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Ranking of C6+ Composition Split Schemes of Pipeline Gas for Hydrocarbon Dewpoint Determination

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Abstract

For energy calculation and hydrocarbon dewpoint calculation of pipeline gas, many gas processors and end-users are now applying equation of state, either a Peng-Robinson (PR) or Soave-Redlich-Kwong (SRK) equation of state, to the pipeline gas composition after splitting the C6+ component into a fixed ratio of n-hexane, n-heptane and n-octane: varying predictions are obtained because the commonly used percentage C6+ composition splits published in GPA standard are based on empirical studies of most pipeline gases. 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 ranking of the common C6+ split schemes for hydrocarbon dewpoint determination on the basis of C6+ mole fraction through the study of several common C6+ composition splits of pipeline gas applied to a large set of field and hypothetical C6+ data by means of HYSYS(with PR EOS and SRK EOS for predicting hydrocarbon dewpoint.

Introduction

The gas industry, over the past few decades, has acknowledged an important need for both the current operations and the management of future gas processing and transportation- the accurate prediction of the hydrocarbon dewpoint of a natural gas stream. The hydrocarbon dew point, or HCDP, is the temperature and pressure at which heavy components of the stream condense and begin to form liquids (See Figure 1). If liquids are allowed to condense within the gas pipeline, the heating value of the gas stream will be lost and also may cause operational problems to the natural gas facilities.

The two methods currently in use for determining hydrocarbon dewpoint (HCDP) are; the manual visual dewpoint approach and the equation of state (EOS) method using Gas Chromatograph 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 [(ASTM), ASTM D 1142-95. 1995]. It uses a chilled mirror or dew point tester. This approach is labour intensive. Although automated continuous units are available, they are expensive and, unlike gas chromatographs, are currently not part of most existing gas transmission facilities (NGC-GPA White Paper, 2005). In addition, the determination of the phase envelope or the cricondentherm would be difficult using this method since

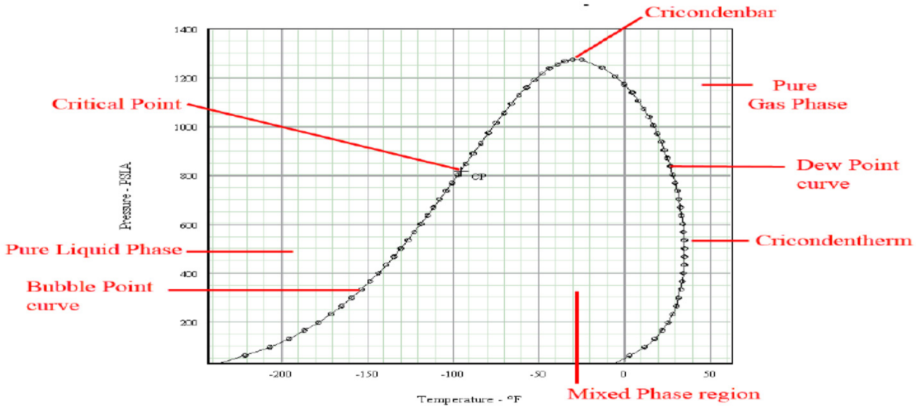

Figure 1—A phase Diagram for a Typical Natural Gas (Source; Shane Hale, 2000; Emerson Process Management, Class # 5300)

