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Comparative Study of the Consistency of C6+ Composition Splits of Pipeline Gas for Hydrocarbon Dewpoint Determination

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ABSTRACT

Several fixed percentage of C6+ composition splits for hydrocarbon dewpoint (HCDP) determination, based on empirical studies of most pipeline gases, have been published in a Gas Processors Association standard; but may not truly reflect the C6+ composition of a particular pipeline gas and for that reason may affect the quality of always predicting the HCDP of a pipeline gas in the same level. In addition, several different software packages are available to the industry to perform dew point calculations, and each of these may yield different predictions using the same gas compositions and equations of state. This work, therefore, presents the examination of the consistency of several common C6+ composition splits of pipeline gas, applied to a large set of field and hypothetical C6+ data, for determining HCDP. Results comparison of calculated HCDP as well as cricondentherm (using HYSYS® with Peng-Robinson equation of state [EOS] and Soave-Redlich-Kwong EOS) between the various C6+ composition splits is made. Ranking of the common C6+ split schemes for HCDP determination on the basis of C6+ mole fraction is also presented.

Key words: *C6+ composition splits, Pipeline gas, Hydrocarbon dew point.*

1. INTRODUCTION

Hydrocarbon is a valuable tool in gas processing and transportation. More recently, it is being written into tariffs as a quality parameter. When natural gas is processed, the heavier components are removed in order to supply high-quality gas to the market and also to ensure the safety and reliability of the pipeline system. For example, gas turbine generator plants have a written requirement in their warranties that the fuel gas must be totally gaseous. In order to comply with this requirement, the gas is superheated to a minimum of 50°F/28°C above the highest dew point of the gas at the pressure regulators located ahead of the burner section. Hydrocarbon dewpoint (HCDP) defines whether the natural gas stream in a pipeline at a given pressure and temperature consists of a single gas phase or two phases, gas and liquid. Figure 1 shows a phase diagram depicting the HCDP for a typical natural gas.

The two methods currently in use for determining HCDP are; the manual visual dewpoint approach and the equation of state (EOS) method using gas chromatograph (GC) analysis. The manual method was developed by the U.S Department of Interior, Bureau of Mines and has been codified into a standard test method by the American Society of Testing and Materials [1]. It uses a chilled mirror or dew point tester. This approach is labor intensive. Although automated continuous units are available, they are expensive and, unlike GCs, are currently not part of most existing gas transmission facilities (NGC-GPA White Paper) [2]. In addition, the determination of the phase envelope or the cricondentherm would be difficult using this method since it is a periodic spot checking only. The indirect method uses a GC for compositional analysis in conjunction with an EOS to estimate the dew point as well as the cricondentherm and phase envelope if desired. As the HCDP is the condition when the heavy components begin to drop out into the liquid phase, the accurate measurement of the heavier components is critical for meaningful determination of the HCDP. The composition of the pipeline gas for custody metering is determined by the use of GCs, most of these analyzers are generally C6+ and a few are C9+ design as reported by Jack [3]. The GC C6+ design measures the individual hydrocarbons up to normal-pentane using GPA 2261 procedure and then report the heavier components as a combined C6+ measurement.

Ernst and Pettigrew [4] stated that the traditional C6+ analysis provides insufficient data for a valid HCDP

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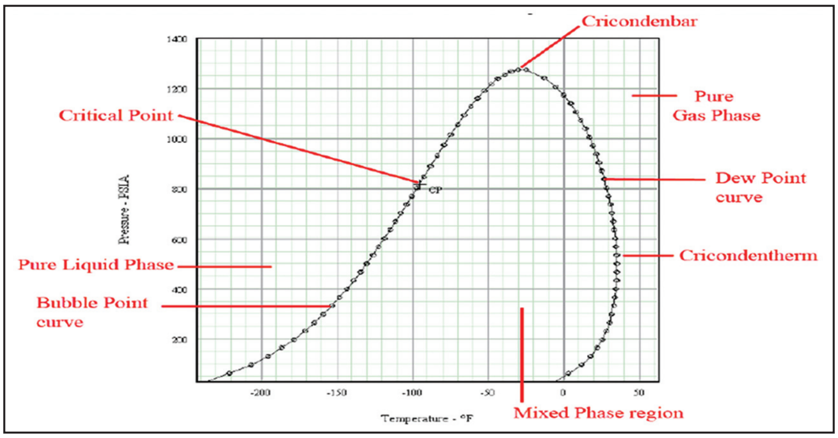

Figure 1: A phase diagram for a typical natural gas (Source: Shane, 2000 [1]; Emerson Process Management, Class # 5300).

