GET WHAT YOU DESERVE!
MEASUREMENT AND PRODUCT ALLOCATION

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Introduction

Determining measured volumes and calculating product allocation results are the culmination of many processes and activities. Of these, two of the most important steps are the collection of representative samples and accurate analysis of product composition. There are other factors that affect measured volumes and product allocation, but for the purposes of this paper, the focus is on the impact of fluid analysis quality.

The key factors in getting what you deserve are the correct determination of measured volumes and the calculation of product allocation results. The fluid analysis has a direct impact on both of these activities. On the measurement side, the density of the fluid impacts the measurement calculation, particularly with gas measurement. On the allocation side, the fluid analyses used in conjunction with the measured volumes determines the value of all measured and allocated product streams. These calculated values are the basis for all revenue and royalty streams reported to all stakeholders.

Unfortunately, errors in fluid analysis results are a common occurrence. On average, 3-5% of all well fluid analyses and up to 20% of facility fluid analyses are not representative of the flowing stream

The cause of most fluid analysis errors can usually be traced back to a sampling error or misapplication of analysis data. Occasionally however, errors are made in the actual analysis at the lab. The most common sampling errors are related to sampling frequency, sampling procedures, sample location and/or sampling equipment. Insufficient sample frequency and air and/or liquid contamination are the most typical sampling problems. *Misapplication of analysis data* refers to when analyses are not correctly applied to the measurement and allocation systems where they are required for calculations. This frequently occurs because companies do not possess the correct processes and tools to manage this information effectively.

Aside from the obvious impact on revenue distribution, one of the most significant areas impacted by errors in measured volumes and product allocation calculations is corporate overhead. Product allocations, at their core, are simply a large proration model. Wells and owners are allocated a share of product from a processing plant based on the volume and quality of fluids that they deliver the plant. If an error in any one measured volume or fluid analysis occurs, the results for every individual well and owner will be affected. The entire product allocation (which includes all revenue, royalty and processing fee calculations) must be redone.

It is estimated that 50% of all monthly product allocations and associated revenue, royalty and processing fee calculations are redone at least once. For most companies, this means that at least one third of their accounting staff, and a certain amount of support from operations and engineering departments, are directly involved in correcting errors. Rework of product allocation calculations has a serious ripple effect in industry. Consider that a processing facility could have as many as 200 different producers with interests in production flowing through a plant. A rework of the product allocation will result in each producer receiving revised volumetric, processing fee and revenue statements. As a result each producer is required to completely replicate the monthly process, which entails rebooking and processing fees, as well as recalculating and re-filing payments.

The objective of this paper is to provide attendees with the knowledge in assessing the risk of measurement and product allocation error and identify ways to mitigate these risks.

Product Allocation Defined

A product allocation is simply a mathematical model that describes the requirements, principles, rules and methods for sharing and/or distributing products processed at a gas processing facility back to the wells and owners that commingled their products for processing. Most allocation procedures follow industry accepted principles and are designed to be fair and equitable to all producers that deliver to gas processing facilities.

A product allocation is typically more complex than an oil battery proration, particularly when raw gas is processed into multiple products (residue gas, LPG, condensate, sulfur, etc.) and if there are multiple dispositions that are not all shared equally. There are no actual industry standards (e.g. GPA, API, EUB, Measurement Canada, etc.) for product allocation from gas processing facilities. The Petroleum Joint Venture Association (PJVA) has created a document that may be used as an allocation procedure template. However, most allocation procedures are customized documents, unique to each processing facility.

Product Allocation - Measurement Requirements

Most product allocation procedures have a measurement clause where key measurement requirements are outlined. Many of these clauses are fairly basic and most do not set rigorous requirements to ensure accurate measurement for accurate allocation results. Sampling requirements are an example of an area where the requirements are often not adequately specified. Many plant allocation procedures are silent on this requirement. The ones that do stipulate a minimum sampling frequency typically state “Samples must be obtained a minimum of once each year or whenever the operator requires.” In many cases, once each year is insufficient and in many other cases it is not frequent enough.

Producers and processors should be reviewing potential risk when determining how often to sample as well as which method of sampling method (Grab sample, proportional sample or gas chromatograph) to use. Consider that the cost of acquiring and analyzing a sample is typically between $100 and $300 and that the typical sampling frequency is annual. If a shift in the composition in a sample could cause a $10,000/year error, is more frequent sampling not warranted?