it is a periodic spot checking only. The indirect method uses a gas chromatograph (GC) for compositional analysis in conjunction with an equation of state (EOS) to estimate the dew point as well as the cricondentherm and phase envelope if desired. As the hydrocarbon dew point 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 hydrocarbon dewpoint. The composition of the pipeline gas for custody metering is determined by the use of Gas Chromatographs, most of these analyzers are generally C6+ and a few are C9+ design as reported by Jack (Jack, 2010). 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 (2005) stated that the traditional C6+ analysis provides insufficient data for a valid hydrocarbon dew point 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 behaviour 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 equation of state calculations. For energy calculation and hydrocarbon dewpoint calculation, many gas processors and end-users are now applying equation of state, either a Peng-Robinson (PR) or Soave-Redlich-Kwong (SRK) equation of state, 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 (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 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 hydrocarbon dewpoint determination has been developed by Livinus and Obah (2013) based on the observation reported by several researchers (Katz, 1983; Lorenz et al, 1964; Pedersen et al, 1982; Ahmed et al, 1985) that lighter hydrocarbon systems exhibit exponential molar distribution, it is essential to rank the prediction capability of the common C6+ composition splits used by pipeline gas operators for determining the HCDP of a pipeline gas. Several different methods are available for predicting hydrocarbon dew points 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 gas chromatography. 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 (2005). In this work, to present the ranking of the common C6+ split schemes for hydrocarbon dewpoint determination on the basis of C6+ mole fraction and gas specific gravity, the common C6+ split methods are applied to a large set of field and hypothetical C6+ data with varying hexane plus fractions and gas specific gravities, for determining hydrocarbon dewpoint. The calculated HCDP as well as cricondentherm values (using HYSYS® with PR EOS and SRK EOS) between the various C6+ composition splits are compared and ranked.

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, 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.

Application of C6+ Splits and EOS Techniques to Field and Hypothetical C6+ Compositions for Hydrocarbon Dewpoint 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 level of degree of these split methods for predicting hydrocarbon dew point was studied.

Results Analyses of the Gas Compositions using HYSYS® with PR EOS

The range of cricondentherm and as well as predicted hydrocarbon dew points, at a pipeline pressure of 215 psia for instance, for the various gas compositions with C6+ mole fractions of 0.01 to 0.03 are presented in Table 1. Figure 2, 3 and 4 present the phase envelopes of some of the gas samples analysed. For gas compositions with C6+ mole fraction of 0.01, the predicted hydrocarbon dewpoint 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 hydrocarbon dewpoint 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 hydrocarbon dewpoint 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 hydrocarbon dew point 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 hydrocarbon dew point 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 neighbourhood of 4°F is observed between Daniels 47/36/17 and GPA 50/25/25.

Table 1—Hydrocarbon Dew point Predictions and Cricondentherm along with Cricondenbar of the gas compositions using HYSYS ® with PR EOS

Gas Composition with C6+ mole fraction of 0.01	**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)**
Hydrocarbon Dew point Prediction at 215 psia	-34.53 to -36.11^{O}F	-30.65 to -32.06 ^{O}F	-39.99 to 41.99 ^{O}F
Cricondentherm	-35.05 ^{O}F	-31.02 ^{O}F	-42.62 ^{O}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^{O}F	-16.18 to -16.31^{O}F	-27.61 to -27.78^{O}F
Cricondentherm	-18.63 ^{O}F	-14.46 ^{O}F	-26.02 ^{O}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^{O}F	1.038 ^{O}F	-8.014 ^{O}F
Cricondentherm	4.627 ^{O}F	7.334 ^{O}F	-0.5866 ^{O}F
Cricondenbar	1104 psia	1107 psia	1091 psia

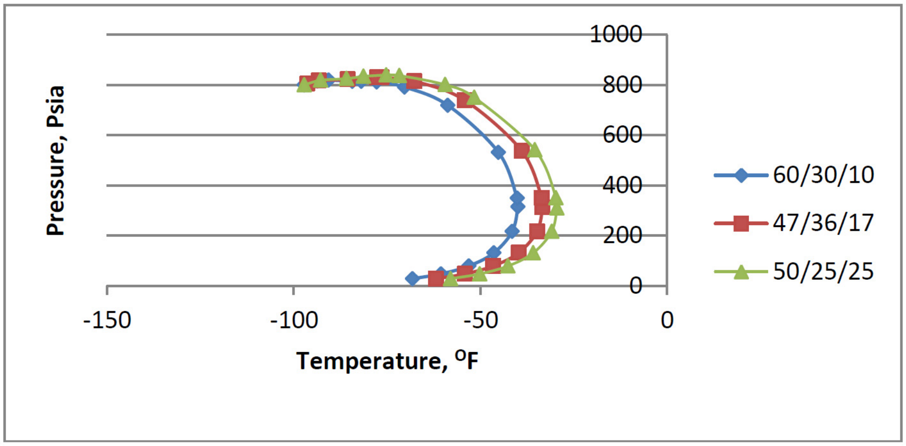

Figure 2—Different Phase envelopes, dew point curve portions, using HYSYS ® PR EOS with different C6+ characterisation methods of a pipeline gas composition with C6+ mole fraction of 0.01

