

Effects of C6+ split versus C9+ Analysis on Gas Measurement

Class # 52116

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Introduction:

This study outlines a process that was used to validate using a C6+ split (i.e. 60-30-10) versus a C9+ chromatograph analysis in natural gas measurement. Given the accepted use of a 60-30-10 split, this study intended to determine the validity/effectiveness of such an assumption relative to a full C9+ analysis within measurement and custody exchange.

Problem Statement:

In natural gas measurement, gas chromatographs (GCs) determine the mole percentages of various gas components. Traditionally, industry practice has been to measure individual components only up to hexane (C6) and assume a distribution of the heavier hydrocarbons as 60% hexane, 30% heptane (C7), and 10% octane (C8). However, with the increasing availability of GCs capable of measuring up to nonane (C9), the accuracy of the 60-30-10 assumption needs to be revisited.

This assumption has implications in two key areas:

1. **Measurement Accuracy:** The composition of natural gas directly influences critical properties such as relative density, compressibility, speed of sound, volume, and heating value. Even minor deviations in the concentrations of heavier hydrocarbons (C6–C8) can significantly impact these properties, potentially leading to system-wide imbalances.
2. **Custody Transfer and Commercial Impact:** Since volume and heating value are derived from gas composition, discrepancies between a C6+ and a C9+ analysis can affect billing at both receipt and delivery points. This, in turn, influences contract negotiations and financial settlements.

Methodology:

Approximately 500 samples were collected from a system with higher and varying quantities of C6+. Each sample underwent both a standard (C6+) and an extended (C9+) chromatographic analysis. Key gas properties—such as specific gravity, heating value, and compressibility—were calculated based on the resulting compositions.

After validating data integrity and removing outliers or erroneous samples, 487 samples were retained for statistical analysis.

To evaluate the impact of the C6+ assumption, the actual distribution of C6–C9 components was compared to the assumed 60-30-10 split using the following formula:

$$\text{CX Actual Split} = \left(\frac{\text{CX Concentration}}{\text{C6} + \text{C7} + \text{C8} + \text{C9 Concentration}} \right) \times 100\%$$

Equation 1: Calculation for finding the true C6+ split of a certain component from hexane to nonane

Given the higher resolution of the C9+ analysis, it is treated as the “true” composition, while the C6+ analysis is considered an approximation. The percentage error between the two was calculated to quantify the deviation.

Four graphs were generated to visualize the differences in key gas properties—heating value, relative density, compressibility, and volume—between the two analysis methods. Each graph plots the sample number (1–487) against the corresponding percentage error, providing a broad overview of how the C6+ assumption affects measurement accuracy across various locations.

T-tests were also used to evaluate how the sample distributions compared to both a hypothesized mean (a single sample t-test) and the mean for each sample component (a two-sample t-test). The single sample t-test compared the 60-30-10 split estimated component quantities to the C9+. The two sample t-test compared the calculated values for the Heating Value and Relative Density using a 60-30-10 split to the values using the C9+ analysis data. If a t-value for a sample is positive the assumption is higher than actual values and lower for a negative result. The following equations were used.

For the single same T-test:

$$t = \frac{x - \mu_0}{s/\sqrt{n}}$$

Where:

- x = sample mean
- μ_0 = hypothesized population mean
- s = sample standard deviation
- n = sample size

For the two sample T-test:

$$t = \frac{x_1 - x_2}{s_p \sqrt{\frac{1}{n_1} + \frac{1}{n_2}}}$$

Where:

- x = sample means
- n_1, n_2 = sample sizes
- s_p = pooled standard deviation

$$s_p = \frac{\sqrt{(n_1 - 1)s_1^2 + (n_2 - 1)s_2^2}}{n_1 + n_2 - 2}$$

Where:

- s_1^2, s_2^2 = sample variances

Results and Data:

The lab provided 509 C9 Analysis Samples, with accompanying C6 analyses taken from the same samples. Direct comparison of these two different sample groups was used to identify the effectiveness of a standard versus extended gas composition analysis.