Impact of Fluid Analysis Error on Measurement Accuracy

For determination of measured volumes, fluid analysis quality has a much larger impact on gas measurement than liquid. The reason for this difference lies with the compressibility of fluids in a gas state versus a liquid state. Gas is a highly compressible fluid and gas volumes can vary significantly when correcting gas volumes to standard conditions (101.325 KPa and 15 Degrees Celsius). Current regulations require that all calculated gas volumes be corrected for fluid compressibility. The most used standard for this calculation is a standard called AGA Report#8. Based on the density derived from a gas composition, a correction factor is calculated that is applied against the uncorrected volume determined in the standard gas volume equation. For orifice meters, the standard calculation is AGA Report #3.

For orifice meters, the compressibility correction falls under a square root operator in the equation. This means that an error in volume calculated will not be directly proportional to the error in density but rather will be closer to the square root of the density error. For example, if an error is made in determining the composition of a fluid and a 9% error in density occurs, the volume error can be estimated at 3%. This estimated volume error is simply calculated as the square root of 9%. Please note that this calculation is used for quick estimate purposes and will vary depending on the flowing temperature and pressure of the gas stream. In typical situations, the maximum expected volume impact from a gas would be +/- 5%. However, there are extreme instances where the error could be as high as 10%.

For liquid meters, there are two ways to impact measured volumes and the impact of analysis error on volume determination is not as significant as it is with gas.

1. When high pressure liquid meters are proved (verified), the liquid density is required to determine the temperature correction. The lighter the liquid density (i.e. LPG) is, the greater the impact of density on the temperature correction factor.

2. However, there is a second way that high pressure liquid volumes can be impacted by fluid analysis error. The composition of a fluid analysis is used to determine gas equivalent volumes for reporting purposes. It is not unheard of to have errors in gas equivalent factors of as much as +/- 10% due to errors in fluid composition. This is somewhat mitigated by the fact the gas equivalent volumes from liquids make up a small part of total gas volumes at a facility when compared to the gas only streams that flow to a plant.

Gas Density Error Example - Solution Gas Sales Meter

A sales meter is measuring flow at about 33.0 1000m3/day at 3100 kPa and 20 degrees Celsius. Average relative density of the gas has been about 0.713. The table below compares the current analysis that is liquid contaminated with the last three samples in history and illustrates the impact on volume and theoretical energy.

Date Sampled	13-Feb-07	11-Jan-07	09-Nov-06	17-Oct-06				
Source Pressure kPa	3100	3100	2300	2344				
Source Temperature °C	20	22	13	18				
Received Pressure kPa	2280	3648	2358	2280				
Received Temperature °C	22	22	22	22				
Components/ Properties	**1**	**2**	**3**	**4**	**Lo Normal**	**Hi Normal**	**% Compare**	**S.D. Validation**
H2	0.0000	0.0000	0.0000	0.0000	✓	✓	✓	✓
He	0.0001	0.0001	0.0002	0.0002	✓	✓	✓	✓
N2	0.0113	0.0101	0.0114	0.0111	✓	✓	✓	✓
CO2	0.0073	0.0072	0.0090	0.0076	✓	✓	✓	✓
H2S	0.0000	0.0000	0.0002	0.0001	✓	✓	✓	✓
C1	0.7637	0.8214	0.8173	0.8219	✓	✓	×	×
C2	0.0728	0.0709	0.0691	0.0686	✓	✓	✓	✓
C3	0.0726	0.0552	0.0544	0.0534	✓	✓	✓	×
IC4	0.0119	0.0076	0.0078	0.0074	✓	✓	×	✓
NC4	0.0324	0.0182	0.0193	0.0182	✓	✓	×	✓
IC5	0.0092	0.0039	0.0046	0.0043	✓	✓	✓	✓
NC5	0.0094	0.0036	0.0043	0.0041	✓	✓	✓	✓
C6	0.0057	0.0012	0.0017	0.0020	✓	✓	✓	✓
C7+	0.0036	0.0006	0.0007	0.0011	✓	✓	✓	✓
Sample Relative Density	0.795	0.709	0.716	0.712	✓	✓	×	
IC4/NC4 Ratio	0.367	0.418	0.404	0.407	✓	✓		
Sample GHV MJ/m^3	50.56	45.59	45.73	45.65	✓	✓	×	
[illegible]imated Volume e3m3	984.968	1024.74						
Volume Gain/(Loss)	-3.88%							
Sample Value $/month	$298,800	$280,307						
Value Gain/(Loss)	6.60%							

The latest analysis is received with a relative gas density of 0.795. A validation of the analysis indicates that the sample is liquid contaminated. The density of the latest sample is 12.05% greater than the previous samples. The Gross Heating Value is 10.90% greater than the previous sample. A calculation of volume using the previous sample and the latest sample shows that using the latest composition would result in a 4.00% shift downward in volume. This is offset by a 10.90% increase in relative value based on the change in Gross Heating Value. At a price of $7.00/GJ, use of the new liquid contaminated composition would result in lower volume, offset by higher heating value.

