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A Short Review about Predicting the Dew Point Pressure for Gas Condensate Reservoirs by Empirical Correlations

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Abstract: **The following essay compiles different correlations found in the literature to determine the dew point pressure of gas condensate reservoirs. An evaluation and comparison study of these methods is performed for 150 gas samples from different regions and literature sources. The tested models were: Shokir, Nemeth-Kennedy, Elsharkawy, Ahmadi, Kamari and Okpo Nnadozie. The before mentioned models were chosen because they are function of reservoir temperature, gas composition, molecular weight, and specific gravity of the heavy component (C7+). The best model representing the dew points pressures of the 150 gases samples in this study was statistically determined.**

Keywords: **Reservoir temperature, dew point pressure, gas composition, molecular weight, specific gravity, retrograde condensation, gas condensate, heavy components.**

I. INTRODUCTION

In gas condensate reservoirs, well-productivity often declines rapidly when near-wellbore pressure drops below the dew point pressure. Radial compositional-reservoir simulation models show that liquid dropout around wellbore causes the productivity decrease. This ring of condensate around the wellbore reduces effective permeability to gas resulting in rapid well-productivity decline. Accurate prediction of dew point pressure is used for ensuring safe transport and processing of natural gas. Avoiding hydrocarbon condensation in pipelines is crucial because if the presence of liquids increases the pressure drop increases and introduces operational problems resulting from the two-phase flow in pipelines designed for single phase transportation. The dew point pressure measurements are usually directly by mean of a dispositive based on the chilled mirror approach, either automatic or manual. The dew point pressure can be determined by the following methods: Constant Mass Expansion (CME) and constant volume depletion (CVD). Equations of state (EOS) can be properly tuned to match some dew point pressure experimental data for a particular reservoir. Other predictive methods rely on the estimation of equilibrium ratio K-values from correlations. These methods involve trial and error computation in addition to that most K-value correlations are not accurate especially at higher temperatures and pressures. The laboratory measurements of gas condensate properties provide the most accurate and reliable determination of reservoir fluid properties. However, due to economical and technical reasons, quite often this information cannot be obtained from laboratory measurements. The need of accurate prediction of the dew point pressure is very essential for fluid characterization, gas performance calculations, and for design of production systems. Also, it is very important in avoiding unnecessary simulation jobs. The main objective of this work is to present the most commonly models used to estimate the dew point pressure of condensate gas. Most of the correlations presented in this essay use the composition of the gas and C_{7+} fraction properties (molecular weight and specific gravity).

II. CORRELATIONS REVIEW FOR CRITICAL PROPERTIES ESTIMATION

Gas condensate reservoirs have a complex behavior due to the existence of two phases flowing. During production activities of a gas condensate-reservoir, the temperature in the formation normally remains constant, however the pressure decreases. Then, there is a great interest to evaluate the accuracy of the correlations relative to the experimental dew point pressure values for the gas-condensate systems. Literature review indicates the existence of three types of equations: working charts, empirical correlations and equations of state. It was mentioned that the objective of this essay is to review several of the well-established correlations to predict the dew point pressure of gas condensate systems.

A. CORRELATION OF NEMETH AND KENNEDY

The correlation of Nemeth and Kennedy has eleven constants and is a function of the composition and is expressed in terms of mole fraction of methane through C_{7+}, non-hydrocarbon components (CO_2, H_2S and N_2), the molecular weight and specific gravity of the C_{7+} fraction. The authors developed the correlation working with 579 data from 489 different gas condensate systems. The dew point pressure and temperature ranges varied from 1270 psia to 10790 psia and from 40°F to 320°F respectively.

The correlation has the following form and coefficients of equation is presenting in table 1:

$$nP_d = A_1\left[x_{C_2} + x_{CO_2} + x_{H_2S} + x_{C_6} + 2\left(x_{C_3} + x_{C_4}\right) + x_{C_5} + 0.4 \cdot x_{C_1} + 0.2 \cdot x_{N_2}\right] + A_2 \cdot \gamma_{C_{7+}} + A_3\left(\frac{x_{C_1}}{x_{C_{7+}}+0.002}\right) + A_4 \cdot T_R + A_5\left(x_{C_{7+}} \cdot M_{C_{7+}}\right) + A_6\left(x_{C_{7+}} \cdot M_{C_{7+}}\right)^2 + A_7\left(x_{C_{7+}} \cdot M_{C_{7+}}\right)^3 + A_8\left(\frac{M_{C7+}}{\gamma_{C_{7+}}+0.0001}\right) + A_9\left(\frac{M_{C7+}}{\gamma_{C_{7+}}+0.0001}\right)^2 + A_{10}\left(\frac{M_{C7+}}{\gamma_{C_{7+}}+0.0001}\right)^3 + A_{11} \quad (1)$$