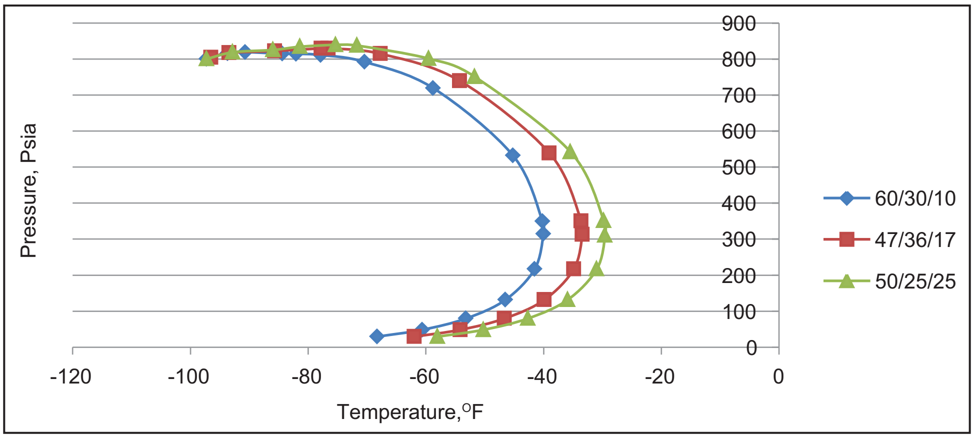

Figure 2: Different phase envelopes, dew point curve portions, using HYSYS® Peng-Robinson equation of state with different C6+ characterization methods of a pipeline gas composition with C6+ mole fraction of 0.01.

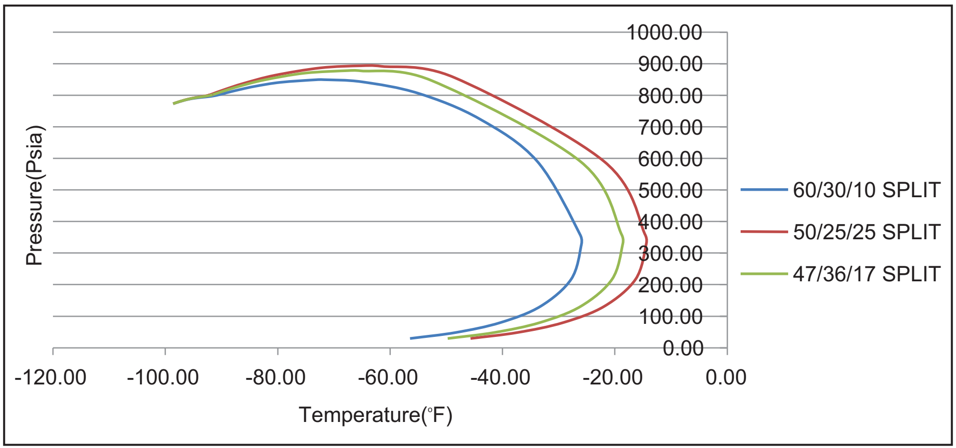

Figure 3: Different phase envelopes, dew point curve portions, using HYSYS® Peng-Robinson equation of state with different C6+ characterization methods of a pipeline gas composition with C6+ mole fraction of 0.02.

calculation; in the absence of detailed analytical data for hydrocarbon plus fractions in a hydrocarbon mixture, erroneous predictions and conclusions can result if the plus fraction is used directly as a single component in the mixture phase behavior calculations. Numerous authors have indicated that these errors can be substantially reduced by splitting or breaking down the plus fraction into a manageable number of fractions for EOS calculations.

