Case Studies in Non-Nuclear Multiphase Flow Meters Well-Testing Applications in Alberta's Oil Sands, Niobrara, Bakken and Eagle Ford Basins

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Overview

- Review of a Canadian regulator approval process for a multiphase meter well testing installation in Alberta
- Niobrara, Bakken & Eagle Ford Installations examples & learnings

Canadian Application Summary

2 Field Trial Program

In an effort to improve metering accuracy and optimize resource recovery, ConocoPhillips conducted a field trial program to evaluate MPFM technology for its Surmont SAGD heavy oil operations. For this field trial, ConocoPhillips installed and tested the Agar MPFM-50 with FFD® and has replicated, as close as possible, the testing procedures and flow conditions expected in future pad operations.

ConocoPhillips began the field trial on February 12th, 2013 and the test ran through to March 25, 2013. The test was conducted in accordance with the stated procedure agreed upon with the ERCB in Application No. 173221. During the test, a net 746 hours of testing time was logged with the Agar MPFM. All 17 producing wells on Pad 102 flowed through the MPFM, which included 16 ESP wells and 1 gas lift well. To better replicate the range of gas lift wells, a gas crossover line was installed at the wellhead on an ESP well for gas injection into the emulsion line.

Prior to completing the test Agar held a 1 day training session with Operations and Maintenance personnel at Surmont. The training included theoretical as well as practical training with the meter and sampler. The results from the MPFM were compared against the test separator for water cut and emulsion flow, and against samples taken across the MPFM for water cut (WC). The table below summarizes the testing results:

Table 1: MPFM Average Error Summary

Comparison	Absolute Error	Relative Error (% or reference)
Volume Flow Rate (vs. Test Separator)	7.96 m3/d	2.40%
Water Cut (vs. Test Separator)	3.59%	5.47%
Water Cut (vs. Sampling)	4.01%	6.02%

The results satisfy the requirements of Directive 017 and are in line with ConocoPhillips expectations. Given the successful trial results at both low and high gas void fractions, ConocoPhillips is seeking ERCB approval for utilization of the Agar MPFM-50 with FFD® in lieu of test separation for the infill wells on Pad 102.

The information presented below was collected from Application # 1744341, submitted by ConocoPhillips to the Alberta Energy Regulator on April 2013.
AER approval #9426R.

Testing Plan

- Minimum equivalent of one month (744 hours) of testing. Test results compared to test separator.
- Run testing at the current standard testing schedule; 8 hours on test per well, 1 hour purge time between wells.
- Coriolis on Pad 102 will be used as the reference mass/volume flow rate readings. MPFM data will be compared to the coriolis and WC readings.
  - Standard correlations will be used to compensate for small differences in P&T; this is expected to account for less than 1% difference in liquid streams.[1]
- Each time an MPFM metered well is put into test, water cut will be determined by collecting a pressurized sample at the throat of the MPFM with a sampling skid. The sampling skid and sampling procedure have already been evaluated at Pad 102 and proved to provide representative samples on a consistent basis. To maintain consistency between samples and average measurements, ConocoPhillips will pay special attention to process stability (based on instantaneous instrument readings).
- One test will be specifically designed to evaluate meter performance during "upset" conditions. Transient performance (ex. start-up and changing wells) will be assessed to improve ConocoPhillips' understanding of the metering system's behavior and allow for optimization of future testing procedures.
- The MPFM vendor (Agar) will provide basic theoretical training to office and field personnel before the meter is tested. During testing, Agar will provide hands on training with the meter and software required for operation to field personnel. This will ensure safe and accurate operation during MPFM testing and will aid in preparing ConocoPhillips personnel for commercial implementation.