TABLE 1. THE COEFFICIENTS OF NEMETH AND KENNEDY CORRELATION

$A_1 = -2.0623054$	$A_4 = 1.0448346 \cdot 10^{-4}$	$A_7 = 7.4299951 \cdot 10^{-5}$	$A_{10} = -1.0716866 \cdot 10^{-6}$
$A_2 = 6.6259728$	$A_5 = 3.2673714 \cdot 10^{-2}$	$A_8 = -1.1381195 \cdot 10^{-1}$	$A_{11} = 1.746622 \cdot 10^{1}$
$A_3 = -4.4670559 \cdot 10^{-3}$	$A_6 = -3.6453277 \cdot 10^{-3}$	$A_9 = 6.2476497 \cdot 10^{-4}$	

B. *CORRELATION OF HUMMOUD AND MARHOUN*

Hummoud and Marhoun developed a correlation using field and laboratory PVT data from several gas condensate fluid samples of reservoirs in the Middle East. The authors using 74 experimental points; their model relates the dew point pressure with the reservoir temperature, primary separator pressure and temperature, gas specific gravity, heptanes plus specific gravity, gas-oil ratio, pseudoreduced pressure and pseudoreduced temperature.

The correlation has the following form and coefficients of equation is presenting in table 2:

$$lnP_d = \beta_0 + \beta_1 \cdot \ln(T_R) + \beta_2 \cdot ln(R_M) + \beta_3 \cdot ln(P_{SP} \cdot T_{SP}) + \frac{\beta_4}{P_{pr}} + \frac{\beta_5}{P_{pr}} + \frac{\beta_6}{\gamma_{C7+}} \quad (2)$$

$$R_M = \frac{R_{SP} \cdot \gamma_{gSP}}{\gamma_{C7+}} \quad (3)$$

TABLE 2. THE COEFFICIENTS OF HUMMOUD AND MARHOUN CORRELATION

$\beta_0 = 43.777183$	$\beta_2 = -0.247436$	$\beta_4 = -4.291404$	$\beta_6 = -4.590091$
$\beta_1 = -3.594131$	$\beta_3 = -0.053527$	$\beta_5 = -3.698703$	

Hummoud and Marhoun also developed correlations for estimation of pseudocritical properties of the Middle East gas-condensate fluids. Using linear least-squares regression, the relationships as function of reservoir gas specific gravity (γ_{gR}) are:

$$P_{pc} = 694.5 - 55.3\gamma_{gR} \quad (4)$$

$$T_{pc} = 208.5 - 213.7\gamma_{gR} \quad (5)$$

C. CORRELATION OF ADEL M. ELSHARKAWY

M. Elsharkawy obtained an equation by means of 340 measurements of dew point pressure (131 experimentally measured values and 209 data collected from the literature were available for this study). The equation covers a pressure range of 1560–11830 psia, a temperature range of 40–340°F and gas-condensate gravities from 0.65 to 1.89.

According to the literature review, most of these gas condensate samples were sweet gases, few samples were highly sour and needed special sampling and testing because of their highly corrosive nature. The gas samples came from very lean gas-condensate (low content of C_{7+} fraction) and from very rich gas-condensate reservoirs.