On a flow rate of 33.0 e3m3/day, this sampling error is valued at $21,575/month in over-stated energy value with a volume reduction of 4.00%. Over the course of a year, this error would total $258,900.

4.0 Impact of Fluid Analysis Error on Product Allocation

Error in fluid analysis has the largest impact on product allocation. The composition of gas and high pressure liquids analyses directly determines the value of a revenue stream. Whenever a component is misstated, there is a direct impact on the value of a stream. Each component in the gas and liquid hydrocarbon streams has a specific value which can vary depending on whether the component is sold as a gas or as a liquid. The table below highlights the differences in product value by component and is based on Alberta Energy December 2006 reference prices.

	Value $/GJ as Residue Gas	Value $/GJ as Liquid	Value Increase
H2	$ 7.05	$ 7.05	
He	$ -	$ -	
N2	$ -	$ -	
CO2	$ -	$ -	
H2S	$ -	$ -	
C1	$ 7.05	$ 7.05	100%
C2	$ 7.05	$ 7.17	102%
C3	$ 7.05	$ 10.48	149%
IC4	$ 7.05	$ 12.46	177%
NC4	$ 7.05	$ 12.01	170%
IC5	$ 7.05	$ 13.94	198%
NC5	$ 7.05	$ 13.80	196%
C6	$ 7.05	$ 15.66	222%
C7+	$ 7.05	$ 17.57	249%

As the table above demonstrates, recovering C3 (propane) and heavier components as a liquid has much higher value for a producer. For example, 1.0 m3 of liquid propane in December 2006 is priced at $268. If it is sold in gas phase, the value is only $180 (1.0 m3 C3 X 0.27222 1000m3 Gas/m3 liquid X 93.936 GJ/1000m3 Gas X$7.05/GJ). This makes propane worth 49% more in liquid form.

The heavier the component, the higher the value is when recovered as a liquid. This table describes why inaccurate analyses typically have a greater impact on the product allocation than they do on measured volumes.

Product Allocation Error Example - Solution Gas Sales Meter

This example is a more precise look at the measurement error, previously discussed for the solution gas sales meter. In the measurement error discussion, the error was quantified on a gross heating value basis which assumes that the volume discrepancy is just a gas value adjustment. In situations where no hydrocarbon liquids are extracted from the gas, a simple heat valuation is all that is required. However, if hydrocarbon liquids are extracted, the effect on liquid and residue gas allocation must be factored in. The table below compares the current liquid contaminated analysis with the previous sample and illustrates the impact on allocated revenue by factoring in both the measurement error and liquid recovery.

	Expected Allocation Jan 11, 2007 Sample Value	Feb 13, 2007 Sample Value	$ Gain/ (Loss)	% Gain/ (Loss)
Ethane (C2) Liquid	$387	$382	($5)	(1.29%)
Propane (C3) Liquid	$11,141	$14,080	$2,939	26.38%
Butane (C4) Liquid	$14,401	$23,740	$9,339	64.85%
Pentane Plus (C5+) Liquid	$19,149	$57,067	$37,918	198.02%
Residue Gas	$300,367	$295,468	($4,899)	(1.63%)
Total Product Revenue	$345,445	$390,738	$45,293	13.11%
Volume Base (e3m3)	1,024.7	985.0		(3.88%)

The example above assumes identical liquid recovery for both streams (1% Ethane, 20% Propane, 40% Butane, 80% Iso-Pentane, 85% Normal-Pentane, 90% Hexane and 98% Heptane Plus) with no fuel, flare or metering difference adjustments. Use of the liquid contaminated analysis in a product allocation results in this particular stream being over-allocated by more than $45,000/month ($543,516/year). In the measurement error discussion, the over-allocation error based on gross heating value was $21,575/month, half of what the error is when the allocation effect is factored in. This clearly illustrates how much more impact the analysis has on product allocation than it does on measurement.