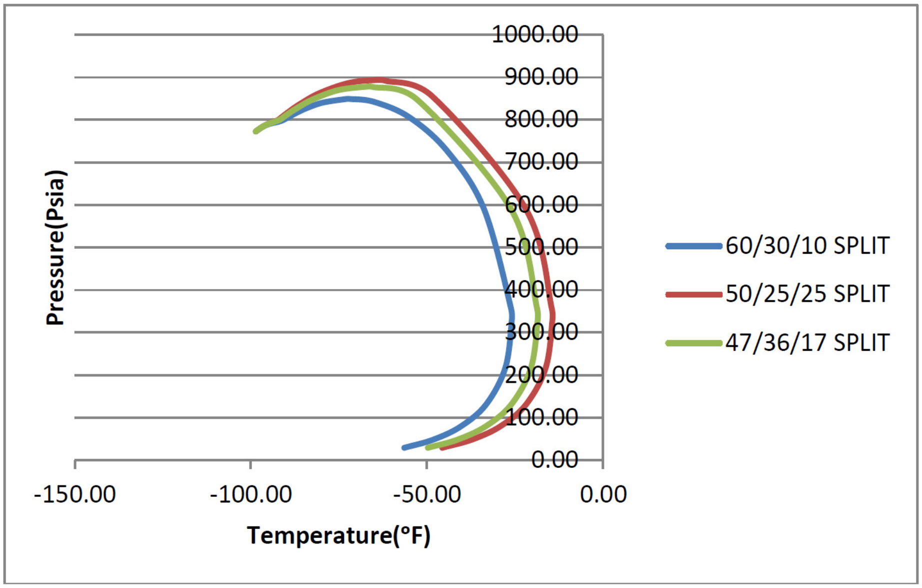

Figure 3—Different Phase envelopes, dew point curve portions, using HYSYS ® PR EOS with different C6+ characterisation methods of a pipeline gas composition with C6+ mole fraction of 0.02

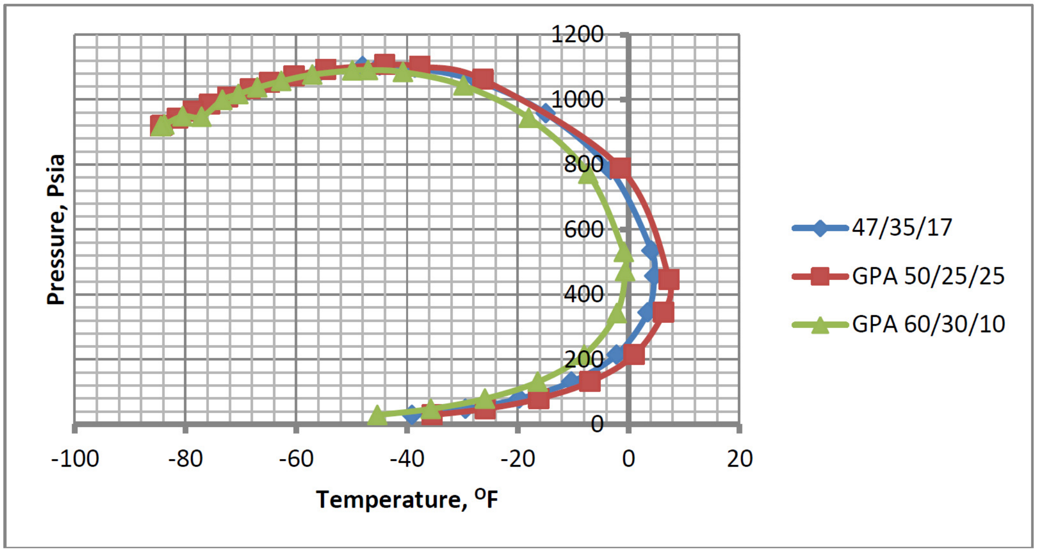

Figure 4—Different Phase envelopes, dew point curve portions, using HYSYS ® PR EOS with different C6+ characterisation methods of a pipeline gas composition with C6+ mole fraction of 0.03

