Experimental Determination of Water Content of Sweet Natural Gas with Methane Component Below 70%

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Abstract— Majority of the experimental data for water content of natural gas had always been based on gas composition with methane component greater than 70%. However, some low pressure natural gases can have a methane component less than 70%. This study therefore, was on measuring the water dew point of sweet natural gas with methane component less than 70 %. To achieve this, natural gas samples were collected from several oil and gas locations in the Niger Delta region, in accordance with ISO 10715. An experimental set up was designed for use with a chilled mirror dew point meter. On performing the experiment, the water dew points were measured and the water contents estimated using appropriate correlations, attached to the dew point meter. The water contents were then validated with a modified version of the Soave Redlich Kwong (SRK) equation of state and the Peng Robinson equation of state suite of the proMax software. The result showed a maximum percentage average absolute deviation (% AAD) and standard deviation (SD) of 11 and 12 respectively. It was also observed that the measured dew point temperatures and water contents of the gas samples in this study were relatively the same, at same pressure, with those with methane component greater than 70%.

Index Terms — Equation of state, gas composition with methane component below 70 %, Water dew point, Water content

1 Introduction

Natural gas always contain a certain amount of water as an impurity at all conditions. It is normally saturated with water inside oil and gas reservoirs in different amounts depending on the prevailing upstream conditions. If not removed, water in natural gas (either liquid or vapour) can result in various equipment failures leading to incessant plant shut down [1]. Some problems that may arise as a result of the presence of water in natural gas include:

1. Gas hydrates formation which may block pipelines, process equipment and instruments.
2. Liquid loading in gas wells.
3. Corrosion of materials in contact with natural gas and condensed water.
4. Reduction in gas well productivity up to 20 % [2].

Water content assessment and evaluation is very crucial to designing and selecting the proper conditions and equipment required for an effective and efficient natural gas dehydration process. Accurate measurement and estimation of water content in natural gas is highly imperative to the gas industry. Therefore, experimental data is crucial for successful development and validation of models used for predicting the phase behaviour of water – natural gas systems.

Most studies on water content of natural gas have been mainly on binary gas mixtures [3], [4]. Only a few authors have reported water content data for real natural gases [5], as majority of the studies have been on synthetic gases [6], [7]. Also, very limited experimental information have been reported in literature for water dew point and water content of natural gas composition having a methane component less than 70 %.

For the studies on water content of lean sweet natural gas, the gas composition for the majority of the gases used had a methane mole component of over seventy percent (70 %), [8]. Hence most of the charts and correlations were developed to estimate the water content of sweet natural gas with methane component of more than seventy percent (70 %). Could sweet natural gas with methane component less than 70 % contain more water than anticipated? Can the available correlations and charts give accurate predictions knowing that they were mostly developed with experimental data having a methane component greater than 70 per cent?

Due to these pertinent questions, new experimental data required to accurately predict water content of sweet natural gas with low methane component (< 70%) is imperative. This would allow for the validation of existing correlations and charts in predicting water content of these gases.

2 Materials and Methods

Natural gas samples were obtained from seven (7) oil and gas locations in the Niger Delta region of Nigeria. Four (4) of these gas samples had methane components less than 70 %. Giving that the dew points and water content of natural gases with methane component greater than 70 %, can be easily obtained from the McKetta & Wehe Chart with good accuracy; Three (3) additional gas samples with methane component greater

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than 70 % were collected for use as reference or control. This was done in order to

1. See how accurate the experimental set - up was, in the measurement of natural gas dew point temperatures.
2. Ascertain whether natural gases with methane components less than 70 %, contained more or less water.

The sampling procedure was done according to ISO 10715. The samples were collected in a 6,000 cc pressurised sampling bottle and taken to the laboratory for compositional analysis. The gas chromatograph (GC) Hewlett Packard 6890 model was used in performing the compositional analysis. The compositional analysis and uncertainty of quantification of the components was done in accordance to ISO 6974 and ISO 6076. The compositions of the natural gases used in this study are given in Table 1.

The chilled mirror dew point device was chosen because of its availability, high precision, high stability and good speed of response [9]. Three stainless steel cylinders were immersed in a temperature controlled water bath filled with water. Two (2) of the steel cylinders contained about 5 ml of distilled water (Moisturizers) while the third was left empty (Entrained water droplet collector). The flow line inlet was connected to the gas sample cylinder, while the outlet was connected to the Chilled mirror dew point tester, where the water dew point of the gas samples was measured, Figure 1.

A = Gas Cylinder, B = Pressure Regulator, C = Valve, D = Water Bath. , E = Stainless Steel Pipe, F = Distilled Water, G = Stainless Steel Cylinder (Moisturizer). H = Stainless Steel Cylinder (Entrained Water Droplet Collector), I = Water and J = Chilled Mirror Dew Point Meter.