For energy calculation and HCDP calculation, many gas processors and end-users are now applying EOS,

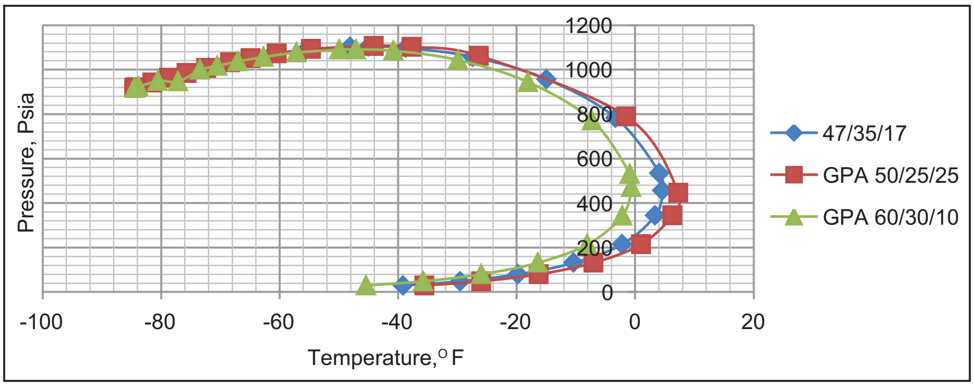

Figure 4: Different phase envelopes, dew point curve portions, using HYSYS® Peng-Robinson equation of state with different C6+ characterization methods of a pipeline gas composition with C6+ mole fraction of 0.03.

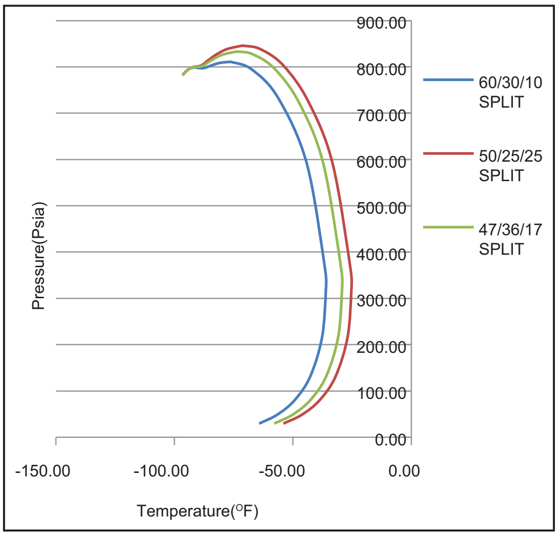

Figure 5: Different phase envelopes, dew point curve portions, using HYSYS® Soave-Redlich-Kwong equation of state with different C6+ characterization methods of a pipeline gas composition with C6+ mole fraction of 0.01.

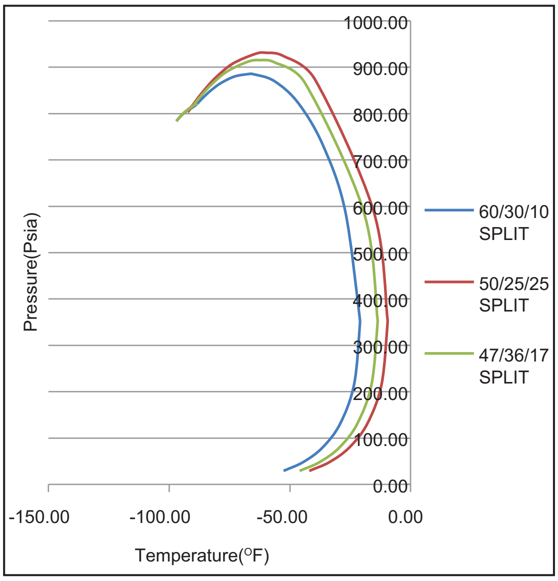

Figure 6: Different phase envelopes, dew point curve portions, using HYSYS® Soave-Redlich-Kwong equation of state with different C6+ characterization methods of a pipeline gas composition with C6+ mole fraction of 0.01.