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 hydrocarbon dew points, at a pipeline pressure of 215 psia for instance, for the various gas compositions with C6+ mole fractions of 0.01 to 0.03 are presented in Table 2. Figure 5, 6 and 7 present the phase envelopes of some of the gas samples analysed. In all cases, similar trend as in PR EOS was observed, the hydrocarbon dew point 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 hydrocarbon dew point 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 neighbourhood of 4°F is observed between Daniels 47/36/17 and GPA 50/25/25.

Table 2—Hydrocarbon Dew point Predictions and Cricondentherm along with Cricondenbar of the gas compositions using HYSYS® with SRK EOS

Gas Composition with C6+ mole fraction of 0.01	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)
Hydrocarbon Dew point Prediction at 215 psia	-30.91 to -31.33^{O}F	-26.93 to -27.31 ^{O}F	-37.68 to -38.19 ^{O}F
Cricondentherm	-29.88 ^{O}F	-25.61 ^{O}F	-36.39 ^{O}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 ^{O}F	-12.00 to -12.02 ^{O}F	-23.37 to -23.78 ^{O}F
Cricondentherm	-14.19 ^{O}F	-10.00 ^{O}F	-21.61 ^{O}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^{O}F	1.038 ^{O}F	-8.014 ^{O}F
Cricondentherm	4.627 ^{O}F	7.334 ^{O}F	-0.5866 ^{O}F
Cricondenbar	1104 psia	1107 psia	1091 psia

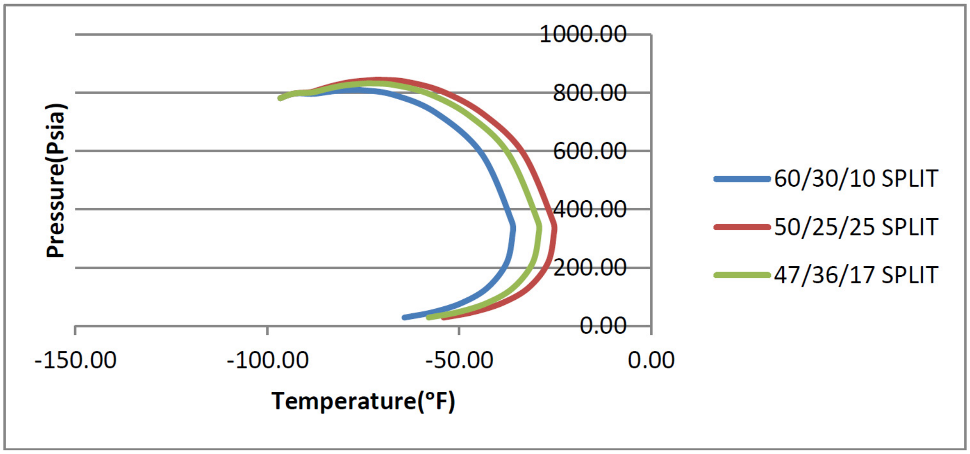

Figure 5—Different Phase envelopes, dew point curve portions, using HYSYS® SRK EOS with different C6+ characterisation methods of a pipeline gas composition with C6+ mole fraction of 0.01

