ACCURATE MEASUREMENT

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MEASUREMENT SCENE INVESTIGATIONS

Class # 8220

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Introduction

Losses in hydrocarbon measurement can be a significant cost to a company's profits. Consequently the gain/loss for system balances gets a lot of attention and scrutiny. In the business of hydrocarbon measurement, we strive to prevent significant gain/loss percentages. Sometimes, however, despite our best efforts, discrepancies will occur and they will have to be investigated. Before you can find a measurement discrepancy, first you need to know what to look for. What does a measurement discrepancy look like? How will you know one when you see it? Discrepancies will reveal themselves in a system balance as either a gain or a loss. Even better than finding a discrepancy, is preventing a discrepancy. Prevention is accomplished by developing and implementing proactive surveillance activities. Monitoring selected data points regularly and often can prevent discrepancies from occurring in the first place. However, significant discrepancies can and do occur even after you have done everything you can to prevent them. That's when you'll have to complete a "measurement scene investigation" in order to pinpoint what caused the discrepancies so you can eliminate the cause and prevent the discrepancy from reoccurring again and again.

Finding Discrepancies – Executing an Investigation

Indicators to watch for that will tip you off that problems have occurred or may be about to occur and cause discrepancies are

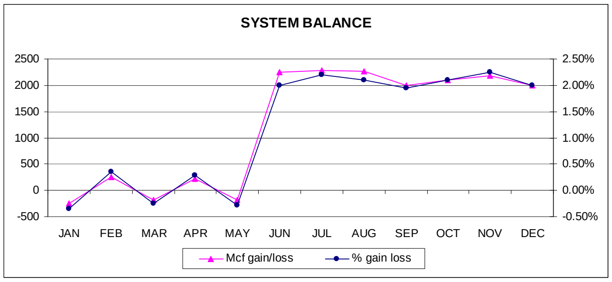
Step changes in trended data. A step change can be described as a significant trend shift in either the positive or negative direction and continues at the level shifted to or it may continue trending gradually over time in the same direction as the initial step change. Step changes should be investigated quickly in order to minimize the impact of a potentially significant error.

Continuous trends in either direction. This is something to watch for when monitoring the meter factor shift for positive displacement (PD) meters or turbine meters for example. As these meters normally operate they are gradually wearing out. Mechanical wear is inevitable. These are mechanical devices and they are made of materials that have a limited life. If the meter factor shift maintains a trend that is steady, and it remains within acceptable tolerance levels, then you can feel comfortable that the device is operating normally and no discrepancy issues are eminent. If a rapid and continuous increase in the slope of the trend occurs it could be indicating that your meter is nearing time for some mechanical maintenance. By conducting preventive maintenance and getting ahead of a more serious potential problem you will minimize the financial impact of making a large adjustment because of erroneous measurement that goes on for long periods of time undetected and unresolved.

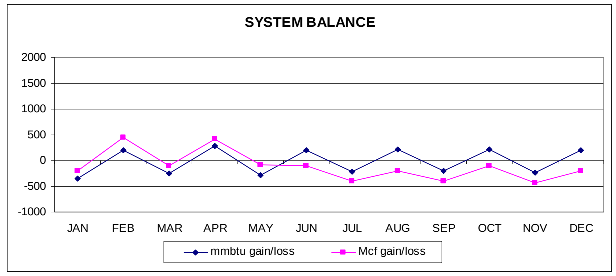
Anomalies can appear unexpectedly and then disappear just as unexpectedly with no apparent cause. Be careful not to begin investigating anomalies without first reviewing and analyzing more data. Anomalies will send you on a wild goose chase if you aren't careful. Wait until you see a definite trend that exceeds what would normally be expected before you begin investigation and troubleshooting activities. It's very likely that you would be wasting time by executing an investigation too soon.