The correlation has the following form and coefficients of equation is presenting in table 3:

$$P_d = A_0 + A_1T_R + A_2X_{H_2S} + A_3X_{CO_2} + A_4X_{N_2} + A_5X_{C_1} + A_6X_{C_2} + A_7X_{C_3} + A_8X_{C_4} + A_9X_{C_5} + A_{10}X_{C_6} + A_{11}X_{C_{7+}} + A_{12}M_{C_{7+}} + A_{13}\gamma_{C_{7+}} + A_{14}(X_{C_{7+}} \cdot M_{C_{7+}}) + A_{15}\left(\frac{M_{C_{7+}}}{\gamma_{C_{7+}}}\right) + A_{16}\left(\frac{X_{C_{7+}} \cdot M_{C_{7+}}}{\gamma_{C_{7+}}}\right) + A_{17}\left(\frac{X_{C_{7+}}}{X_{C_1} + X_{C_2}}\right) + A_{18}\left(\frac{X_{C_{7+}}}{X_{C_3} + X_{C_4} + X_{C_5} + X_{C_6}}\right) \quad (6)$$

TABLE 3. THE COEFFICIENTS OF ELSHARKAWY CORRELATION

$A_0 = 4268.850$	$A_4 = -4663.55$	$A_8 = -4257.10$	$A_{12} = 205.260$	$A_{16} = 8.1330$
$A_1 = 0.094056$	$A_5 = -1357.56$	$A_9 = -1417.10$	$A_{13} = -7260.32$	$A_{17} = 94.916$
$A_2 = -7157.87$	$A_6 = -7776.10$	$A_{10} = 691.5298$	$A_{14} = -352.413$	$A_{18} = 238.252$
$A_3 = -4540.58$	$A_7 = -9967.99$	$A_{11} = 40660.36$	$A_{15} = -114.519$	

D. CORRELATION OF MARRUFFO, MAITA, HIM & ROJAS

Marruffo and collaborators developed two correlations to determine the $\%C_{7+}$ and Gas Oil ratio (R_p) from the production data such as specific gravity in the separator, API gravity in the stock tank and reservoir temperature. The correlation was obtained from 80 PVT tests. The equation is valid for dew point pressures from 3000 to 5000 psia, Gas oil ratios from 2000 to 200000, specific gravity from 0.655 to 0.904 and condensate API gravity from 39 to 61.

The correlation has the following form and coefficients of equation is presenting in table 4:

$$\%C_{7+} = \left[\frac{R_p}{70680}\right]^{-0.8207} \quad (7)$$

or (8)

$$\%C_{7+} = 10260\left[R_p \cdot \gamma_g\right]^{-0.8499}$$

$$A = \left(K_4 \cdot T_R^{K_5}\right) - K_6 \cdot (\%C_{7+})^{K_7} \quad (9)$$

$$P_d = K_1 \cdot \left[\frac{R_p^{K_2}}{(\%C_{7+})^{K_3}} \cdot K_8 \cdot {}^\circ API^A\right] \quad (10)$$

TABLE 4. THE COEFFICIENTS OF MARRUFFO, MAITA, HIM & ROJAS CORRELATION

$K_1 = 346.7764689$	$K_3 = -0.294782419$	$K_5 = 0.281255219$	$K_7 = 1.906328237$
$K_2 = 0.0974139$	$K_4 = -0.047833243$	$K_6 = 0.00068358$	$K_8 = 8.417626216$

E. CORRELATION OF MOHAMMAD AL-DHAMEN AND MUHAMMAD AL-MARHOUN

These authors developed models to predict the dew point pressure for gas condensate reservoirs with three different techniques, their models are function of reservoir temperature, gas specific gravity, condensate specific gravity and gas-oil ratio.

The models were developed working with 113 data sets obtained from Constant Mass Expansion Experiment (CME) collected from Middle East Fields.

The data used by the authors covers a reservoir temperature from 100 to 309°F, gas oil ratios from 3321 to 103536 SCF/STB, gas specific gravity from 0.64 to 0.82 and condensate specific gravity from 0.73 to 0.81.

The authors developed the models utilizing three approaches: traditional correlation and non-parametric approach

***Traditional correlation Model**:* The authors used square regression analysis to develop the following equation and coefficients is presenting in table 5:

$$ln(P_d) = a_1 + a_2 \cdot ln\left[\frac{R_p \cdot \gamma_g}{x_{C_{7+}}}\right] + a_3 \cdot ln(T_R) + a_4 \cdot \gamma_g + \frac{a_5}{\gamma_{cond}} + a_6 \cdot e^{a_7 + a_8 \cdot ln(R_p)} \tag{11}$$