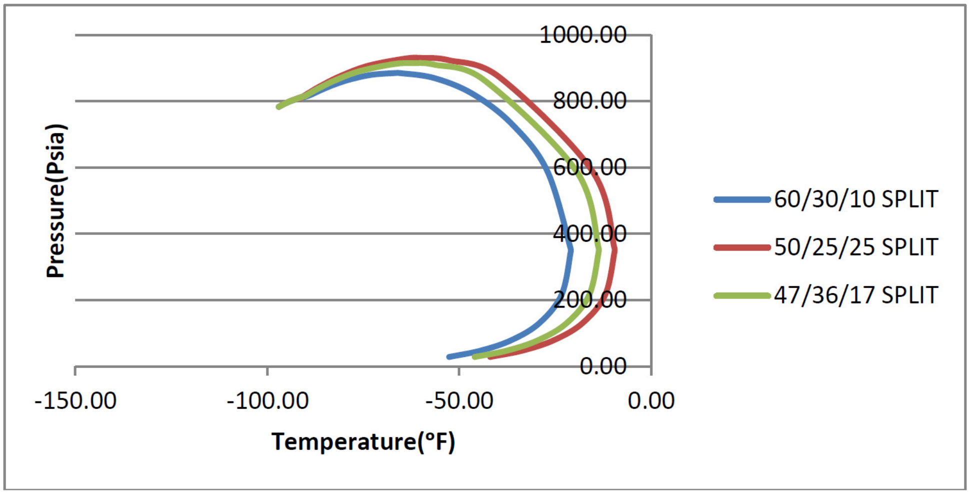

Figure 6—Different Phase envelopes, dew point curve portions, using HYSYS® SRK EOS with different C6+ characterisation methods of a pipeline gas composition with C6+ mole fraction of 0.01

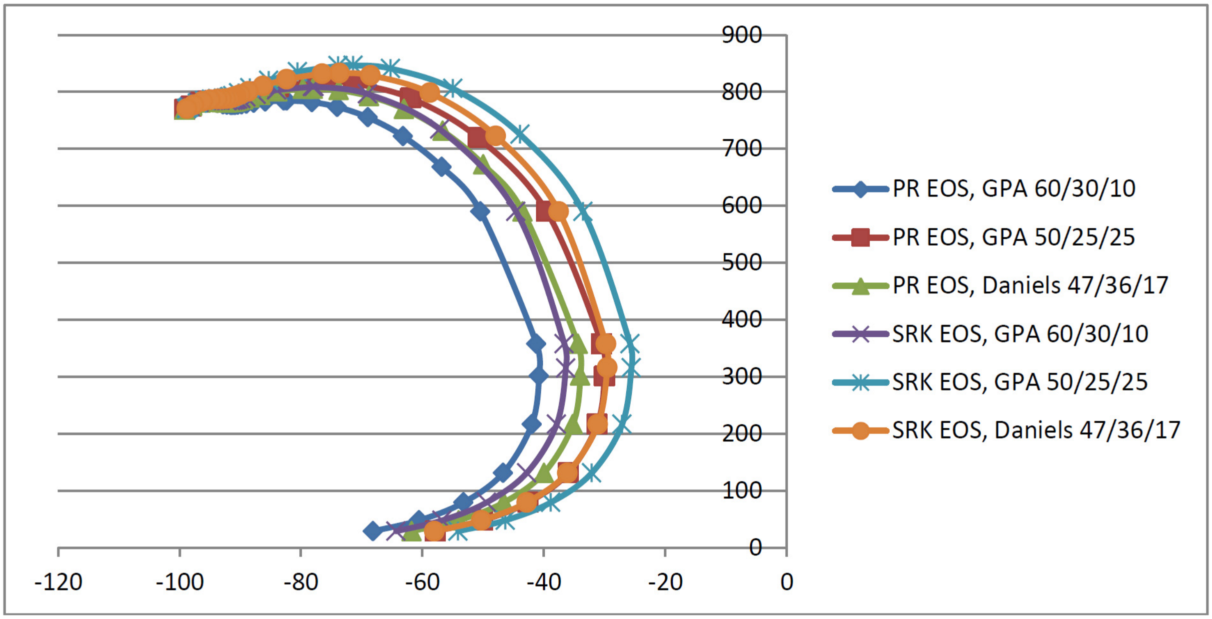

Figure 7—The comparisons of the different Phase envelopes, dew point curve portions, using HYSYS® SRK EOS and PR EOS with different C6+ characterisation methods of a pipeline gas composition with C6+ mole fraction of 0.01.