A few different samples were removed from the sample size for various reasons. First, samples with a flow rate of 0 MCF/Day at the time of sampling were excluded. During periods of no flow the possibility of condensation increases and would add additional uncertainty to the analysis. Additionally, samples with over 1% H₂S were removed because of a miscommunication with the lab on how these samples needed to be reported (more specifically, H₂S is not included in the heating value calculation but is included in the relative density). With these samples removed, the final sample size came to 487.

With the complete C9 sample size compiled, each sample was paired with its corresponding C6 analysis. With the assumption that C9 is more accurate than C6 (a reasonable assumption given (1) the nature of gas chromatography, and (2) the steps taken to ensure the quality of the data), the percentage error was taken between a samples C6 and C9 analysis for various gas property values. With a 95% Confidence level a T-value greater than ± 1.964 (the number of samples being 487 and the confidence level being 0.95 is what gives us a t-critical value of ± 1.964) indicates the t-test fails and the difference is deemed "statistically significant."

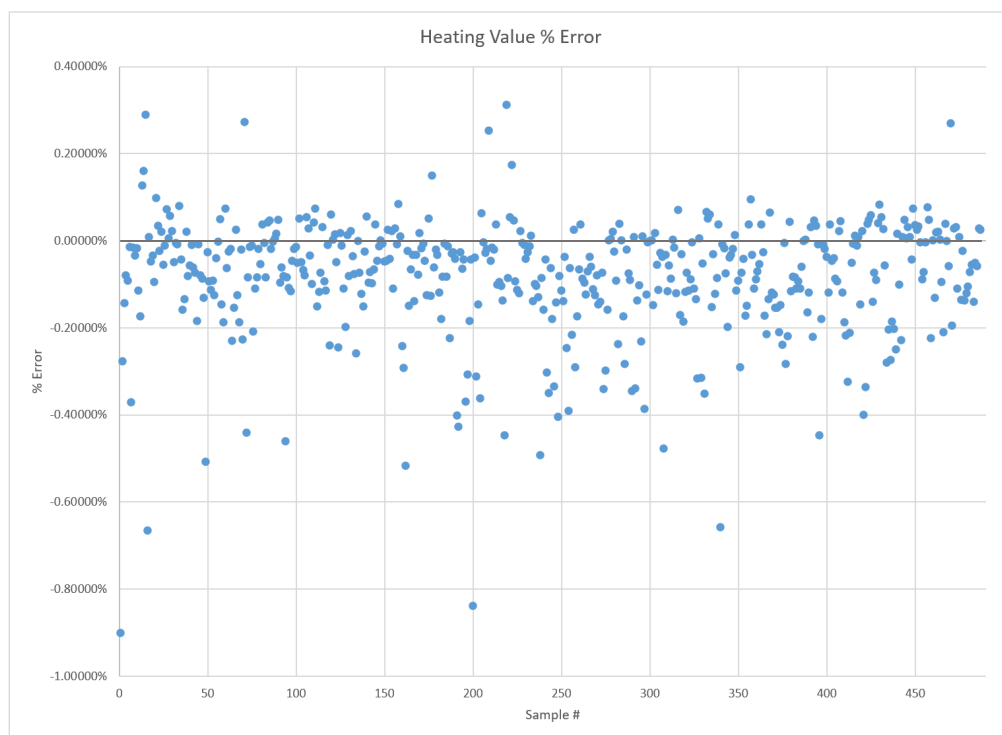


Figure 1: Scatter Plot Mapping Sample Number to *Heating Value* % Error Between C6+ and C9+ Analysis