TABLE 5. THE COEFFICIENTS OF MARRUFFO, MAITA, HIM & ROJAS CORRELATION

$a_1 = 18.6012$	$a_3 = -0.1674$	$a_5 = -5.8982$	$a_7 = 8.4960$
$a_2 = -0.1520$	$a_4 = -0.0685$	$a_6 = -0.0559$	$a_8 = -0.7466$

Nonparametric Model: by Nonparametric statistics they transformed each independet variable into the next equations and coefficients is presenting in table 6:

$$P_d = e^{c_1 \cdot T(P_d)^3 + c_2 \cdot T(P_d)^2 + c_3 \cdot T(P_d) + c_4} \tag{12}$$

$$T(P_d) = ln\left[T(T_R) + T(R_p) + T(\gamma_g) + T(\gamma_{cond}) + 10\right] \tag{13}$$

$$T(T_R) = p_1 T_R^3 + p_2 T_R^2 + p_3 T_R + p_4 \tag{14}$$

$$T(R_p) = r_1 \cdot ln(R_p) + r_2 \tag{15}$$

$$T(\gamma_g) = q_1 \gamma_g^2 + q_2 \gamma_g + q_3 \tag{16}$$

$$T(\gamma_{cond}) = s_1 \gamma_{cond}^3 + s_2 \gamma_{cond}^2 + s_3 \gamma_{cond} + s_4 \tag{17}$$

TABLE 6. THE COEFFICIENTS OF AL-DHAMEN AND AL-MARHOUN NON-PARAMETRIC CORRELATION

$c_1 = 49.1377$	$p_1 = -0.350x10^{-6}$	$r_1 = -0.3990$	$q_1 = -23.8741$	$s_1 = -30120.78$
$c_2 = -336.5699$	$p_2 = 0.18048x10^{-3}$	$r_2 = 5.13770$	$q_2 = 36.94480$	$s_2 = 69559$
$c_3 = 770.0995$	$p_3 = -0.32315x10^{-1}$		$q_3 = -12.0398$	$s_3 = -53484.21$
$c_4 = -580.0322$	$p_4 = 1.2058$			$s_4 = 13689.39$

F. CORRELATION OF OKPONNADOZIE GODWIN

Godwin presented a correlation to predict dew point pressure for gas condensate reservoirs as a function of gas composition and reservoir temperature.

The correlation was developed using data of 259 gas condensate sample covering a wide range of gas properties and reservoir temperatures obtained from specialized literature.

The model has the following configuration and coefficients is presenting in table 7 and table 8.

$$P_d = A_0 + A_1B_1 + A_2B_2 + A_3B_3 + A_4B_4 + A_5B_5 + A_6B_6 + A_7B_7 + A_8B_8 + A_9B_9 + A_{10}B_{10} + A_{11}B_{11} + A_{12}B_{12} + A_{13}B_{13} + A_{14}B_{14} + A_{15}B_{15} \quad (18)$$

TABLE 7. THE *AI* COEFFICIENTS OF OKPONNADOZIE GODWIN CORRELATION

$A_0 = 1$	$A_4 = 11$	$A_8 = 19.08$	$A_{12} = 19.1$
$A_1 = 8.5$	$A_5 = 19.35$	$A_9 = 19.1$	$A_{13} = 19.1$
$A_2 = 9.4$	$A_6 = 22.35$	$A_{10} = 19.1$	$A_{14} = 19.12$
$A_3 = 9.9$	$A_7 = 22.3$	$A_{11} = 19.09$	$A_{15} = 5$

TABLE 8. THE *BI* COEFFICIENTS OF OKPONNADOZIE GODWIN CORRELATION.

$B_1 = T_R$	$B_4 = x_{C2}$	$B_7 = x_{C5}$	$B_{10} = x_{C7+} \cdot M_{C7+}$	$B_{13} = \frac{x_{C7+} \cdot M_{C7+}}{\gamma_{C7+}}$
$B_2 = x_{H2S} + x_{CO2} + x_{N2}$	$B_5 = x_{C3}$	$B_8 = x_{C6}$	$B_{11} = M_{C7+}$	$B_{14} = \frac{x_{C7+}}{x_{C1} + x_{C2}}$
$B_3 = x_{C1}$	$B_6 = x_{C4}$	$B_9 = x_{C7+}$	$B_{12} = \gamma_{C7+}$	$B_{15} = \frac{x_{C7+}}{x_{C3} + x_{C4} + x_{C5} + x_{C6}}$

G. CORRELATION OF SHOKIR

Shokir developed a mathematical genetic programming-based model using experimental data of 245 gas condensate systems covering a wide range of gas properties and reservoir temperatures in gas condensate systems.