The gas samples were first heated to temperatures above the sampling temperature using an electric heating tape to maintain a single gas phase during analysis. . For each gas sample, the pressure was set at the opening pressure and then reduced in a step wise manner depending on the opening pressure inside the gas cylinder, until a final pressure was attained. For each set temperature of the water bath, the pressure was varied from the opening pressure of the gas cylinder and the dew point of the gas measured and recorded.

As the gas flowed in the rig set up, it entered the first moisturizer. The pressure of the gas allowed for mixing of water and the gas at that temperature. Only saturated gas with water vapour left the first moisturizer and entered the next cylinder (second moisturizer). This was so because the second moisturizer acted as the final process of moisturizing the gas so that any gas leaving the second container was saturated with water vapour at that temperature and pressure. The third cylindrical container was left empty (free of water).

TABLE 1
NATURAL GAS COMPOSITIONS

	C_1<70%				C_1>70%		
Composition	NG1	NG 2	NG 3	NG 4	NG 5	NG 6	NG 7
C_1	63.37	66.12	61.25	62.16	83.77	86.88	86.90
C_2	13.51	11.86	15.86	12.19	8.11	7.31	7.36
C_3	8.63	7.35	8.87	7.58	3.88	3.20	3.17
n- C_4	4.60	3.36	2.36	4.73	1.19	0.78	0.77
i- C_4	3.40	1.89	1.77	3.67	0.92	0.65	0.64
n-C_5	1.50	0.93	0.89	1.88	0.29	0.16	0.16
i-C_5	1.90	1.9	1.94	1.82	0.47	0.29	0.25
C_{6+}	2.10	1.87	1.10	0.19	0.08	0.04	0.04
C_{7+}	-----	-----	------	------	0.04	0.02	0.02
CO_2	0.85	2.58	1.82	1.63	1.21	0.64	0.65
N_2	0.14	2.14	4.14	4.15	0.03	0.03	0.03

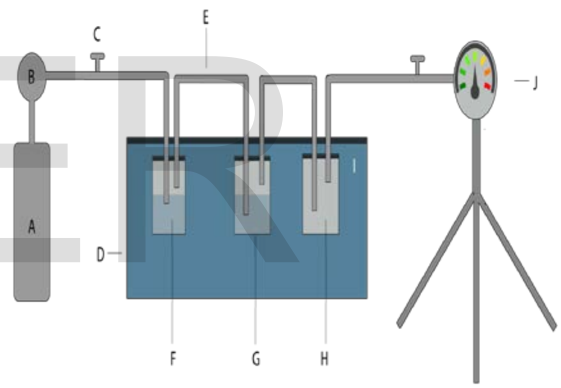

Fig 1: Schematics of Experimental Set- Up

This was because saturated gas leaving the second container (moisturizer) might contain entrained water droplet which might give erroneous dew point temperature readings, when allowed to get to the dew point meter (for measurement), without removing the entrained water droplets. To avoid this, the third container was kept empty to collect any entrained water droplet that remained in the flowing gas leaving the second moisturizer. Dew point measurements were taken at selected pressure readings for each gas sample. The experiments were conducted in the open only on sunny days (ambient temperature of 33 ^{0}C). This was in order to get accurate dew point temperature readings and avoid hydrate formation. The measured dew point temperatures were then converted to water contents using the specialized correlation (chart) attached to the Bureau of mines dew point tester device. For accuracy the measurements were done three (3) times and the average of the three (3) readings were recorded. The measurement and calculated uncertainties are stated in the next section. Table 2 gave the experimental water dew point temperatures and water contents of the natural gas samples NG 1 to NG 7. All seven natural gas samples had three (3) experimental readings corresponding to three (3) different pressure values except sample NG 3 with only two (2) points. This was because this gas sample had a low opening pressure of 184 psi and thus only one more additional pressure value was considered.

2.1 Experimental Uncertainty

The temperature reading (and thus the recorded dew point temperature), had a measuring uncertainty of ± 0.5 °C
The pressure readings had an uncertainty of ± 1 psia.
The estimated Water Content had an uncertainty of ± 2 lb/MMSCF.

3 Results and Discussion

From the results of water dew point and water content obtained for all the samples considered in this study, the water dew point temperatures were in the range of 10.5 to 18°C, while the water contents were in the range of 35 to 130 lb/MMSCF. The lowest dew point and water content corresponded to the lowest pressures and vice versa. The results in Table 2 also showed that water dew points and water contents were the same for any two or more gas samples with approximately the same pressure, irrespective of whether the methane component was less or greater than 70 %.
For the reference or control gas samples (NG 5 to NG 7), the % AAD of experimental and McKetta & Wehe Chart (water dew points and water contents), was 2.5% and 4%, respectively.