either a Peng-Robinson (PR) or Soave-Redlich-Kwong (SRK) EOS, to pipeline gas composition; the C6+ component is split into a fixed ratio of n-hexane, n-heptane, and n-octane. Some commonly used percentage C6+ composition splits, based on empirical studies of most pipeline gases, are published in a GPA standard [3] (NGC-GPA White Paper, 2005): GPA 60% C6, 30% C7, 10% C8; Daniels 47% C6, 36% C7, 17% C8; GPA 50% C6, 25% C7, 25% C8. Application of any of these fixed ratios for a particular delivery point of natural gas may not be a truly representative of the measured gas because the specific gravity of C6+ generated with the fixed ratios may likely deviate from that of the measured gas. Even with the most recent approach, used by gas processors and end-users to determine the percentage characterization of C6+ for a given pipeline, which is by taken the weighted average compositions of the regional supply on that pipeline, the ability of the average characterization to reflect the true composition of a particular gas within a region greatly depends on the variance of the individual components of all gases throughout the region [3] and thus, for that reason, may affect the quality of always predicting the HCDP of a pipeline gas in the same level. Even though, a new and simple procedure for the estimation of the appropriate percentage distribution of C6+ composition to improve HCDP determination has been developed by Livinus and Obah [5] based on the observation reported by several researchers (Katz [6]; Lorenz et al [7]; Pedersen et al [8]; Ahmed et al [9]) that lighter hydrocarbon systems exhibit exponential molar distribution, studying the consistency of the prediction capability of the common C6+ composition splits used by pipeline gas operators is essential for always determining the HCDP of a pipeline gas in the same level.

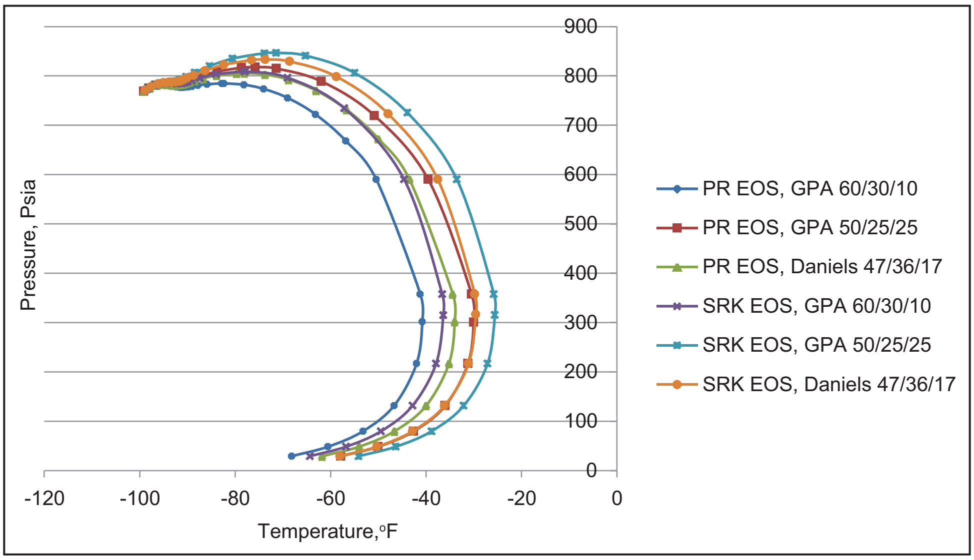

Figure 7: The comparisons of the different phase envelopes, dew point curve portions, using HYSYS® Soave-Redlich-Kwong equation of state and Peng-Robinson equation of state with different C6+ characterization methods of a pipeline gas composition with C6+ mole fraction of 0.01.

Table 1: Hydrocarbon dew point predictions and cricondentherm along with cricondenbar of the gas compositions using HYSYS® with PR EOS.