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Meter on Test

2.4 *Agar MPFM Technical Operations*

The Agar MPFM-50 is a complete system that integrates commonly used oilfield measurement technologies. Agar combines these devices to accurately measure the flow rates for oil, water and gas in a multiphase environment. The Agar MPFM-50 consists of 5 major components as shown in Figure 1:

A. Coriolis meter
B. Agar OW-200 water cut meter
C. Agar ID-201 interface detector
D. Dual venturi meter
E. Pressure transmitters

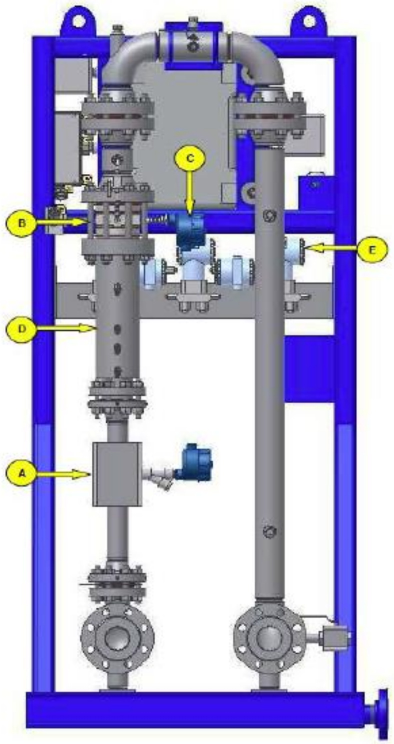

***Figure 1**: Agar MPFM-50 Components*

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AER approval #9426R.

Test Schematic

7.1 Construction

ConocoPhillips Canada conducted its MPFM field test upstream of test separator V-2201 outside building 2200 on Pad 102. This location utilized the existing tie in points which were necessary to transport emulsion flow through the Agar MPFM-50 with FFD® and then into test separator V-2201. A simplified testing schematic is depicted in Figure 45.

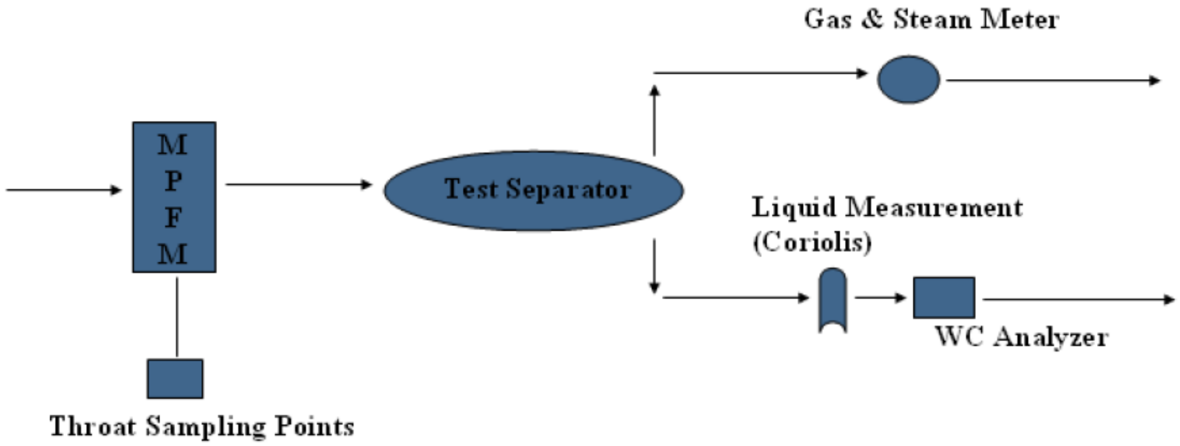

Figure 45: Simplified Testing Schematic

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AER approval #9426R.

Error Definitions

2.8 Error Definitions

Data from the MPFM was compared to the test separator and to sampling data. In evaluating the success of the Agar multiphase flow meter during testing, ConocoPhillips applied the following metrics:

$$\text{Absolute Error} = |\text{MPFM} - \text{Reference}|$$

$$\text{Average Absolute Error} = \frac{\sum_{1}^{N} |\text{MPFM - Reference}|}{N}$$

$$\text{Relative Error} = \frac{100 \times |\text{MPFM} - \text{Reference}|}{\text{Reference}}$$

$$\text{Average Relative Error} = \frac{\sum_{1}^{N} \frac{100 \times |\text{MPFM} - \text{Reference}|}{\text{Reference}}}{N}$$

Where 'N' = Number of well tests.