As a result of their high accuracy in handling natural gas with a wide range of composition, temperature and pressure, two Equations of state (EoS) [10] ; and [11] of the ProMax software; were chosen as standards for validating the experimental water content results in Table 2.

On comparing the results of the EoS's, with those from experiments (Figures 2 to 8), it was observed that the trends of experimental water content followed that of the modified SRK and ProMax predictions with reasonable accuracy.

TABLE 2
Experimental Water Dew Points and Water Contents.

Samples	Pressure (psia)	Dew Point (°C)	Water Content (lb / MMSCF)
NG 1	377	16	38
Opening Pressure = 377 psia	152	12	70
	73	11	130
NG 2	436	17	36
Opening Pressure = 436 psia	179	13	65
	73	11	130
NG 3	184	13	65
Opening Pressure = 184 psia	64	11	128
NG 4	274	14.5	52
Opening Pressure = 274 psia	168	12.5	66
	76	10.5	128
NG 5	465	18	40
Opening Pressure = 465 psia	275	14	50
	76	11	120
NG 6	425	17	35
Opening Pressure = 425 psia	264	14	50
	156	12	77
NG 7	324	15.5	43
Opening Pressure = 324 psia	166	12.5	75
	73	11	120

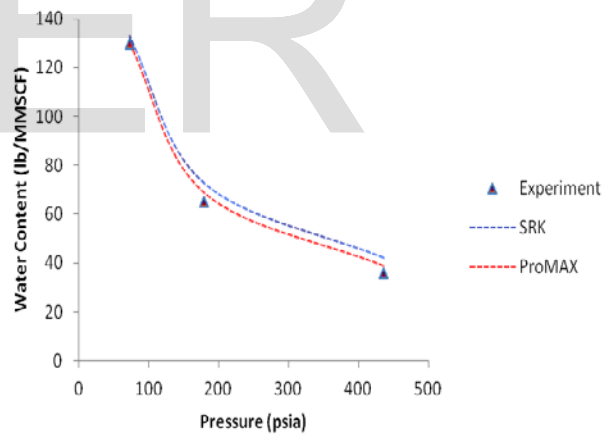

Fig. 2: Water Content Comparison for NG 1

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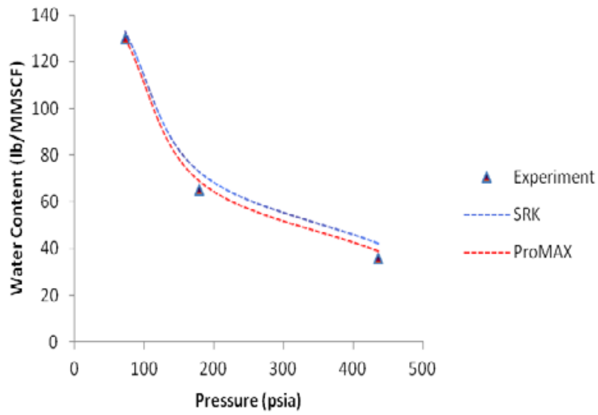