Specifications	**C6+ Data with 47/36/17 split ratio**	**C6+ Data with GPA 2261 split ratio (50/25/25)**	**C6+ Data with GPA 2261 split ratio (60/30/10)**
Gas composition with C6+mole fraction of 0.01			
Hydrocarbon dew point prediction at 215 psia	−34.53 to −36.11°F	−30.65 to −32.06°F	−39.99 to 41.99°F
Cricondentherm	−35.05°F	−31.02°F	−42.62°F
Cricondenbar	802.7 psia	816.6 psia	779 psia
Gas Composition with C6+mole fraction of 0.02			
Hydrocarbon dew point prediction at 215 psia	−20.35 to −20.50°F	−16.18 to −16.31°F	−27.61 to −27.78°F
Cricondentherm	−18.63°F	−14.46°F	−26.02°F
Cricondenbar	877.3 psia	894 psia	849 psia
Gas composition with C6+mole fraction of 0.03			
Hydrocarbon dew point prediction at 215 psia	−2.151°F	1.038°F	−8.014°F
Cricondentherm	4.627°F	7.334°F	−0.5866°F
Cricondenbar	1104 psia	1107 psia	1091 psia

EOS: Equation of state, PR: Peng-Robinson

Several different methods are available for predicting HCDPs from an analytical gas composition. These include different software packages, different equations of state and equation parameters, and different methods of characterizing the heavy ends that cannot be resolved by typical field GC. However, industry experience indicated that these different methods could produce significantly different results, particularly as the percentages of hexane (C6) and heavier components increased as discussed by Darin et al. [10].

In this work, the study of the consistency of several common C6+ composition splits of pipeline gas, applied to a large set of field and hypothetical C6+ data with varying hexane plus fractions and gas specific gravities, for determining HCDP is presented. Results comparison of calculated HCDP, as well as cricondentherm (using HYSYS(with PR EOS and SRK EOS) between the various C6+ composition splits, is made. Ranking of the common C6+ split schemes for HCDP determination on the basis of C6+ mole fraction and gas specific gravity is also presented.

2. FIELD AND HYPOTHETICAL C6+ COMPOSITIONS DATA GATHERING

The pipeline gas samples used for the study are from Queensland gas pipeline reported by Jemena Asset

Management [12], Gulf Coast Division gas pipeline, Midwestern Tennessee Gas Transmission pipeline, Northern Natural gas pipeline, Alliance gas pipeline and from a gas flow station from the Niger Delta. Many of the pipeline gases have lumped C6+ mole fractions ranging from 0.01 to 0.03 with varying specific gravity. The non-hydrocarbon components of the gas samples - Nitrogen, carbon IV oxide, and oxygen, have varying mole fractions. Hypothetical C6+ pipeline compositions data are derived from the field C6+ data. Over 100 gas samples were used in this paper; some of the gas samples' information, gas molecular compositions and sample properties are presented in Appendix.

2.1. Application of C6+ Splits and EOS Techniques to Field and Hypothetical C6+ Compositions for HCDP Predictions

Several different software packages are available to the industry to perform dew point calculations, and each of these may yield different predictions using the same gas compositions, equations of state and pressure conditions. Applying the common C6+ split methods - 60/30/10, 47/36/17, and 50/25/25 to the gathered set of field and hypothetical C6+ data grouped based on the same hexane plus mole fraction values, using HYSYS® software with PR EOS and SRK EOS, the consistency of these split methods for predicting HCDP was studied.

3. RESULTS ANALYSES OF THE GAS COMPOSITIONS USING HYSYS® WITH PR EOS

The range of cricondentherm and as well as predicted HCDPs, at a pipeline pressure of 215 psia for instance, for the various gas compositions with C6+ mole fractions of 0.01-0.03 are presented in Table 1. Figures 2-4 present the phase envelopes of some of the gas samples analyzed. For gas compositions with C6+ mole fraction of 0.01, the predicted HCDP ranges from as low as an average value of −40.98°F for the C6+ data with GPA 60/30/10 split ratio to an average value of −31.35°F for the GPA 50/25/25 split method; for gas compositions with C6+ mole fraction of 0.02, the predicted HCDP ranges from as low as an average value of −27.78°F for the C6+ data with GPA 60/30/10 split ratio to an average value of −16.31°F for the GPA 50/25/25 split method; for gas compositions with C6+ mole fraction of 0.03, the predicted HCDP ranges from as low as an average value of −8.014°F for the C6+ data with GPA 60/30/10 split ratio to an average value of 1.038°F for the GPA 50/25/25 split method. In all cases, the HCDP results for GPA 50/25/25 seem to be the highest, followed by that of Daniels 47/36/17 and the least results are from GPA 60/30/10. The HCDP results, at the pipeline pressure, shows a slight variance among the C6+ split methods (Daniels 47/35/17, GPA 50/25/25 and the GPA 60/30/10); a difference of about 10°F between the GPA 60/30/10 and GPA 50/25/25 is observed, while a slight variance within the neighborhood of 4°F is observed between Daniels 47/36/17 and GPA 50/25/25.