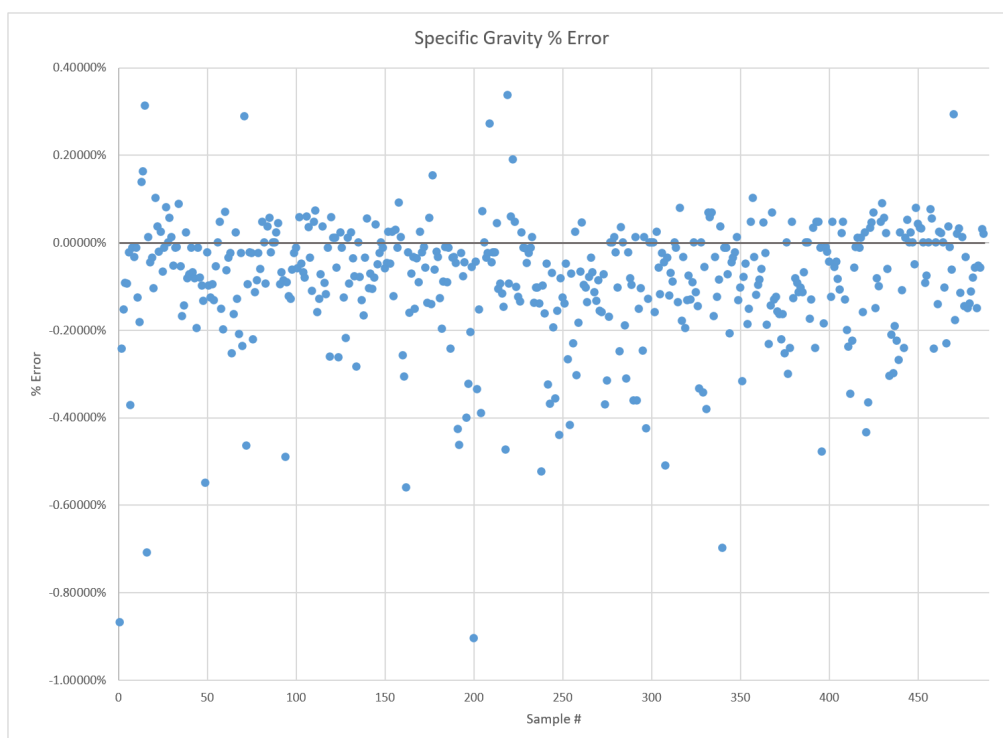


Figure 2: Scatter plot mapping sample number to *relative density* % error between C6+ and C9+ analysis

T-Test				
Heating Value:			Relative Density:	
n	487		n	487
Average Difference	1.2410745		Average Difference	0.000802
Standard Deviation	2.0707928		Standard Deviation	0.001341
t-critical	+/-1.964		t-critical	+/-1.964
t-value	-13.225914		t-value	-13.19855

Table 1: Matched sample t-tests for heating value and relative density with 95% confidence level

The T-tests for Heating Value and Relative Density fail and show a significant statistical difference (Table 1). Both tests indicate that the assumed values using a 60-30-10 split are skewed lower than the actual from a C9+ analysis.

This is further supported by looking at the true split of hexane, heptane, octane, and nonane within these samples. This was calculated using Equation 1.