Figure 1
Graphic Examples of Discrepancies

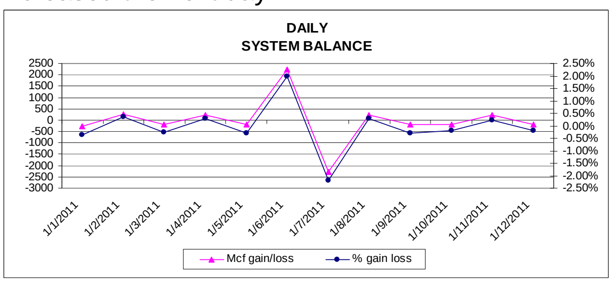
Step Change



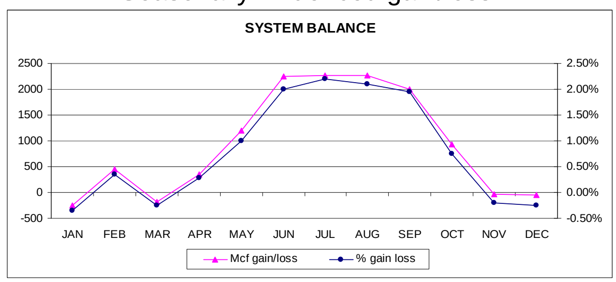
Mcf trend line intersects the mmbtu trend line



Anomaly: Pipeline pressure reduced one day and increased the next day



Seasonally influenced gain/loss



Avoid the **wild goose chase**. A wild goose chase is when you investigate a problem that doesn't exist, such as a sudden gain or loss in the system balance. A sudden gain can occur after pulling down inlet pipeline pressure (line pack). A sudden loss in the balance will occur after allowing inlet pipeline pressure to increase. Always review and analyze historical data and ask questions before you start physically searching in the field. Pursuing a problem that doesn't exist is very frustrating. It wastes time and costs your company in lost opportunity. The lost opportunity is missing out on solving other real problems and being engaged in other productive work instead of pursuing a perceived problem that never existed.

System balances are commonly used for finding measurement discrepancies. Simply stated a system balance is a comparison of the inlets into a system and the outlets from the system. The difference in the comparison of the inlets and outlets is the imbalance (gain/loss). The inlets into a typical system balance may include streams of natural gas, crude oil, condensate, and produced water from one or more sources. The outlets consist of vents, flares, sales points, and extracted contaminants such as H_2S, CO_2, and produced water. Other system outlets are fuel consuming equipment that are used in various processes such as treating crude oil and natural gas, stabilizing condensate, regenerating treatment fluids such as glycol and amine, process heaters, steam production, generating electricity, and for natural gas compression.

- System balances may be based on one or more of the following units of measure
  - Volume (mcf)
  - Mass (lbs)
  - Energy (mmbtu)/(dth)
  - Component (moles)
- One basis may be more appropriate to use than another depending on what type of material is in the system being balanced. For a system containing fractionated liquid hydrocarbons it would be preferable to balance mass or components instead of volume.
- Natural gas streams are typically balanced based on volume and energy.

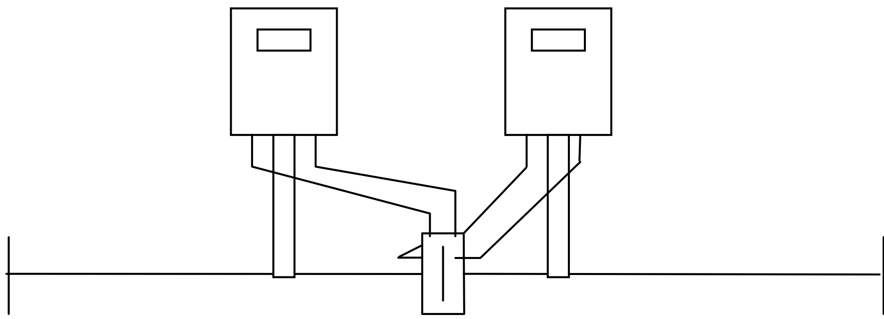
[A tabular example of a system balance spreadsheet is found in Appendix A at the end of the document]

Check meters are another tool used for identifying discrepancies. There are two types of check measurement that are most commonly used in the oil and natural gas industry. One is the "true" check meter. The other is the redundant flow chart recorder/flow computer.