3.1. Results Analyses of the Gas Compositions using HYSYS® with SRK EOS

Performing similar calculations using SRK EOS, the range of cricondentherm and as well as predicted HCDPs, at a pipeline pressure of 215 psia for instance, for the various gas compositions with C6+ mole fractions of 0.01-0.03 are presented in Table 2. Figures 5-7 present the phase envelopes of some of the gas samples analyzed. In all cases, a similar trend as in PR EOS was observed, the HCDP results for GPA 50/25/25 are the highest, followed by that of Daniels 47/36/17 and the least results are from GPA 60/30/10. There are slight variations in HCDP results, at the pipeline pressure, among the C6+ split methods (Daniels 47/35/17, GPA 50/25/25 and the GPA 60/30/10); a difference of about 10°F between the GPA 60/30/10 and GPA 50/25/25 is observed, while a slight variance within the neighborhood of 4°F is observed between Daniels 47/36/17 and GPA 50/25/25.

3.2. Comparisons of Predicted HCDPs and Cricondentherm between PR EOS and SRK EOS

When the values predicted by SRK EOS and PR EOS were compared, a variation within the neighborhood of 5°F is observed in all cases of the C6+ split methods for all the pipeline gas compositions. The ranking order in which the two equations of state for the various C6+ split methods predicted the HCDP values for the various gas compositions with C6+ mole fraction of 0.01-0.03 is presented in ascending order as follows; SRK EOS, GPA 50/25/25; SRK EOS, Daniels 47/36/17; PR EOS, GPA 50/25/25; PR EOS, Daniels 47/36/17; SRK EOS, GPA 60/30/10; and PR EOS, GPA 60/30/10. Figure 7 shows the comparisons of the different phase envelopes, dew point curve portions, using HYSYS® SRK EOS and PR EOS with different C6+ characterization methods of a pipeline gas composition with C6+ mole fraction of 0.01.

4. CONCLUSION

Though current methods of predicting dew points, particularly software packages using the PR and SRK equations of state, are likely to under-estimate the HCDPs of a gas stream. However, the accuracy of predicted dew points can be improved when a proper characterization of the heavy ends is used. The predicted HCDP for the various gas compositions with C6+ mole fractions of 0.01-0.03 using PR EOS, in all cases, the HCDP results for GPA 50/25/25 seem to be the highest, followed by that of Daniels 47/36/17 and the least results are from GPA 60/30/10. The HCDP results, at the pipeline pressure, shows a slight variance among the C6+ split methods (Daniels 47/35/17, GPA 50/25/25 and the GPA 60/30/10); a difference of about 10°F between the GPA 60/30/10 and GPA 50/25/25 is observed, while

Table 2: Hydrocarbon dew point predictions and cricondentherm along with cricondenbar of the gas compositions using HYSYS® with SRK EOS.

Specifications	C6+ Data with 47/36/17 split ratio	C6+ Data with GPA 2261 split ratio (50/25/25)	C6+ Data with GPA 2261 split ratio (60/30/10)
Gas composition with C6+mole fraction of 0.01			
Hydrocarbon dew point prediction at 215 psia	−30.91 to −31.33°F	−26.93 to −27.31°F	−37.68 to −38.19°F
Cricondentherm	−29.88°F	−25.61°F	−36.39°F
Cricondenbar	833.5 psia	847.30 psia	809.50 psia
Gas composition with C6+mole fraction of 0.02			
Hydrocarbon dew point prediction at 215 psia	−16.15 to −16.49°F	−12.00 to −12.02°F	−23.37 to −23.78°F
Cricondentherm	−14.19°F	−10.00°F	−21.61°F
Cricondenbar	909.3 psia	927.1 psia	879.2 psia
Gas composition with C6+mole fraction of 0.03			
Hydrocarbon dew point prediction at 215 psia	−2.151°F	1.038°F	−8.014°F
Cricondentherm	4.627°F	7.334°F	−0.5866°F
Cricondenbar	1104 psia	1107 psia	1091 psia