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Emulsion Rate & Watercut Test Results

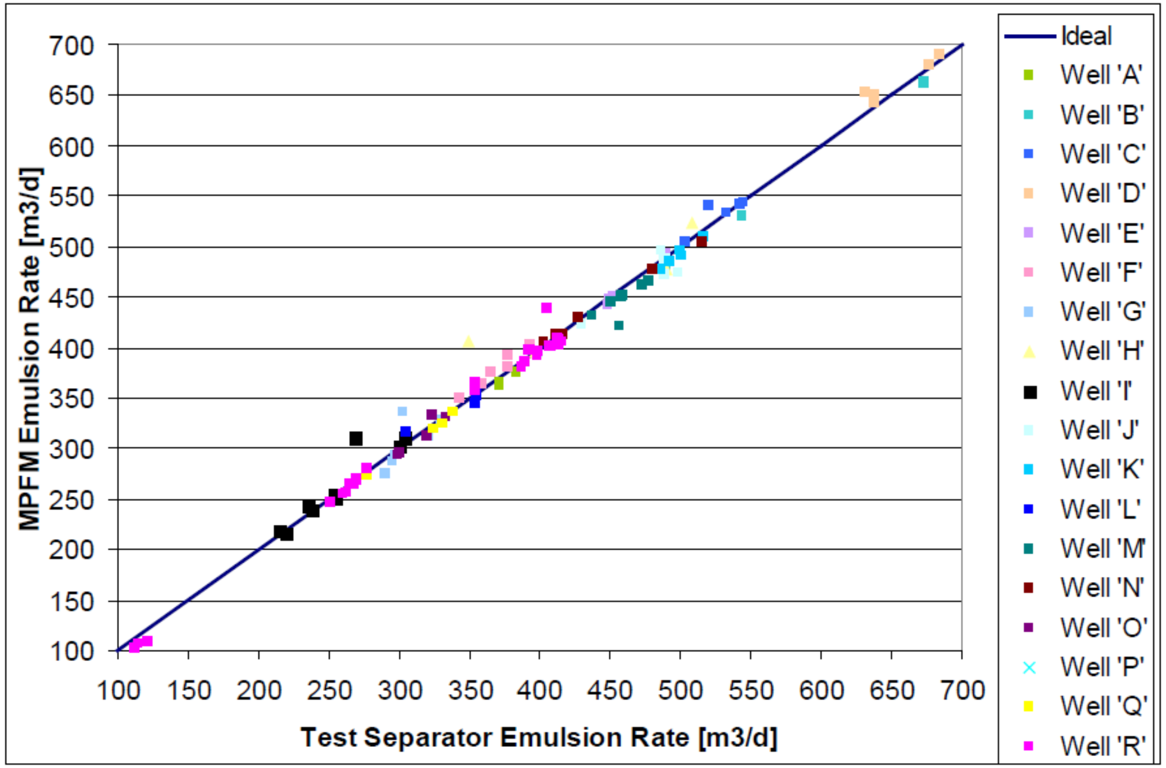

Figure 14: MPFM Emulsion Rate vs. Test Separator Emulsion Rate for all Well Tests

Table 1: MPFM Average Error Summary

Comparison	Absolute Error	Relative Error (% or reference)
Volume Flow Rate (vs. Test Separator)	7.96 m3/d	2.40%
Water Cut (vs. Test Separator)	3.59%	5.47%
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Gas Lift / Gas Jumper Test