Comparisons of predicted hydrocarbon dew points and cricondentherm between PR EOS and SRK EOS

When the values predicted by SRK EOS and PR EOS were compared, a variation within the neighbourhood 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 hydrocarbon dew point values for the various gas compositions with C6+ mole fraction of 0.01 to 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+ characterisation methods of a pipeline gas composition with C6+ mole fraction of 0.01.

Conclusion

Most of the Gas Chromatographs used for determing the composition of pipeline gas for custody metering are generally C6+ and a few are C9+ design; though the traditional C6+ analysis provides insufficient data for a valid hydrocarbon dew point calculation, however it is essential to rank the predictive capability of the common C6+ composition splits used by pipeline gas operators for determining the HCDP of a pipeline gas: the predicted hydrocarbon dewpoint results for the various gas compositions with C6+ mole fractions of 0.01 to 0.03 using PR EOS, in all cases, indicate GPA 50/25/25 to have the highest, followed by that of Daniels 47/36/17 and the least results are from GPA 60/30/10. The hydrocarbon dew point 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 neighbourhood 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 slight variation. The ranking order in which the two equations of state for the various C6+ split methods predicted the hydrocarbon dew point values for the various gas compositions with C6+ mole fraction of 0.01 to 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.

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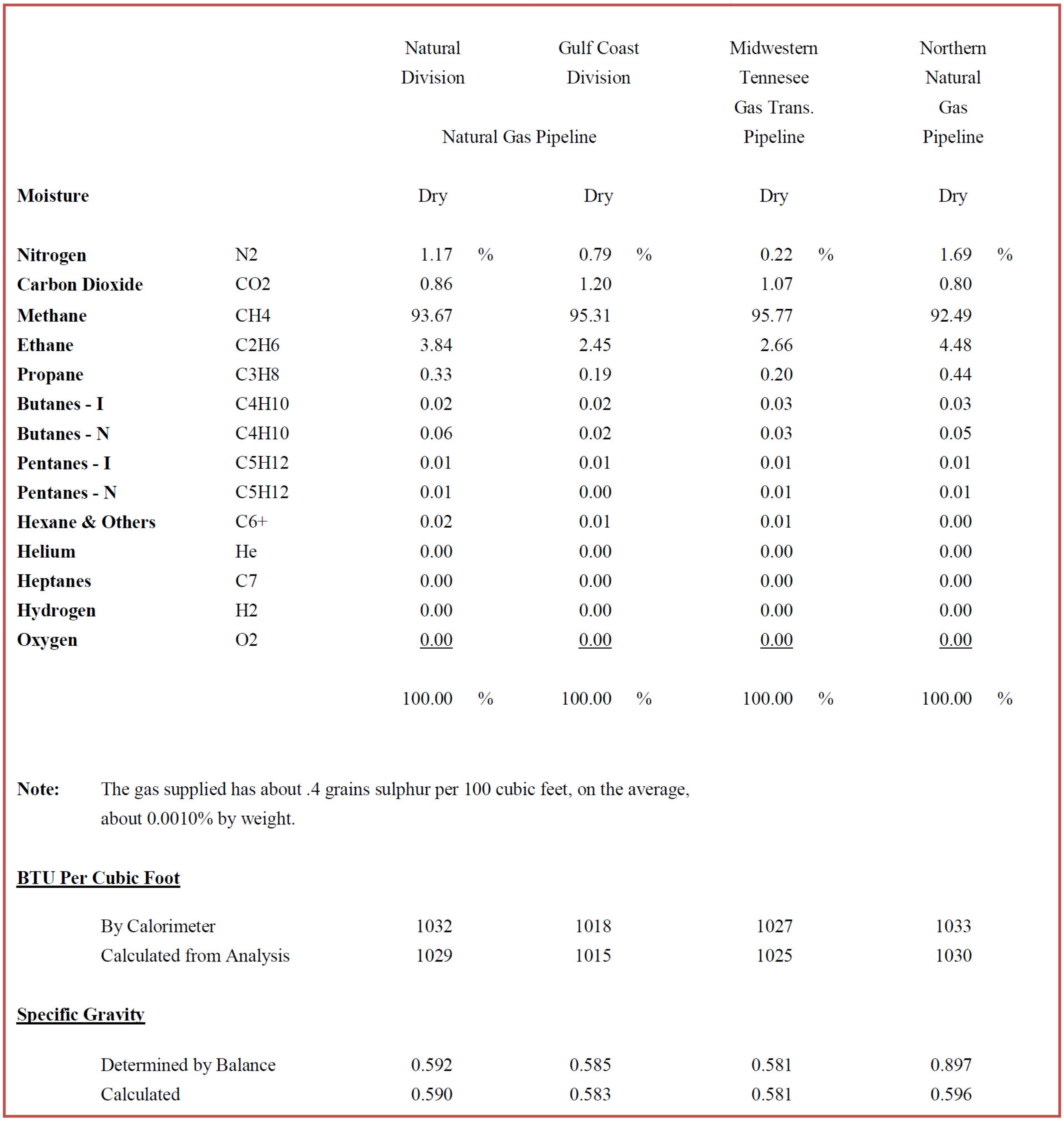
APPENDIX