- Redundant flow computers (EFM's)/chart recorders
  - Collects measurement data from the same primary fitting as the custody transfer EFM / recorder
  - Uses a separate set of pressure taps on the custody transfer primary fitting for sensing pressure
  - Records temperature data from a separate RTU or it may be fed temperature data directly from the custody EFM
  - May also be fed gas composition data from the same on-line GC that is used by the custody EFM

Figure 2

Redundant EFM/Chart Recorder

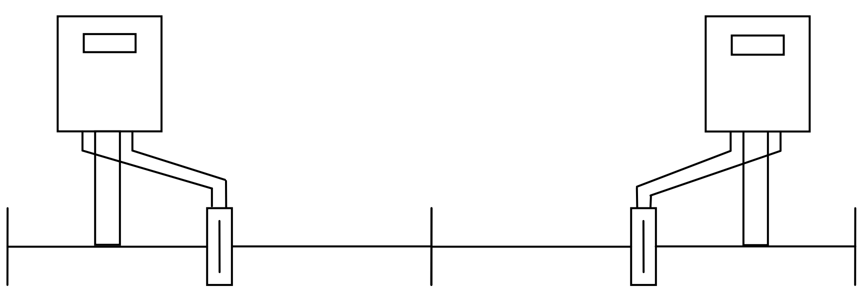


This type of check measurement is probably the most common method of check measurement currently being used in the oil and natural gas industry. The reason is because it is less expensive. The most effective of these two check meter configurations for identifying and eliminating discrepancies is the true check meter. It is the most effective because it is completely independent of the custody transfer meter. If something fouls up on either one of the check or custody meter, the other is likely to not be affected or at least not be affected in exactly the same way or the same magnitude. Because each meter in this configuration is independent of the other, a discrepancy will always be identifiable when one occurs.

- True check meter
  - A complete meter station
  - Located in the same pipeline as the custody transfer meter station
  - Configured in series
  - Located near the custody meter
  - Completely independent of the custody transfer meter

Figure 3

True Check Meter



Tracking specific data points and monitoring the data's history will also indicate discrepancies. Monitoring data points will help to identify discrepancies sooner when they are minor and the financial impact is less of a burden to adjust for. An undetected small problem can grow into a large problem over time. Large problems can result in large discrepancies which have a greater impact on business. An example of tracking a data point would be tracking the meter factor for a turbine meter or a positive displacement (PD) meter.

- Tracking the meter factor shift from one meter proving to the next will indicate to you that the meter factor is either shifting normally or that there may be a problem that needs to be investigated. There are benefits to identifying problems early. Early detection will reduce the financial impact of subsequent corrections that may be required. Early detection may help you avoid a correction entirely if the error is small and is within the acceptable tolerance range where an adjustment is not required. [See Appendix C for example of meter factor tracking tool]
- Other factors that can affect volume calculations are CTL, CPL, S&W%, specific gravity, and VCF (volume correction factor). Monitoring these values will aid in identifying problems earlier. You can also benefit from their use during the troubleshooting stage of a discrepancy investigation.

Definitions

- CPL factor - Correction for compressibility of liquid at normal operating conditions
- CTL factor - Correction for the effect of temperature on liquid at normal operating conditions
- S&W% - The percent sediment and water determined by a representative sample of the quantity of liquid being measured. It represents the non hydrocarbon portion of the liquid.
- Specific gravity (relative density) - The ratio of the mass of a given volume of liquid at a specific temperature to the mass of an equal volume of pure water at the same or different temperature. Both reference temperatures shall be explicitly stated.
- VCF – The volume correction factor for effluent measurement is derived by conducting a well test using either portable or stationary well testing equipment. An effluent stream is full well stream production before any separation occurs. The well testing equipment is connected downstream of the effluent meter. After the full well stream passes through the effluent meter it enters the 3-phase separator on the test skid. The effluent stream is separated into individual streams of natural gas, oil, and water. Each of these streams is measured separately. Metered volume data that is collected using the test skid is used to calculate a VCF that is applied to the effluent meter's volume calculation as a correction factor. The correction factor adjusts the effluent volume calculation so that it is equivalent to the combined individually measured streams calculated volume from the test skid. [See Appendix B for well test schematic]

Improper Sampling

The sample bite size and bite frequency configuration will affect how representative the composite sample is of the total throughput.