However, the effect of the specific gravity of heptanes-plus was not considered in the developed model.

$$P_d = B_1 + B_2 + B_3 + B_4 \quad (19)$$

$$B_1 = 201.875481 \cdot x_{C7+}\Big(\big(T_R[x_{C3} - x_{H2S} + x_{CO2} - x_{C6} + x_{CO2} - x_{C4} - x_{C2}] - [x_{C4}(x_{CO2} - x_{C4} - M_{C7+} + x_{N2} - x_{C5} \cdot M_{C7+}{}^2) - x_{C7+}]\big) - (x_{H2S} - x_{N2}T_R[x_{C1}{}^2 - x_{C7+}] + M_{C7+} - x_{C2} + x_{H2S})\Big) + 38456.87953 \cdot x_{C6} \quad (20)$$

$$B_2 = (0.000007 \cdot T_R \cdot x_{N2})\big[(x_{CO2} - M_{C7+} - x_{C7+})(T_R - M_{C7+} - x_{CO2} - T_R) - (x_{H2S} - T_R)(M_{C7+}{}^2 - x_{C3}M_{C7+})\big] + 225500.9399 \cdot x_{C6} \quad (21)$$

$$B_3 = 120586.9719 \cdot x_{c1} \cdot \big[x_{H2S}(x_{C3} \cdot x_{H2S} - x_{C5} - x_{C7+}) - \big((x_{C7+} - x_{C1})(x_{C7+} - x_{C6}) - x_{H2S} \cdot x_{N2}{}^2\big)\big] + 72.6908 \cdot M_{C7+} \quad (22)$$

$$B_4 = -1962.40851 \cdot x_{C5}(M_{C7+} - x_{C1}{}^2) - 253385.67764 \cdot x_{C7+} \cdot x_{CO2} \cdot x_{C3}(x_{CO2} \cdot x_{C3} - x_{C4} + x_{C7+})(x_{C3} - M_{C7+}) - 13358.59271 \cdot x_{C4} + 4676.933602 \cdot x_{C2} - 6567.9 \quad (23)$$

H. CORRELATION OF KAMARI ET AL.

Kamari and collaborators developed a simple correlation for the prediction of the dew point pressure in gas condensate reservoirs using a soft computing approach known as gene expression programming.

The computational approach utilizes a comprehensive dataset of dew point pressures, as well as properties of C_{7+}, reservoir temperature and hydrocarbon and non-hydrocarbon reservoirs fluids composition.

The correlation has the following configuration:

$$P_d = A + B \tag{25}$$

$$A = \frac{13.145 - 4.942 x_{C1} + 1961.71 x_{C2} - 6212.71 x_{C4} + 39335.07 {x_{C4}}^2 + 2097 x_{C5} - 3451.17 x_{C6} + 201.93 x_{H2S} - 0.065224 T_R}{0.0031904 \cdot T_R + 0.094398} \tag{26}$$

$$B = \frac{1367.4 + 9.98 x_{C1} MW_{C7+} - 1697.6 x_{C3} - 5096.8 x_{C7+} + 358.07 \cdot \ln(x_{C7+}) + 933.35 x_{CO2} + 1909 x_{N2}}{1.0214 - \gamma_{C7+}} \tag{27}$$

I. CORRELATION OF WANG ET AL.

Wang and coworkers developed a correlation to predict the dew point as a function of the reservoir temperature, gas composition, and C_{7+} component properties. The authors used fourteen groups of gas condensate samples from different areas in China. The correlation has a wide application range, with methane composition between 65.59% and 93.09% and gas-oil ratio for gas condensate reservoir of from 1002 to 63377 m^3/m^3.