Table A-1—Gas Samples used in the Study



		Natural Division	Gulf Coast Division	Midwestern Tennesee Gas Trans. Pipeline	Northern Natural Gas Pipeline
		Natural Gas Pipeline			
Moisture		Dry	Dry	Dry	Dry
Nitrogen	N2	1.17 %	0.79 %	0.22 %	1.69 %
Carbon Dioxide	CO2	0.86	1.20	1.07	0.80
Methane	CH4	93.67	95.31	95.77	92.49
Ethane	C2H6	3.84	2.45	2.66	4.48
Propane	C3H8	0.33	0.19	0.20	0.44
Butanes - I	C4H10	0.02	0.02	0.03	0.03
Butanes - N	C4H10	0.06	0.02	0.03	0.05
Pentanes - I	C5H12	0.01	0.01	0.01	0.01
Pentanes - N	C5H12	0.01	0.00	0.01	0.01
Hexane & Others	C6+	0.02	0.01	0.01	0.00
Helium	He	0.00	0.00	0.00	0.00
Heptanes	C7	0.00	0.00	0.00	0.00
Hydrogen	H2	0.00	0.00	0.00	0.00
Oxygen	O2	0.00	0.00	0.00	0.00
		100.00 %	100.00 %	100.00 %	100.00 %

Note: The gas supplied has about .4 grains sulphur per 100 cubic feet, on the average, about 0.0010% by weight.