Measurement Review

A measurement review can expose unknown problems that contribute to discrepancies. Measurement reviews consist primarily of meter station inspections, standard operating procedures review; observations of standard practices and procedures as they are being carried out by a Technician, and an extensive review and analysis of historical data. Problems that may be identified are:

- Improper procedures
- Improper maintenance
- Incorrect methods applied in volume calculation
- Incorrect meter station design
- Improperly used metering equipment
- Deliberate disregard of proper procedures
- Poorly trained personnel

Improper Procedures

- Improper procedures are used because of
  - Inadequate training
  - Knowingly or unknowingly violating established procedures
  - Incorrect procedure is implemented by mistake
- Problems that can occur when proper procedures are not followed
  - Incorrect S&W determination

- Incorrect gravity determination
- Incorrect meter factor established
- Incorrect VCF derived
- Erroneous volume and mmbtu calculations due to improperly collected sample
- Incorrect meter calibrations due to use of uncertified test instruments that are out of tolerance
- Erroneous sample analysis due to use of a gas chromatograph that is not properly calibrated
    - Incorrectly calibrated gas chromatograph due to <u>improper handling</u> of calibration gas standards
    - Incorrectly calibrated gas chromatograph due to use of calibration gas standard that is the <u>wrong proportional blend of components</u>.
    - Unacceptable gas chromatograph performance due to use of low grade carrier gas (below UHP)
    - Erroneous gas chromatograph results caused by applying incorrect industry standards
    - Erroneous gas chromatograph results caused by applying incorrect physical properties

Improper Maintenance

- Maintenance problems that are either unidentified or that are identified but go unrepaired can cause significant discrepancies and can result in a serious financial impact.
    - Leaking double block and bleed valves. A proving should not be completed if any valves are leaking. Unfortunately, there are occasions when this is done and an incorrect meter factor is derived and applied to the volume calculation. The significance of the financial impact caused by applying a meter factor derived from a bad proving depends on how long the problem persists, total volume throughput during the period of time in question, and the magnitude of the calculated error.
    - Sampling system problems can have a significant impact on volume calculation. Leaks in any part of the sample system will compromise the integrity of the sample. Leaking valves on sample cylinders will compromise the integrity of a sample. Sample systems must collect a representative sample before an accurate volume can be calculated.

<u>Follow-up (Troubleshoot)</u>

- Review all manually keyed entries for each inlet and outlet stream looking for “0” values or “missed entries”.
- Look for data fields with values other than “0” that have been entered where a “0” value is usually found.
- Review system balance entries for accuracy that were calculated in one-off spreadsheets.
- Compare current value to historic data.
- Determine if any operational changes have been made recently.
- Find out if there have been any leaks or other maintenance activities conducted recently where significant amounts of gas may have been vented, flared, purged, or displaced that has not been accounted for in the balance.
- Has a new pipeline been commissioned requiring a purge and line fill volume?
- Has any fuel burning equipment been commissioned recently that hasn’t been accounted for on the balance?
- Has a new inlet been tied in but not added to the balance?
- Has a new delivery point been tied in and not added to the balance?
- Is new product coming in from a 3rd party for processing?
- What is different now since the last balance cycle?
- Has inlet line pressure been pulled down (daily balance)?
- Has inlet line pressure built up (daily balance)?

These are some of the most obvious possible causes of errors and also are the easiest to identify. If after completing the preceding investigative steps and you are satisfied that the imbalance is not because of a data entry error or operational changes then there are two other likely causes, measurement error and leaks in the system. A gain would most likely indicate a possible measurement error. A loss could be either a measurement error or possibly a leak in the system.