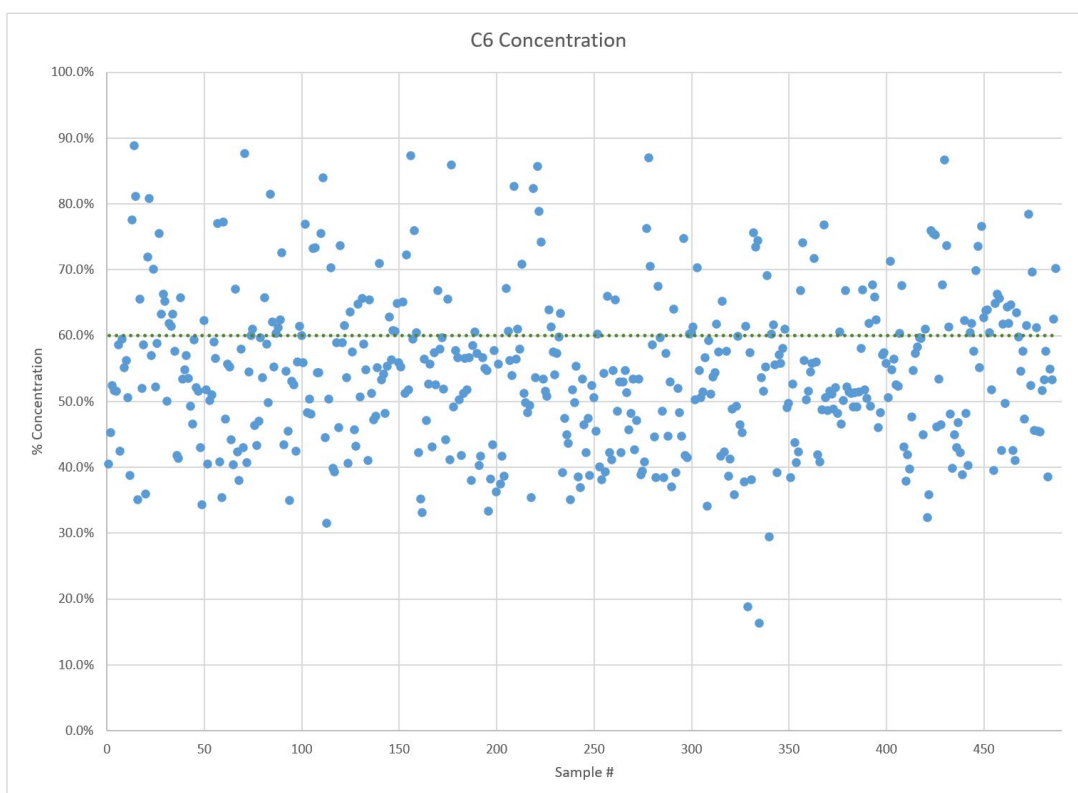


Figure 3: Scatter plot depicting *true* hexane split for each sample

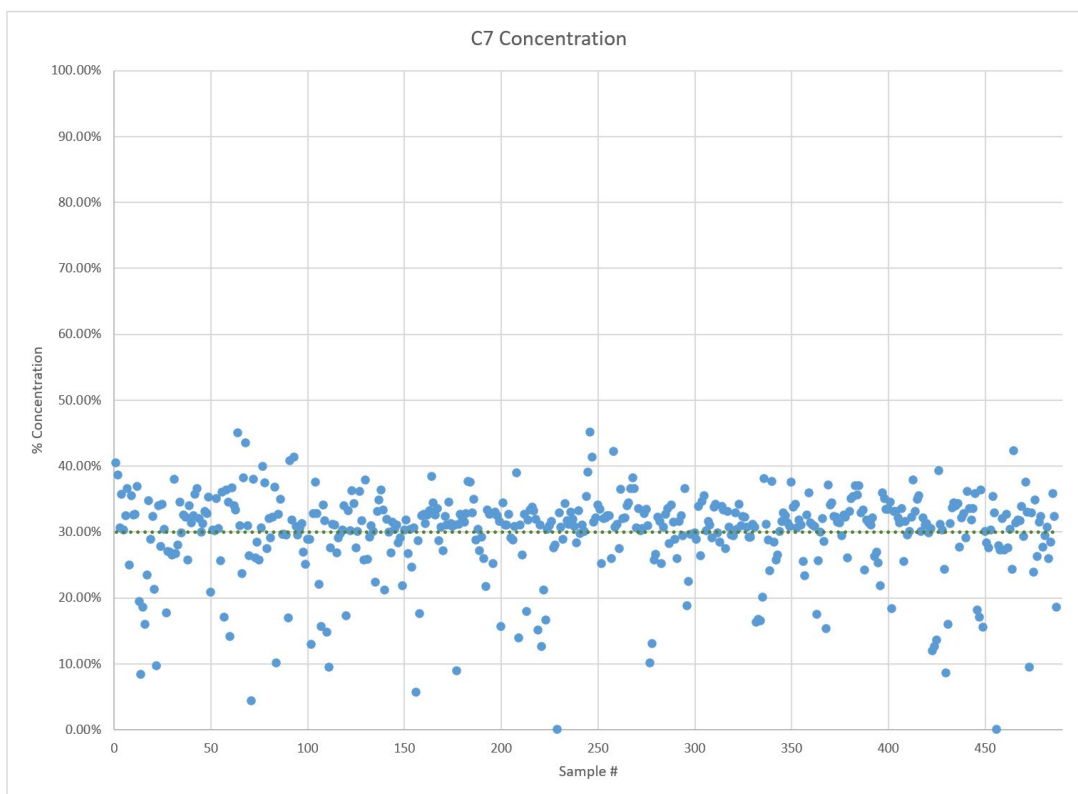


Figure 4: Scatter plot depicting *true heptane* split for each sample

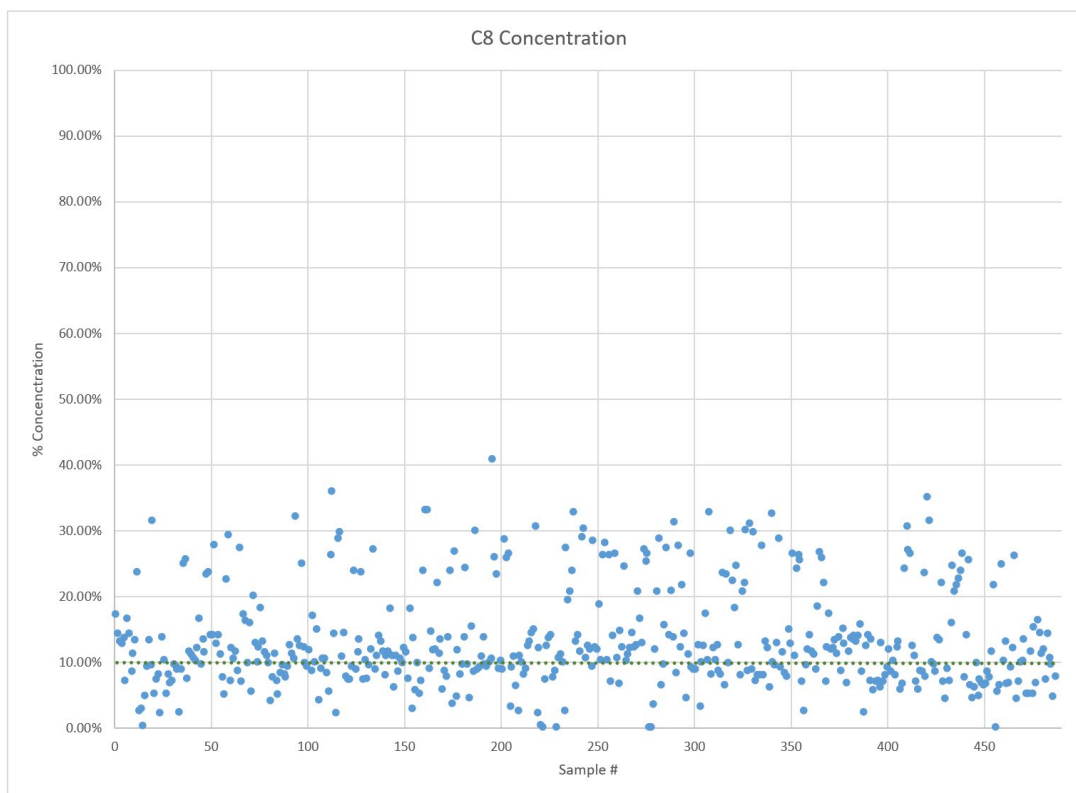


Figure 5: Scatter plot depicting true *octane* split for each sample

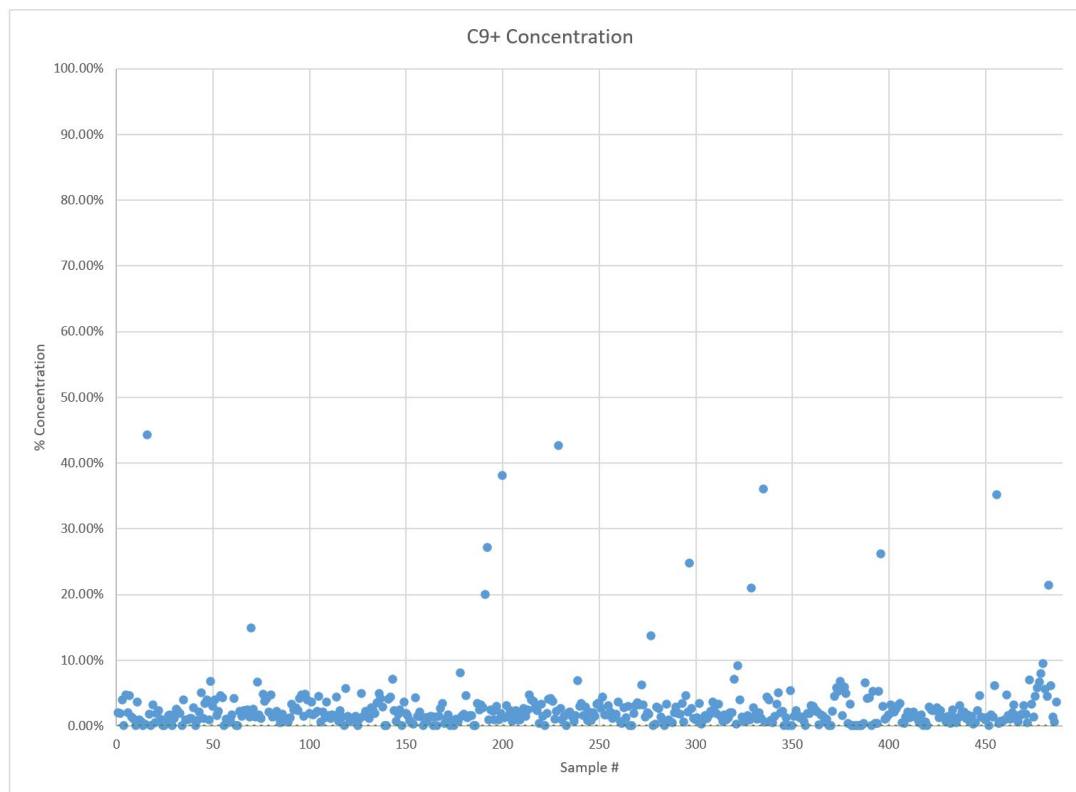


Figure 6: Scatter plot depicting true *nonane* split for each sample

t-Test:				
	C6	C7	C8	C9+
n	487	487	487	487
Average Difference	0.057487	0.002396	-0.03265	0.027229
Standard Deviation	0.115829	0.065325	0.075781	0.04782
t-critical	+/-1.964	+/-1.964	+/-1.964	+/-1.964
t-value	-10.95264	-0.809441	-9.50933	-12.56558

Table 2: Matched sample t-tests (95% confidence level) for actual versus assumed split

The t-test indicates the 60-30-10 split does not sufficiently describe the hexane, octane, and nonane split retrieved from the C9+ analysis. Hexane's concentration seems to be generally overestimated, while octane is underestimated and nonane is completely ignored. This data also explains why the Heating Value and Specific Gravity were generally skewed downwards: because the 60-30-10 split, on average, lowers the true concentration of the heavier components of the gas.

Conclusion:

For the samples that were analyzed, the 60-30-10 split appears to be inaccurate due to higher variable quantities of C6+ components. By analyzing actual component data and performing T-tests comparing actual C6+ splits to the assumed values, it is clear the assumed 60% C6 and 10% C8 are inaccurate (Table 2 and Figures 3 & 5). C6 concentrations are generally lower, while C8 concentrations are higher. These inaccuracies can be addressed in a couple of different ways. The first option is to utilize a C9+ analysis and develop a more accurate split based on T-test results. Adjusting the split values would improve measurement accuracy. Additionally, C9 should be considered, as over 70% of the samples analyzed showed at least 1% of the C6+ concentration as C9+ (Figure 6). Another option would be to transition to a C9+ analysis where the actual values would be used for calculations versus utilizing assumed values. Given the significant variance observed in nearly every gas measurement parameter, the second option appears more effective.