Figure 48: Well R Gas Cross-over Line

Figure 23: Gas Crossover Trials shown with GVF

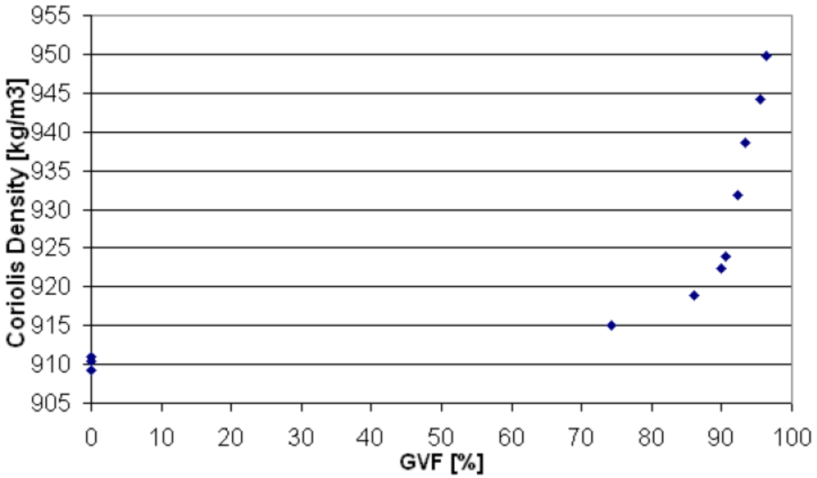

Figure 24: Test Separator Coriolis Density vs. GVF

The information presented below was collected from Application # 1744341, submitted by ConocoPhillips to the Alberta Energy Regulator on April 2013.
AER approval #9426R.

Gas Lift / Gas Jumper Test

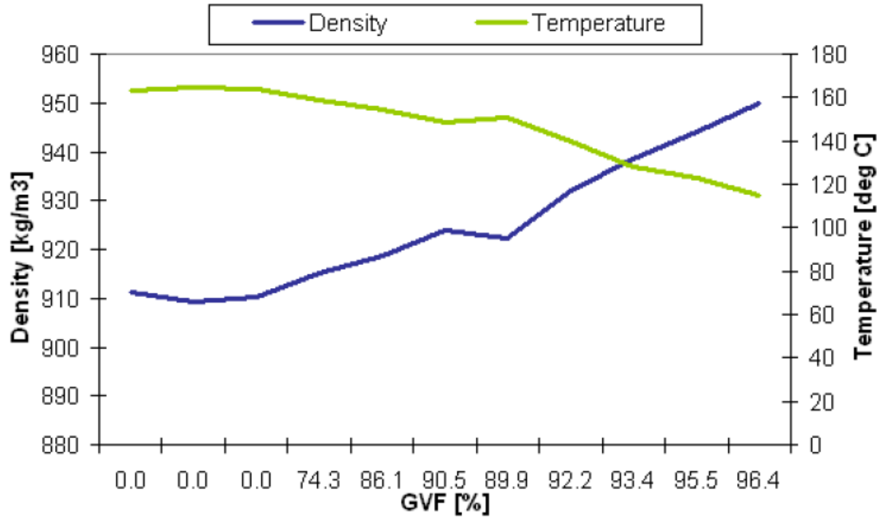

Figure 25: Test Separator Coriolis Density and Test Separator Temperature vs GVF

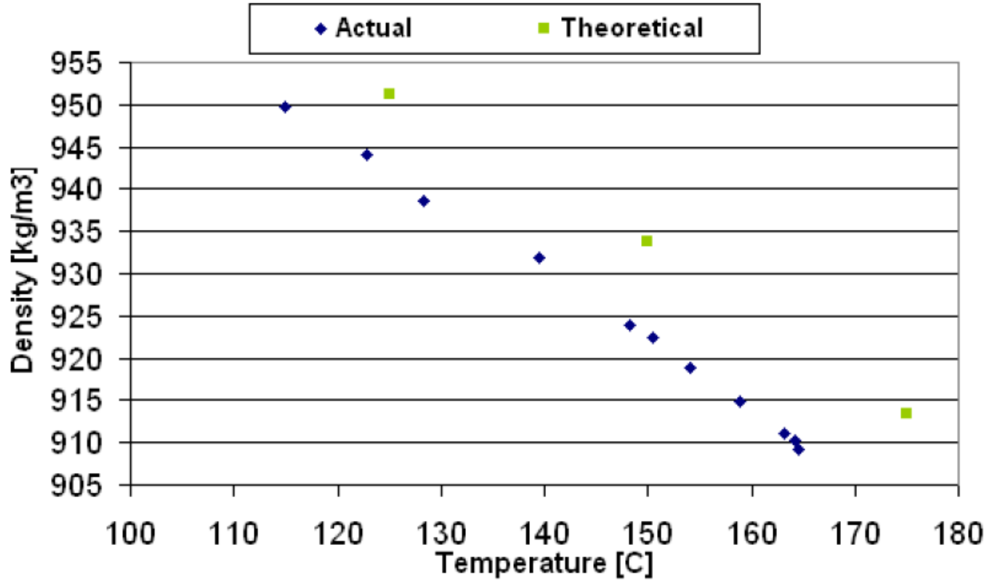

Figure 26: Theoretical and Test Separator Coriolis Density vs. Test Separator Temperature

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AER approval #9426R.