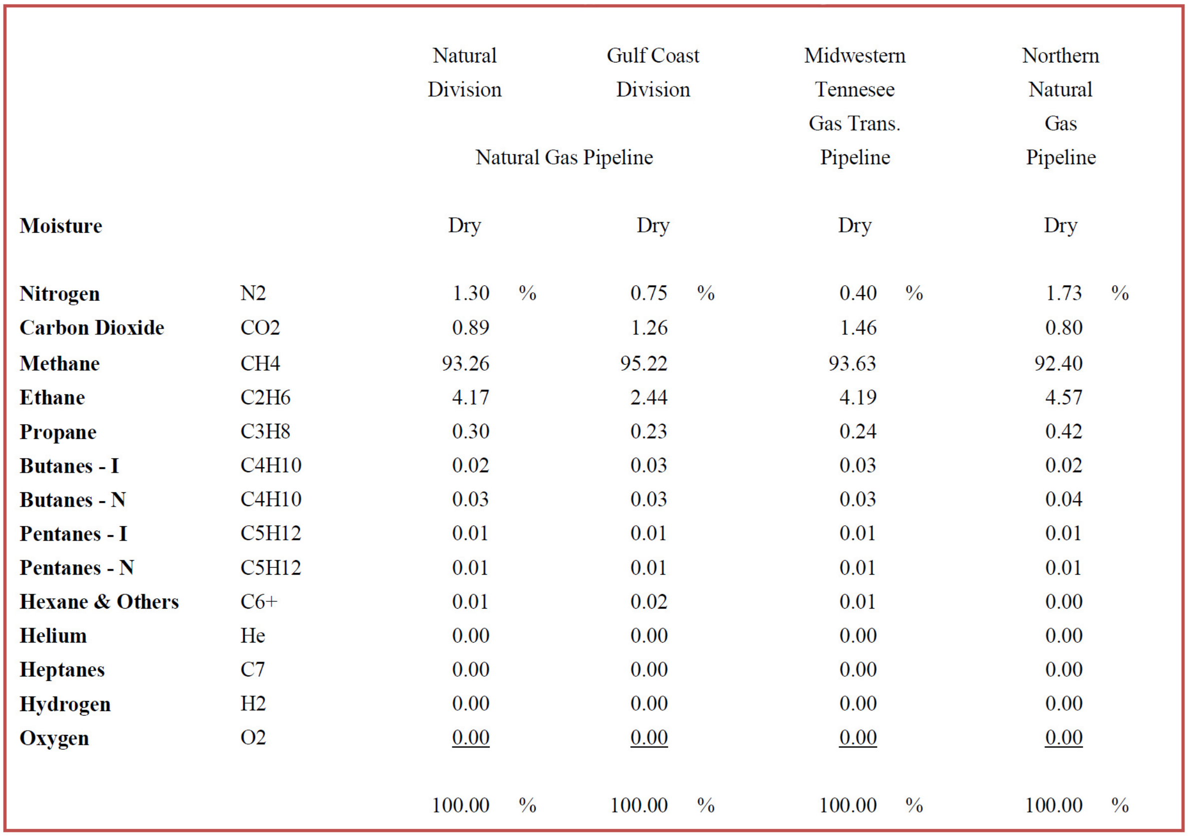
BTU Per Cubic Foot

	Natural Division	Gulf Coast Division	Midwestern Tennesee Gas Trans. Pipeline	Northern Natural Gas Pipeline
By Calorimeter	1032	1018	1027	1033
Calculated from Analysis	1029	1015	1025	1030

Specific Gravity

	Natural Division	Gulf Coast Division	Midwestern Tennesee Gas Trans. Pipeline	Northern Natural Gas Pipeline
Determined by Balance	0.592	0.585	0.581	0.897
Calculated	0.590	0.583	0.581	0.596

Table A-2—Gas Samples used in the Study



		Natural Division	Gulf Coast Division	Midwestern Tennesee Gas Trans. Pipeline	Northern Natural Gas Pipeline
		Natural Gas Pipeline			
Moisture		Dry	Dry	Dry	Dry
Nitrogen	N2	1.30 %	0.75 %	0.40 %	1.73 %
Carbon Dioxide	CO2	0.89	1.26	1.46	0.80
Methane	CH4	93.26	95.22	93.63	92.40
Ethane	C2H6	4.17	2.44	4.19	4.57
Propane	C3H8	0.30	0.23	0.24	0.42
Butanes - I	C4H10	0.02	0.03	0.03	0.02
Butanes - N	C4H10	0.03	0.03	0.03	0.04
Pentanes - I	C5H12	0.01	0.01	0.01	0.01
Pentanes - N	C5H12	0.01	0.01	0.01	0.01
Hexane & Others	C6+	0.01	0.02	0.01	0.00
Helium	He	0.00	0.00	0.00	0.00
Heptanes	C7	0.00	0.00	0.00	0.00
Hydrogen	H2	0.00	0.00	0.00	0.00
Oxygen	O2	0.00	0.00	0.00	0.00
		100.00 %	100.00 %	100.00 %	100.00 %