The correlation has the following form and coefficients is presenting in table 9:

$$P_d = A_1 + A_2 T_R + A_3(x_{N2} + x_{CO2}) + A_4 x_{C1} + A_5(x_{C2} + x_{C3} + x_{iC4} + x_{nC4} + x_{C5} + x_{C6}) + A_6 x_{C7+} + A_7 M_{C7+} + A_8 \gamma_{C7+} + A_9 \frac{x_{C7+}}{x_{C1}} + A_{10} \cdot \frac{x_{C7+}}{x_{C2} + x_{C3} + x_{iC4} + x_{nC4} + x_{C5} + x_{C6}} \tag{28}$$

TABLE 9. THE A_I COEFFICIENTS OF WANG ET AL. CORRELATION

$A_1 = 554.5602$	$A_3 = -445.6469$	$A_5 = -713.0550$	$A_7 = 0.1744$	$A_9 = -156.8583$
$A_2 = -0.2118$	$A_4 = -447.1420$	$A_6 = 457.5477$	$A_8 = -62.9316$	$A_{10} = -49.4133$

III. METHODOLOGY

150 data points were acquired and made available for this comparative study (75 experimentally measured values and 75 data collected from different literature sources).

Each data set includes reservoir temperature, composition of the gas-condensate system (expressed in terms of mole fraction of methane through C_{7+} and non-hydrocarbon components like CO_2, H_2S and N_2) molecular weight and specific gravity of the C_{7+} fraction.

The natural gas samples are natural gases with low concentration of N_2, CO_2 and H_2S. Their composition was determined by gas chromatography. In this section, the results of statistical analyses of all samples were used without excluding or eliminating any data.

The 75 experimental data were obtained using a chilled mirror apparatus and a PVT cell to cover a temperature range from 40 to 313 °F K and pressure range from 2405 to 11830 psia. Table 10 lists the ranges of the main parameter that were used in this comparative study among correlations for predicting dew point pressure of gas condensate systems as a function of the parameters before mentioned.

The performance and accuracy of the correlations to predict the dew point pressure is compared, table 11 reports the accuracy of various methods existing in literature for predicting DPP. It is noticeably that in this study the correlation of

Kamari has the best overall accuracy. The correlation of Kamari has an Average percent relative error (APE) of 1.09%.

Average absolute relative percent error (AAPE) of 8.26 and correlation coefficient (R2) of 94.58%.

TABLE 10. RANGES AND THEIR CORRESPONDING STATISTICAL PARAMETERS USED IN THIS COMPARATIVE STUDY

Parameter	Minimum	Average	Maximum	Standard Deviation
P_d (Psia)	2405	4954.12	11830	1552.15
T_R (°F)	40	217.02	313	50.56
M_{C7+}	106	152.22	253	24.03
γ_{C7+}	0.7300	0.7906	0.8500	0.0236
x_{C1}	0.3344	0.7886	0.9650	0.1174
x_{C2}	0.0040	0.0610	0.1453	0.0303
x_{C3}	0.0023	0.0314	0.0902	0.0191
$x_{C4's}$	0.0022	0.0199	0.0630	0.0118
$x_{C5's}$	0.0009	0.0127	0.1230	0.0132
$x_{C6's}$	0.0000	0.0095	0.0871	0.0094
x_{C7+}	0.0036	0.0427	0.1356	0.0314
x_{N2}	0.0000	0.0128	0.4322	0.0408
x_{CO2}	0.0000	0.0135	0.1036	0.0171
x_{H2S}	0.0000	0.0068	0.2657	0.0317

TABLE 11. STATISTICAL ANALYSIS RESULTS OF THE CORRELATIONS USED IN THIS COMPARATIVE STUDY.

Correlation	APE	AAPE	RMSE	R^2
Shokir	−0.0069	0.0971	0.1463	0.8250
Nemeth-Kennedy	0.0598	0.0869	0.1205	0.7397
Elsharkawy	−0.0567	0.1354	0.1995	0.5937
Ahmadi	0.0077	0.0790	0.1067	0.7765
Kamari	0.0109	0.0826	0.1096	0.9458
Okpo Nnadozie	−0.0750	0.1887	0.2467	0.5985

IV. RESULTS AND DISCUSSION

Firstly, we examinen the accuracy of various correlation methods by means of a comparison between the observed and predicted values.

Due to varying compositions of gas-condensate fluids from reservoirs of different regions, different empirical correlations provided unacceptable predictions of dewpoint pressures when they were applied to gas-condensate fluids behaving differently from the fluid samples on which they were developed.

