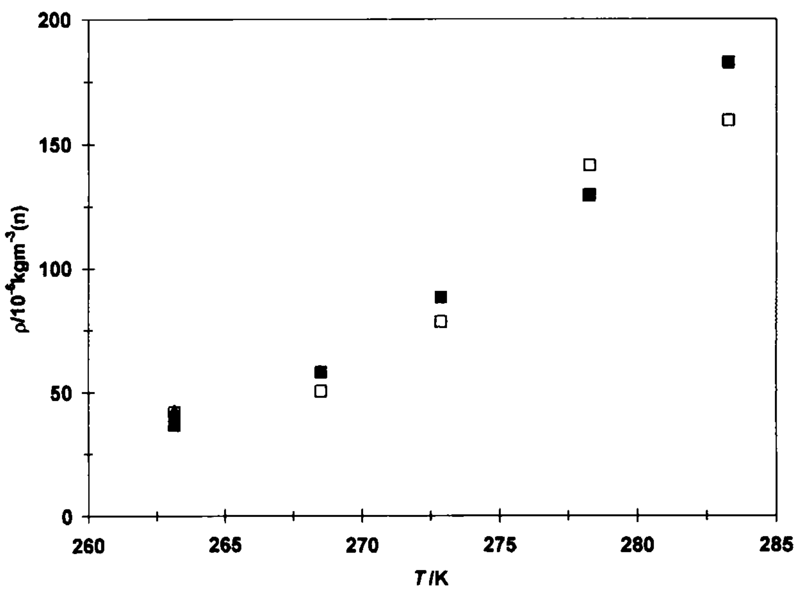

FIGURE 3 Comparison between experimental water contents (ρ) obtained in this work (■) at 60 10^5 Pa, and from the literature: Bogoya *et al.* [7] (□) and Le Nöe *et al.* [8] (▲).

of the system mixtures shows a displacement of the dew points to higher values of dew temperatures for constant dew pressure, and to lower values of dew pressures for constant dew temperatures.

The values of dew points obtained in this work at $60\,10^5$ Pa and those from the literature [7, 8] are represented in Figure 3. Except for the dew points corresponding with 278.3 K and 283.7 K, the differences between the values of water content obtained in this work and those from literature [7, 8] are lower than the reproducibility value of experimental data presented in this paper.

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