EOS: Equation of state, SRK: Soave-Redlich-Kwong

a slight variance within the neighborhood of 4°F is observed between Daniels 47/36/17 and GPA 50/25/25. Performing similar calculations using SRK EOS, the same trend as in PR EOS was observed, but with a slight variation. The ranking order in which the two equations of state for the various C6+ split methods predicted the HCDP values for the various gas compositions with C6+ mole fraction of 0.01-0.03 is presented in ascending order as follows; SRK EOS, GPA 50/25/25; SRK EOS, Daniels 47/36/17; PR EOS, GPA 50/25/25; PR EOS, Daniels 47/36/17; SRK EOS, GPA 60/30/10; and PR EOS, GPA 60/30/10.

5. ACKNOWLEDGMENT

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***Bibliographical Sketch**

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APPENDIX

Table 1: Some gas samples used in the study.

	Natural gas pipeline (%)		**Midwestern Tennesee gas trans. pipeline %**	**Northern Natural gas pipeline %**
	Natural division	**Gulf coast division**		
Moisture	Dry	Dry	Dry	Dry
Nitrogen (N_2)	1.17	0.79	0.22	1.69
Carbon dioxide (CO_2)	0.86	1.20	1.07	0.80
Methane (CH_4)	93.67	95.31	95.77	92.49
Ethane (C_2H_6)	3.84	2.45	2.66	4.48
Propane (C_3H_8)	0.33	0.19	0.20	0.44
Butanes - I (C_4H_{10})	0.02	0.02	0.03	0.03
Butanes - N (C_4H_{10})	0.06	0.02	0.03	0.05
Pentanes - I (C_5H_{12})	0.01	0.01	0.01	0.01
Pentanes - N (C_5H_{12})	0.01	0.00	0.01	0.01
Hexane and others (C6+)	0.02	0.01	0.01	0.00
Helium (He)	0.00	0.00	0.00	0.00
Heptanes (C_7)	0.00	0.00	0.00	0.00
Hydrogen (H_2)	0.00	0.00	0.00	0.00
Oxygen (O_2)	0.00	0.00	0.00	0.00
	100.00	100.00	100.00	100.00
BTU per cubic foot				
By calorimeter	1032	1018	1027	1033
Calculated from analysis	1029	1015	1025	1030
Specific gravity				
Determined by balance	0.592	0.585	0.581	0.897
Calculated	0.590	0.583	0.581	0.596

The gas supplied has about 0.4 grains sulfur per 100 cubic feet, on the average, about 0.0010% by weight

Table 2: Some gas samples used in the study.

	Natural gas pipeline (%)		**Midwestern Tennessee gas trans. pipeline %**	**Northern natural gas pipeline %**
	Natural division	**Gulf coast division**		
Moisture	Dry	Dry	Dry	Dry
Nitrogen (N_2)	1.30	0.75	0.40	1.73
Carbon dioxide (CO_2)	0.89	1.26	1.46	0.80
Methane (CH_4)	93.26	95.22	93.63	92.40
Ethane (C_2H_6)	4.17	2.44	4.19	4.57
Propane (C_3H_8)	0.30	0.23	0.24	0.42
Butanes - I (C_4H_{10})	0.02	0.03	0.03	0.02
Butanes - N (C_4H_{10})	0.03	0.03	0.03	0.04
Pentanes - I (C_5H_{12})	0.01	0.01	0.01	0.01
Pentanes - N (C_5H_{12})	0.01	0.01	0.01	0.01
Hexane and others (C6+)	0.01	0.02	0.01	0.00
Helium (He)	0.00	0.00	0.00	0.00
Heptanes (C_7)	0.00	0.00	0.00	0.00
Hydrogen (H_2)	0.00	0.00	0.00	0.00
Oxygen (O_2)	0.00	0.00	0.00	0.00
	100.00	100.00	100.00	100.00