Gas Lift / Jumper Test

Throughout the Agar MPFM trial, Well I was the only gas lift well on Pad 102. The MPFM displayed a high degree of accuracy for both water cut and emulsion rate on this well. Gas lift wells are typically characterized by liquid slugging and GVF swings. Well I, depicted below from 11:45 to 19:45, demonstrates the irregular nature of emulsion flow from GL wells.

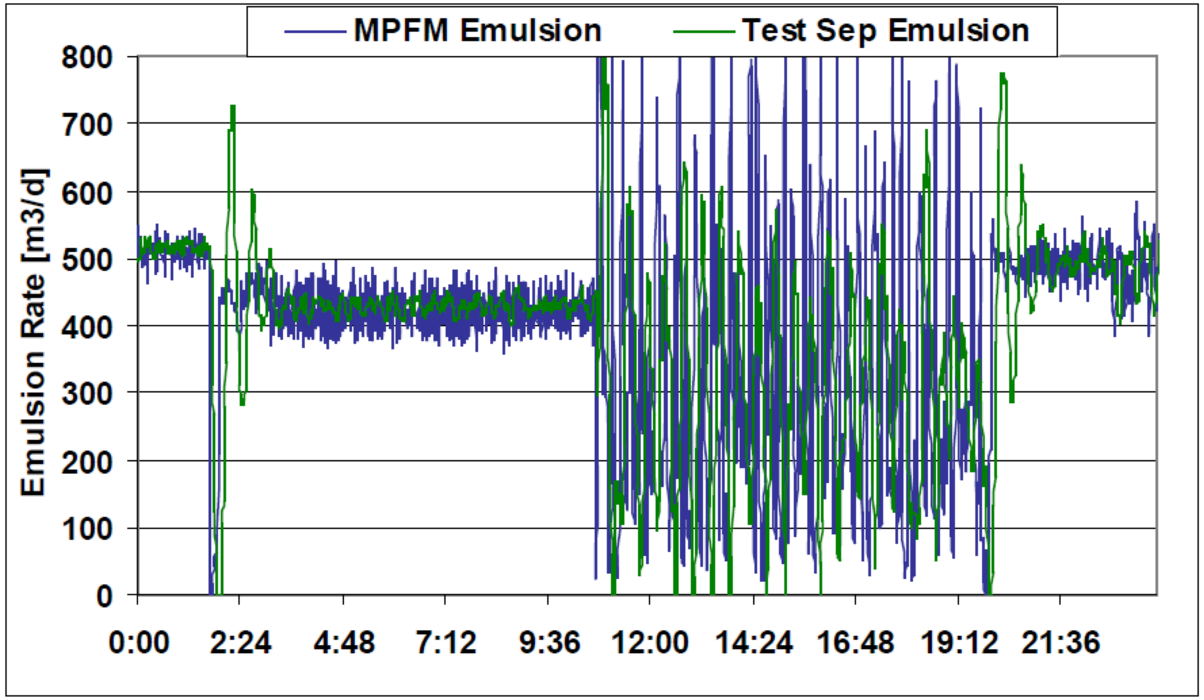

Figure 29: Gas Lift Well Emulsion Rates

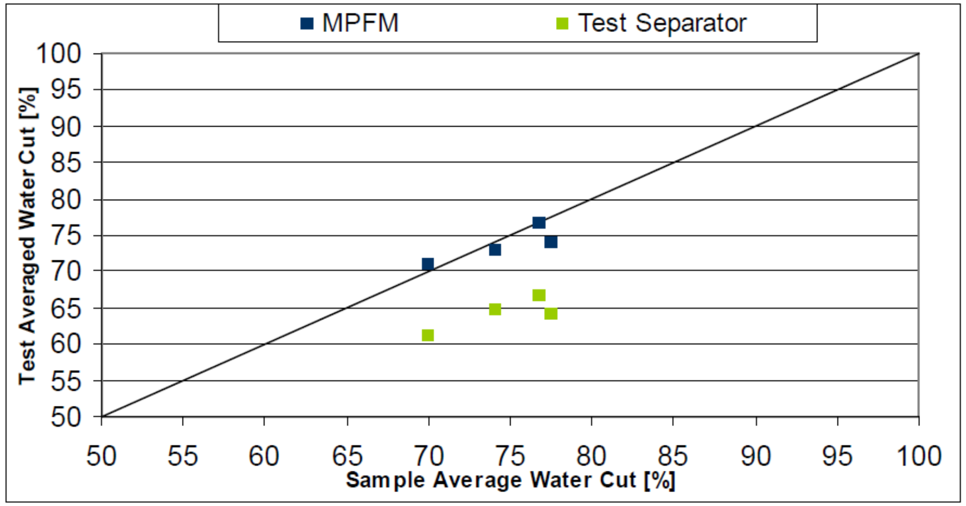

Figure 30: Well I MPFM & Test Separator WC vs. Sampled WC

When plotting the Agar MPFM and test separator water cuts against the sampled water cuts it is evident that the MPFM reads water cut very accurately for gas lift Well I. The average GVF for this well is approximately 85%. The MPFM averaged a water cut of 73.04% during sampled well tests, at an average error of 2.29%. The test separator averaged a water cut of 63.97% during sampled well tests at an average error of 11.01%. The GVF range for historical gas lift wells at Surmont range anywhere from 65%-95% GVF. Table 7 shows the ranges of gas lift flow rates from wells on Pad 102 while they were on gas lift (before conversion to ESP).

The information presented below was collected from Application # 1744341, submitted by ConocoPhillips to the Alberta Energy Regulator on April 2013.
AER approval #9426R.

Canadian Regulator Approval

ERCB Energy Resources Conservation Board

Calgary Office Suite 1000, 250 – 5 Street SW, Calgary, Alberta, Canada T2P 0R4 Tel 403-297-8311 Fax 403-297-7336 www.ercb.ca

Via email: Jodi.A.Prior@conocophillips.com

May 30, 2013

Jodi Prior
Development Approvals Coordinator
ConocoPhillips Canada Resources Corp. (ConocoPhillips)
401-9th Avenue S.W.