Narrow your search by comparing current volumes to historical volumes in an attempt to identify a recent and sudden volume change. The current volume should be reasonably close to the historic volumes.

The first meters to be investigated should be those that have the greatest likelihood of contributing to an imbalance. Then begin working toward what is least likely to be the problem beginning with meters that measure the largest volumes. Check meters should be among the first meters to be reviewed. Compare the custody and check volumes to make sure the difference is within acceptable tolerance.

Inspect measurement equipment.

- Manifold valves on gas meters can be left in the out-of-service configuration causing erroneous readings.
- Gas flow conditioning devices can become partially or completely blocked by foreign materials such as rags, gaskets, filter material, mist pad material, rocks, etc. which have entered the gas stream and lodged against the flow conditioner causing erroneous measurement.
- Ultrasonic meters can sometimes have a greater measurement uncertainty if they are dirty.
- Temperature can also have a big effect on ultrasonic meters. Make sure temperature transmitters are calibrated and operating properly.
- Ensure that orifice plates and seals are in good condition and are properly installed.
- Verify that flow computers are using the correct factors and constants to calculate volumes accurately.
- Recalibrate and re-prove meters.

Figure 4

<u>Resolution</u>

- Develop good tools
- Monitor and track data diligently
- Analyze data and look for problems daily
- After a problem is identified, take action and don't procrastinate, be proactive and get ahead of issues and fix them before the small problems turn into a big ones

Troubleshoot the discrepancy

- Review and analyze data. This is the fastest and cheapest step in troubleshooting an imbalance and identifying the cause
- Ask questions. Find out if anything has changed (operational, technological, software changes/upgrades, etc.) that could possibly be contributing to an imbalance
- Begin physical inspections by reviewing the most likely (high volume station) and work your way down to the least likely suspects (low volume station)
- In steps one through last always be aware of the potential to fall into the wild goose chase trap

Examples of specific points that may be monitored in order to identify reoccurring issues that need improvement

Methods and Procedures

- Sample collection and handling
- Gas chromatograph calibrations and operation
- EFM/chart recorder calibrations and orifice plate/seal inspections
- Proper procedures diligently and consistently applied

Equipment Maintenance and Operation

- Flow computers and chart recorders
- Meter tube internal inspections (High volume with greater financial risk exposure)
- Analytical instruments
- Calibration instruments

Meter station design and installation

- Correct meter tube length compliant with current industry standards
- Flow conditioning installation as required in appropriate applications (clean dry gas)
- Sample point location
- Composite sampler configuration
- Sample cylinder care and maintenance (clean prior to each use and repair leaking valves)

Analytical and Tracking Tools

- System balances
- Volume correction factor (VCF)
- Meter factor (MF)
- K-factor