Fig. 3: Water Content Comparison for NG 2

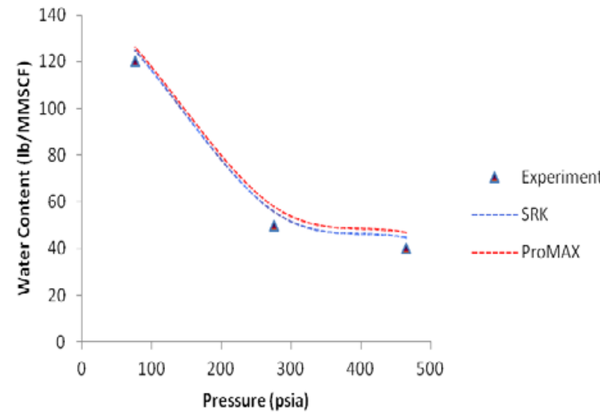

Fig. 6: Water Content Comparison for NG 5

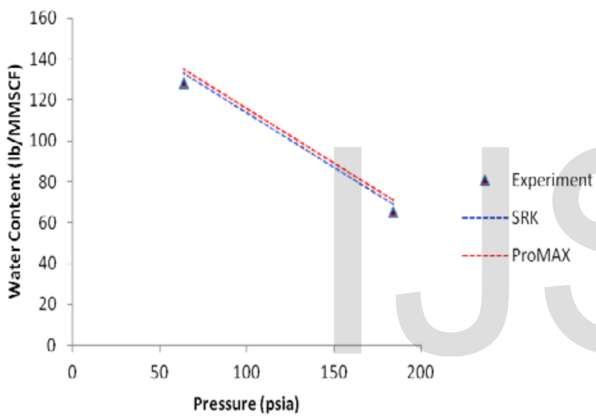

Fig. 4: Water Content Comparison for NG 3

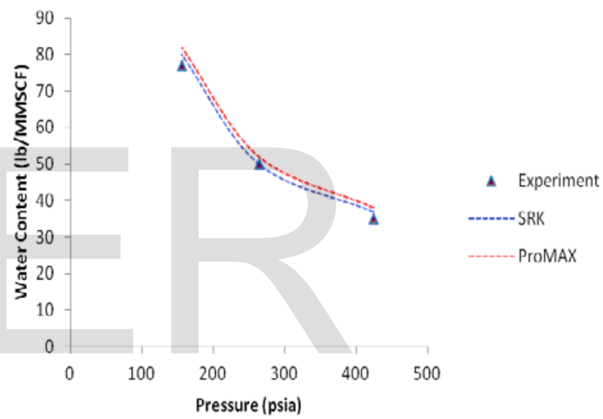

Fig. 7: Water Content Comparison for NG 6

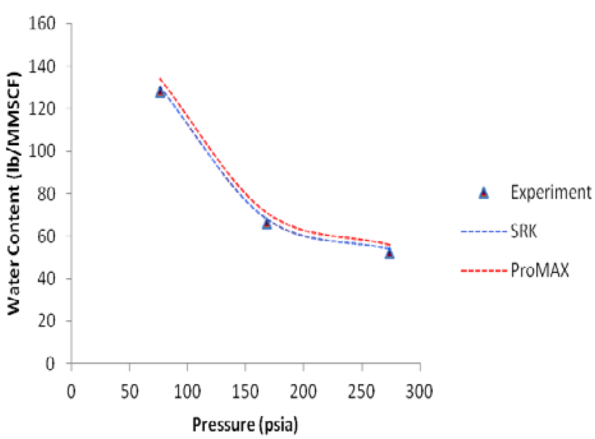

Fig. 5: Water Content Comparison for NG 4

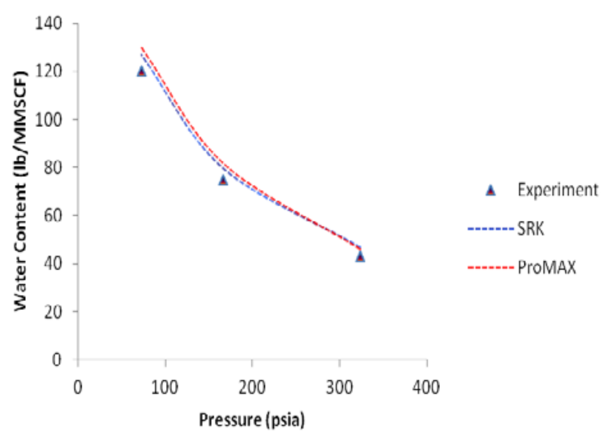

Fig. 8: Water Content Comparison for NG 7

In order to ascertain the error margins between the water contents predicted by the modified SRK EoS by Twu *et al*. (1995) and ProMax as against the experimental values, two statistical measures of dispersion were used. They include:

1. **Percentage Average Absolute Deviation (*%AAD*):** Mathematically, the percentage average absolute deviation is given as;

$$\% AAD = \frac{1}{N}\sum_{i=1}^{N}\left|\frac{W_{Exp} - W_{Calculated}}{W_{Exp}}\right| \times 100 \qquad (1)$$

2. **Standard Deviation (*SD*):**

Mathematically, the standard deviation is given as;

$$SD = \sqrt{\frac{1}{N}\sum_{i=1}^{N}\left[\frac{W_{Exp} - W_{Calculated}}{W_{Exp}} \times 100\right]^2} \qquad (2)$$

Where N = number of data points and Exp = Experiment, W=Water content.

Table 3 show the results obtained from the error analysis. It indicated that the water content of the gas samples studied had a maximum average absolute and standard deviations of about 11 and 12 respectively, and a minimum of 5.2 and 5.8 respectively.

4 Conclusion

1. The experimental set up in this study has been used *to* measure the dew point temperature of sweet natural gas with methane component less or greater than 70 %, with reasonable accuracy.
2. New water dew point and water content experimental data have been produced for natural gas with a methane component less than 70 %.
3. The dew point temperatures and water contents of sweet natural gas with methane mole fraction < 70 % were found to be the same as those with methane mole fraction greater than 70 %, at same pressures.

TABLE 3
Error Analysis of SRK and ProMAX versus Experimental Water Content.

	SRK		ProMAX	
Sample	% AAD	SD	% AAD	SD
NG 1	10.4	11.9	6.2	7.4
NG 2	10.5	11.3	9.1	9.5
NG 3	9.8	10	9.8	10
NG 4	6.7	7.6	11.6	11.7
NG 5	10.8	11.2	10.8	11.2
NG 6	5.2	5.8	6.1	6.7
NG 7	10.9	11.9	10.9	11.9

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