Secondly, the graphical error analysis (crossplots) of estimated versus experimental values of dew point pressures for gas condensate systems was developed, the comparative evaluation of the existing correlations is shown from Fig.1 to Fig.6.

The cross plot of Kamary correlation’s presented in Fig.5, shows that the data points fit to a straight line.

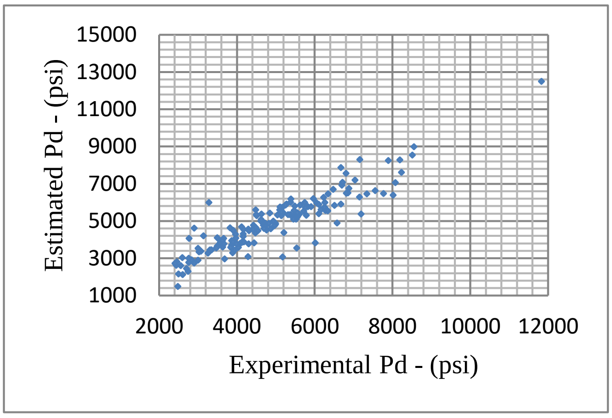

Fig.01. Cross plot of dew point pressure (Shokir)

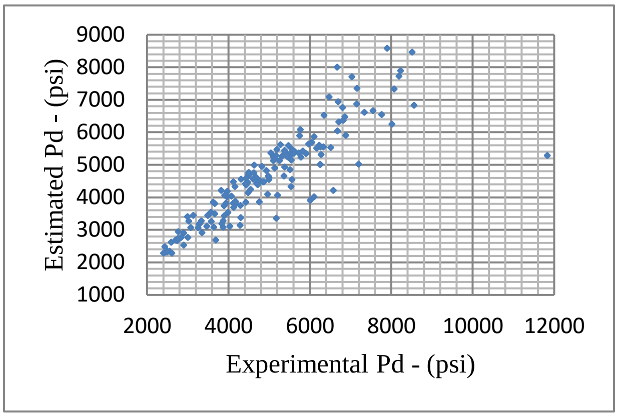

Fig.02. Cross plot of dew point pressure (Nemeth)

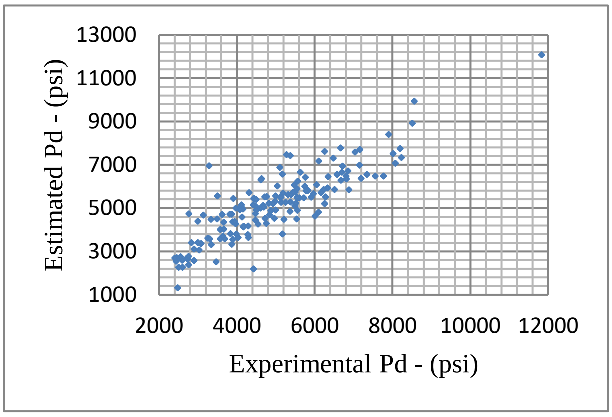

Fig.03. Cross plot of dew point pressure (Elsharkawy)

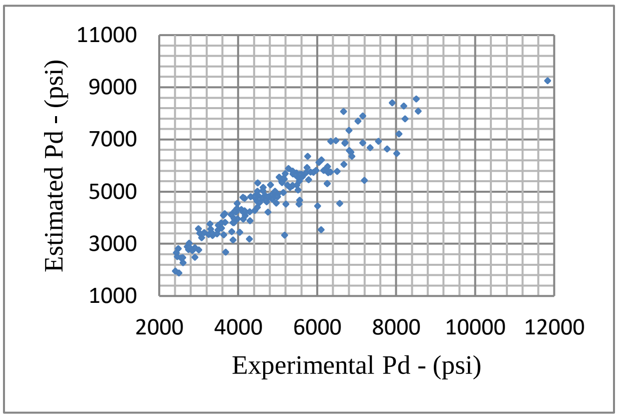

Fig.04. Cross plot of dew point pressure (Ahmadi)