Measurement data management

- Manage quality control
- Review data
- Properly edit data

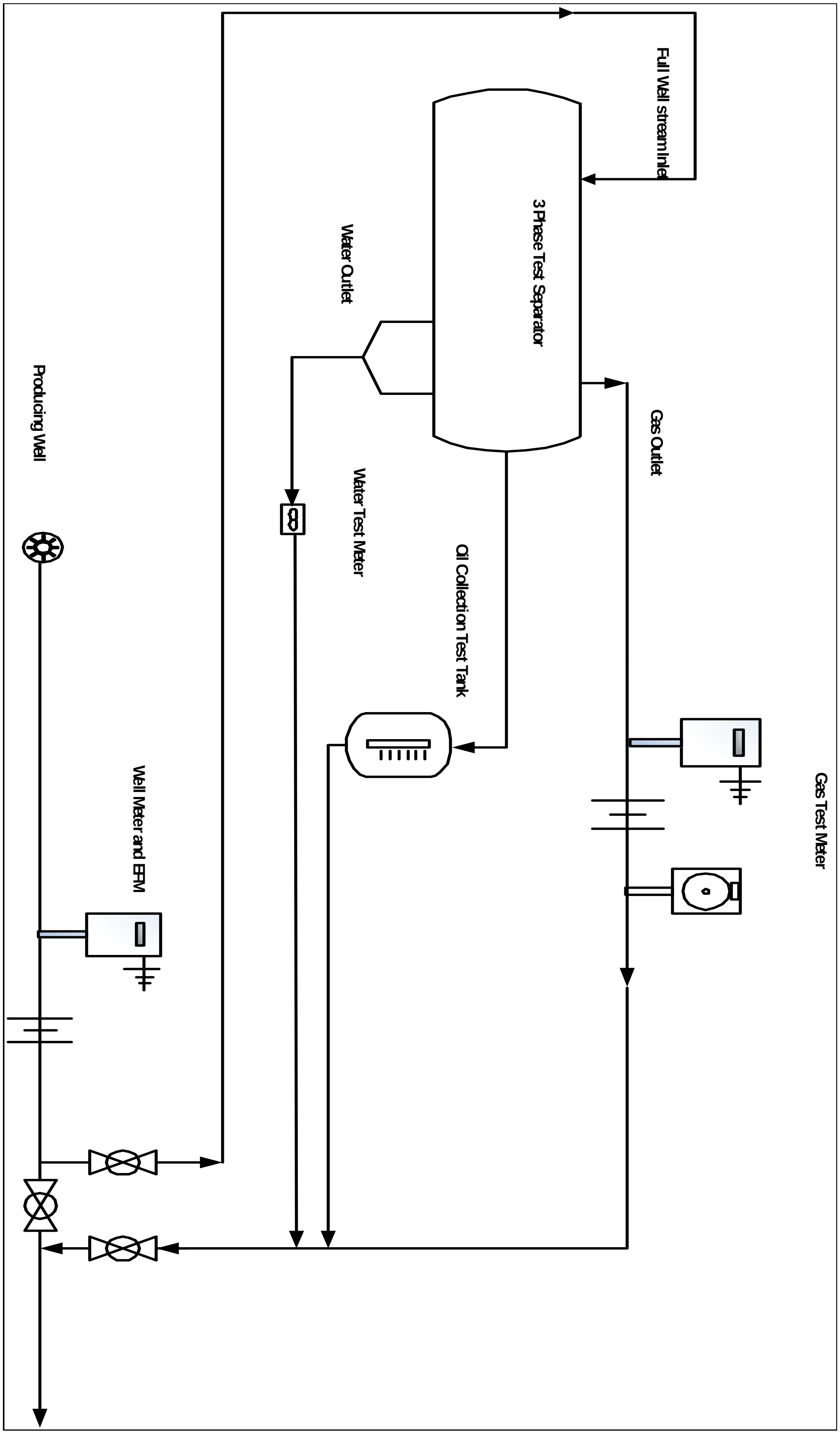
Conclusion

Losses in hydrocarbon measurement can have a significant impact on a company's profits. Consequently the gain/loss for system balances gets a lot of attention and scrutiny. In the business of hydrocarbon measurement, we strive to prevent significant gain/loss percentages. Sometimes, however, despite our best efforts, discrepancies will occur and they will have to be investigated. So in order to keep your investigations both productive and as brief as possible, always remember to know what to look for and where you are most likely to find it. Know where to look first, second, third, and so on all the way to last. Develop good tools for monitoring and tracking and use them diligently. Discrepancies and their causes will eventually reveal themselves but first you have to know what to look for and where to look before they can be found. And finding them sooner is always better than finding them later. Happy hunting and watch out for those wild-goose-chases.