4.1 Impact of Misapplied Analysis Updates

One of the most important requirements when using analyses is to ensure that analyses are correctly applied to the measurement and product allocation systems that use them. In the gas measurement example, the use of the liquid contaminated analysis would cause a 3.88% understatement of volume. In the product allocation example, subsequent use of the liquid contaminated analysis in the product allocation would result in an overstatement of allocated revenue in the amount of 13.11%.

However, the errors change significantly if the liquid contaminated sample is applied in only one of the systems. If the contaminated sample is applied only in the measurement system and not the allocation system, both the volume and revenue for the solution gas sales stream will be understated by 3.88% ($13,403/month), the amount of the volume error. However, if the contaminated sample is applied only to the product allocation system and not the measurement system, the total revenue allocation error will be about 17% (13.11% + 3.88% or ~$60,000/month). This highlights the importance of ensuring that analyses are applied to measurement and allocation systems for the same period of time.

4.2 Impact of C7+ Property Errors

The impact of errors in C7+ properties (molar mass and density) is an often discussed item in measurement and product allocation. For all “pure” hydrocarbon components (N2, CO2, H2S, C1, C2, C3, IC4, NC4, etc.), all physical properties (molar mass, density, gross heating value, etc.) are known constants. However, the component C7+ is not a “pure” component. It is called a grouped component and is made up of C7 and heavier components, the makeup of which can vary from sample to sample at any given point. As a result, there are no constants that can be applied to this component reliably. The impact on gas measurement is relatively small, but the impact on product allocation is potentially significant.

Currently, no methodologies exist on how to handle C7+ properties for measurement and allocation standards. Some product allocation procedures specify a method for handling but most do not.

Throughout the industry, the most accepted practice has been to use C8 properties for C7+ when the properties are not provided. However, some companies use C7 properties for C7+ and others use the average of C7 and C8. Some companies apply the actual C7+ properties when provided by the lab and a default property when the values are not provided.

Using our solution gas sales example, the table below highlights the differences in allocated value when different C7+ properties are applied.

C7+ Properties	C7+ Mol Mass	C7+ Density	Theoretical C5+ m3	Total Monthly Allocation Value	$ Variance from Actual	% Variance from Actual
C8	114.229	706.73	125.0	$393,406	$ 2,668	0.68%
C7	100.202	687.98	122.6	$392,283	$ 1,545	0.40%
Actual	92.000	744.00	119.4	$390,738		

The table above shows that the allocation variance can be as much as 0.68% for the analysis examples used earlier in this document. This is relatively small when compared to the total revenue amount but over the course of a year, the total error becomes $32,016. In other testing, the error caused by C7+ property error has been found to be as high as 1.5%. This type of error is a persistent bias error that may consistently impact any given stream and is significant enough to warrant attention.

On lean gas streams with very little C7+, this is of little concern. In richer streams, particularly solution gas inlets, this can be a significant error, especially over a long period of time.

4.2 The Myth – It All Works Out in the End

A common remark heard when discussing measurement and allocation error is “It all works out in the end.” People that espouse this theory believe that any losses caused by measurement and allocation error will be made up somewhere by a gain somewhere else. While this may be true in some cases, it is unlikely that it is true for most cases. Some companies monitor their production and allocations very closely and whenever they believe they are receiving less than their share, they will investigate and correct or request correction of the measurement or product allocation error identified. Conversely, they seldom investigate when the production or allocations are more than what they expect. These companies typically always benefit from measurement and product allocation errors because they investigate the situations that negatively affect them. The companies that do not proactively monitor data quality tend to be negatively affected by measurement and product allocation errors.

Summary

Fluid analyses have a significant impact on measurement and product allocation. A proactive approach to managing the sampling and analyses of fluids is required to ensure that revenue is maximized, and rework and risk are minimized. The quality of data used in measurement and product allocations has a direct impact on the accuracy of the revenue numbers calculated. The use of best practices and effective tools will ensure that your company gets repeatable, accurate results. A more proactive approach to sampling and analysis by all producers and processors will result in benefits to all.

Sampling and Analysis Do's

1. Establish processes to manage sampling and analysis
2. Assign clear roles and responsibilities for the sampling/analysis process
3. Ensure all personnel taking samples are trained to take proper samples
4. Ensure all sample points meet new EUB standards
5. Validate all analyses before using them in measurement and allocation calculations
6. Ensure the analysis used for allocation is the same as the one used for determining measured volumes
7. Perform periodic component balances on systems to evaluate analysis quality
8. Perform allocation validations periodically to test accuracy