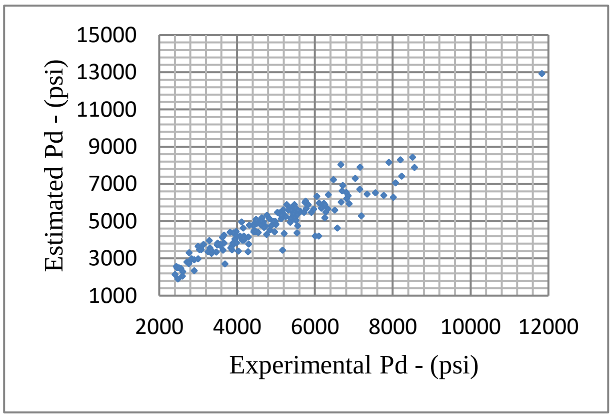

Fig.05. Cross plot of dew point pressure (Kamari)

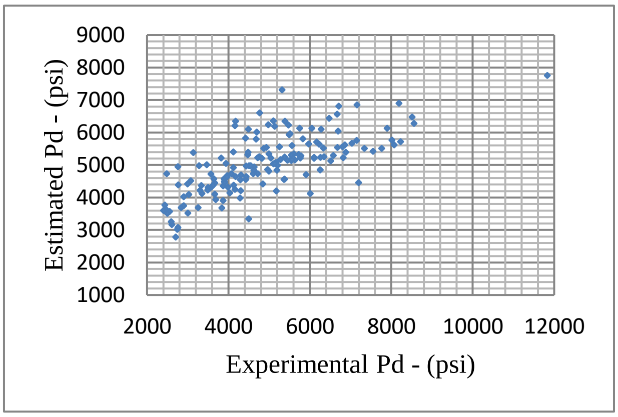

Fig.06. Cross plot of dew point pressure (Okpo Nnadozie)

V. CONCLUSIONS

In this study the best correlation representing the dew point pressures was the correlation of Kamari. The empirical correlations, proposed in different forms (mathematical expression, graphical, or tabulated) for determining the dew point pressures of gas-condensate systems, are considered very limited in the literature. In Most of these empirical correlations are a function of the composition of the gas-condensate system. A study should be carried out to verify the change in the dew point as a function of CO_2, H_2S and N_2.

LIST OF SYMBOLS

APE – Average percent relative error.
AAPE – Average absolute relative percent error.
RMSE – Root mean square error.
°API – American petroleum institute gravity.
R_p – Gas Oil Ratio (GOR).
M_{C7+} – Molecular weight of C_{7+} fraction.
γ_{C7+} – Specific gravity of C_{7+} fraction.
P_d – Dew point pressure
T_R – Reservoir temperature

X_{C1} – Molar fraction of methane
X_{C2} – Molar fraction of ethane
X_{C3} – Molar fraction of propane
$X_{C4's}$ – Molar fraction of butanes
$X_{C5's}$ – Molar fraction of pentanes
$X_{C6's}$ – Molar fraction of hexanes
X_{C7+} – Molar fraction of heptanes plus
X_{N2} – Molar fraction of nitrogen
X_{CO2} – Molar fraction of carbon dioxide
X_{H2S} – Molar fraction of hydrogen sulfide

APPENDIX - A

PERFORMANCE MEASUREMENT

a) Average percent relative error (APE)

$$E_r = \frac{1}{n}\sum_{i=1}^{n} E_i \quad \text{(A.1)}$$

$$E_i = \left[\frac{(x_i)_{exp.} - (x_i)_{est.}}{(x_i)_{exp.}}\right] \cdot 100 \quad \text{(A.2)}$$

Where, $(x_i)_{exp.}$ is the actual value of dew point pressure. $(x_i)_{est.}$ is the estimated value for dew point pressure.

b) Average absolute relative percent error (AAPE)

$$E_a = \frac{1}{n}\sum_{i=1}^{n} |E_i| \quad \text{(A.3)}$$

c) Root mean square error (RMSE)

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n} (E_i)^2} \quad \text{(A.4)}$$

d) The correlation coefficient (R^2)

$$R^2 = 1 - \frac{\sum_{i=1}^{n}\left[(x_i)_{exp.} - (x_i)_{est.}\right]^2}{\sum_{i=1}^{n}\left[(x_i)_{exp.} - \bar{X}\right]^2} \quad \text{(A.5)}$$

$$\bar{X} = \frac{1}{n}\sum_{i=1}^{n} \left[x_{exp}\right]_i \quad \text{(A.6)}$$

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