Appendix A
Example of a Typical System Balance Spreadsheet

INLET MCF	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Inlet 1	3,200	3,300	3,600	3,900	4,200	4,500	4,800	5,100	4,800	5,700	6,000	6,300
Inlet 2	3,429	3,536	3,857	4,179	4,500	4,821	5,143	5,464	5,143	6,107	6,429	6,750
Inlet 3	3,673	3,788	4,133	4,477	4,821	5,166	5,510	5,855	5,510	6,543	6,888	7,232
Inlet 4	3,936	4,059	4,428	4,797	5,166	5,535	5,904	6,273	5,904	7,011	7,380	7,749
Inlet 5	4,217	4,349	4,744	5,139	5,535	5,930	6,325	6,721	6,325	7,512	7,907	8,302
Inlet 6	4,518	4,659	5,083	5,507	5,930	6,354	6,777	7,201	6,777	8,048	8,472	8,895
Inlet 7	4,841	4,992	5,446	5,900	6,354	6,808	7,261	7,715	7,261	8,623	9,077	9,531
Inlet 8	5,187	5,349	5,835	6,321	6,808	7,294	7,780	8,266	7,780	9,239	9,725	10,211
Inlet 9	5,557	5,731	6,252	6,773	7,294	7,815	8,336	8,857	8,336	9,899	10,420	10,941
TOTAL INLET	38,558	39,763	43,378	46,993	50,607	54,222	57,837	61,452	57,837	68,681	72,296	75,911
SALES MCF												
Sales Meter 1	12,059	12,250	13,154	14,039	14,906	15,758	16,594	17,417	16,239	19,025	19,813	20,591
Sales Meter 2	4,020	4,217	4,668	5,125	5,590	6,061	6,537	7,019	6,687	7,996	8,491	8,990
Sales Meter 3	8,039	8,166	8,769	9,359	9,938	10,505	11,063	11,611	10,826	12,684	13,209	13,727
Sales Meter 4	6,030	6,326	7,001	7,688	8,385	9,091	9,806	10,528	10,030	11,994	12,737	13,485
Sales Meter 5	7,416	7,781	8,612	9,456	10,313	11,182	12,061	12,949	12,337	14,753	15,666	16,587
Condensate mcfe	386	398	434	470	506	542	578	615	578	687	723	759
TOTAL SALES	37,950	39,137	42,637	46,137	49,638	53,138	56,638	60,139	56,698	67,139	70,639	74,140
FUEL MCF												
Gas Compressors	110	110	110	110	110	110	110	110	110	110	110	110
Heaters	75	75	75	75	75	75	75	75	75	75	75	75
Boilers	30	30	30	30	30	30	30	30	30	30	30	30
TOTAL FUEL	215	215	215	215	215	215	215	215	215	215	215	215
FLARE MCF												
High pressure flare	10	10	10	10	10	10	10	10	10	10	10	10
Low pressure flare	5	5	5	5	5	5	5	5	5	5	5	5
TOTAL FLARE	15	15	15	15	15	15	15	15	15	15	15	15
VENT MCF												
High pressure vent (calculated)	10	10	10	10	10	10	10	10	10	10	10	10
Low pressure vent (calculated)	5	5	5	5	5	5	5	5	5	5	5	5
TOTAL VENT	15	15	15	15	15	15	15	15	15	15	15	15
CONTAMINANTS MCF												
Carbon dioxide (calculated)	76	78	85	92	99	106	113	120	113	134	141	148
Hydrogen sulfide (calculated)	19	20	22	23	25	27	29	31	29	34	36	38
TOTAL CONTAMINANTS	95	98	107	116	125	133	142	151	142	169	177	186
Total Inlet (available) per Month	38,558	39,763	43,378	46,993	50,607	54,222	57,837	61,452	57,837	68,681	72,296	75,911
Total Sales per Month	37,950	39,137	42,637	46,137	49,638	53,138	56,638	60,139	56,698	67,139	70,639	74,140
Total Fuel/Flare/Vent/Contaminants	340	343	352	361	370	378	387	396	387	414	422	431
G/L per Month	-268	-283	-389	-494	-600	-706	-811	-917	-751	-1129	-1234	-1340
% G/L per Month	-0.69%	-0.71%	-0.90%	-1.05%	-1.19%	-1.30%	-1.40%	-1.49%	-1.30%	-1.64%	-1.71%	-1.77%
Total Inlet (available) YTD	38,558	78,321	121,699	168,691	219,298	273,520	331,357	392,809	450,646	519,327	591,624	667,535
Total Sales YTD	37,950	77,087	119,724	165,862	215,499	268,638	325,276	385,414	442,113	509,252	579,891	654,031
Total Fuel/Flare/Vent/Contaminants YTD	340	683	1,035	1,396	1,766	2,144	2,531	2,927	3,315	3,728	4,151	4,582
G/L YTD	(268)	(550)	(939)	(1,433)	(2,033)	(2,739)	(3,550)	(4,467)	(5,219)	(6,347)	(7,582)	(8,922)
%G/L YTD	-0.69%	-0.70%	-0.77%	-0.85%	-0.93%	-1.00%	-1.07%	-1.14%	-1.16%	-1.22%	-1.28%	-1.34%

Appendix B
Full Well Stream Well Testing Skid Schematic



Appendix C
Meter Factor Tracking Chart

METER NAME	METER ID NO.	NOMINAL SIZE (INCHES)	TYPE	MAKE	MODEL	SERIAL NO.	DATE INSTALLED	MINIMUM FLOW RATE bbls/hr	MAXIMUM FLOW RATE bbls/hr	PROVER TYPE	PROVER SERIAL No.	PRODUCT	ACTION LIMIT	Revised by: Ray Glidewell July 2, 2009
												Crude	+or- 0.50%	Enter data in shaded cells

Date	BASE K_FACTOR	Meter Factor	Mean	LCL	UCL	Report #	% Deviation Last Proving	% Deviation Baseline	Flow Rate BPH	Flow Rate GPM	Meter Temp.	Meter Press.	Gravity API@60°F	Comments
Jan-09		1.00025	1.00025	0.99895	1.00145		0.00%	0.00%		-				Baseline meter factor
Feb-09		1.00015	1.00020	0.99895	1.00145		-0.01%	-0.01%		-				
Mar-09		1.00035	1.00025	0.99895	1.00145		0.02%	0.01%		-				
Apr-09		1.00045	1.00030	0.99895	1.00145		0.01%	0.02%		-				
May-09			1.00030	0.99895	1.00145		-	-		-				
Jun-09			1.00030	0.99895	1.00145		-	-		-				
Jul-09			1.00030	0.99895	1.00145		-	-		-				
Aug-09			1.00030	0.99895	1.00145		-	-		-				
Sep-09			1.00030	0.99895	1.00145		-	-		-				
Oct-09			1.00030	0.99895	1.00145		-	-		-				
Nov-09			1.00030	0.99895	1.00145		-	-		-				
Dec-09			1.00030	0.99895	1.00145		-	-		-				
Jan-10			1.00030	0.99895	1.00145		-	-		-				
Feb-10			1.00030	0.99895	1.00145		-	-		-				
Mar-10			1.00030	0.99895	1.00145		-	-		-				
Apr-10			1.00030	0.99895	1.00145		-	-		-				
May-10			1.00030	0.99895	1.00145		-	-		-				
Jun-10			1.00030	0.99895	1.00145		-	-		-				
Jul-10			1.00030	0.99895	1.00145		-	-		-				
Aug-10			1.00030	0.99895	1.00145		-	-		-				
Sep-10			1.00030	0.99895	1.00145		-	-		-				
Oct-10			1.00030	0.99895	1.00145		-	-		-				
Nov-10			1.00030	0.99895	1.00145		-	-		-				
Dec-10			1.00030	0.99895	1.00145		-	-		-				

Appendix D
API MPMS Standards

The following sources will provide guidance on proper S&W determination.

- API MPMS Ch.10 sec.2 Distillation
- API MPMS Ch.10 sec.3 Centrifuge Laboratory
- API MPMS Ch.10 sec.3 Centrifuge Field

The following sources will provide guidance on proper gravity determination.

- API MPMS Ch.9 sec.1 Hydrometer method
- API MPMS Ch.9 sec.2 Light Hydrocarbons by Pressure Hydrometer
- API MPMS Ch.9 sec.3 API Gravity of Crude Petroleum and Liquid Petroleum Products by Thermo Hydrometer Method