Calgary AB T2P 2H7

Dear Ms. Prior:

APPLICATION NO: 1744341
CATEGORY 2 COMMERCIAL SCHEME AMENDMENT
SURMONT IN-SITU OIL SANDS PROJECT
ATHABASCA OIL SANDS AREA
APPROVAL NO. 9426R

The Energy Resources Conservation Board (ERCB) has considered your application dated November 7, 2012 and the associated addendums, requesting approval to drill and operate five additional infill well pairs at Pad 102 and to install a single Agar MPFM-50 meter to measure production from those five well pairs. Your application has been granted and Approval No. 9426R is enclosed for this purpose.

The ERCB has approved the use of the Agar MPFM-50 meter based on the proposed operating conditions at Pad 102 at Surmont. Should ConocoPhillips apply in the future to implement different operating conditions (e.g., solvent or surfactant co-injection, >95% gas voidage fractions, etc.) at this pad or any future pads, the ERCB may require validation that the Agar MPFM-50 measurement technology is capable of ensuring accurate production measurement for those proposed conditions. As such, ConocoPhillips is requested to commence discussions with the ERCB well in advance of filing an application requesting to use the Agar MPFM-50 meter on pads with operating conditions different from those referenced in the subject application. Finally, all future well pad applications for the Surmont Project are to specify the method(s) proposed to be utilized to estimate well production for ERCB reporting purposes.

Questions may be directed to Shay Dodds at 403-297-7023 or by email at Shay.Dodds@ercb.ca.

Yours truly,

Steve Thomas

Steve Thomas, P.Eng.
Section Leader, In Situ Oil Sands Applications
Oil Sands and Coal Branch

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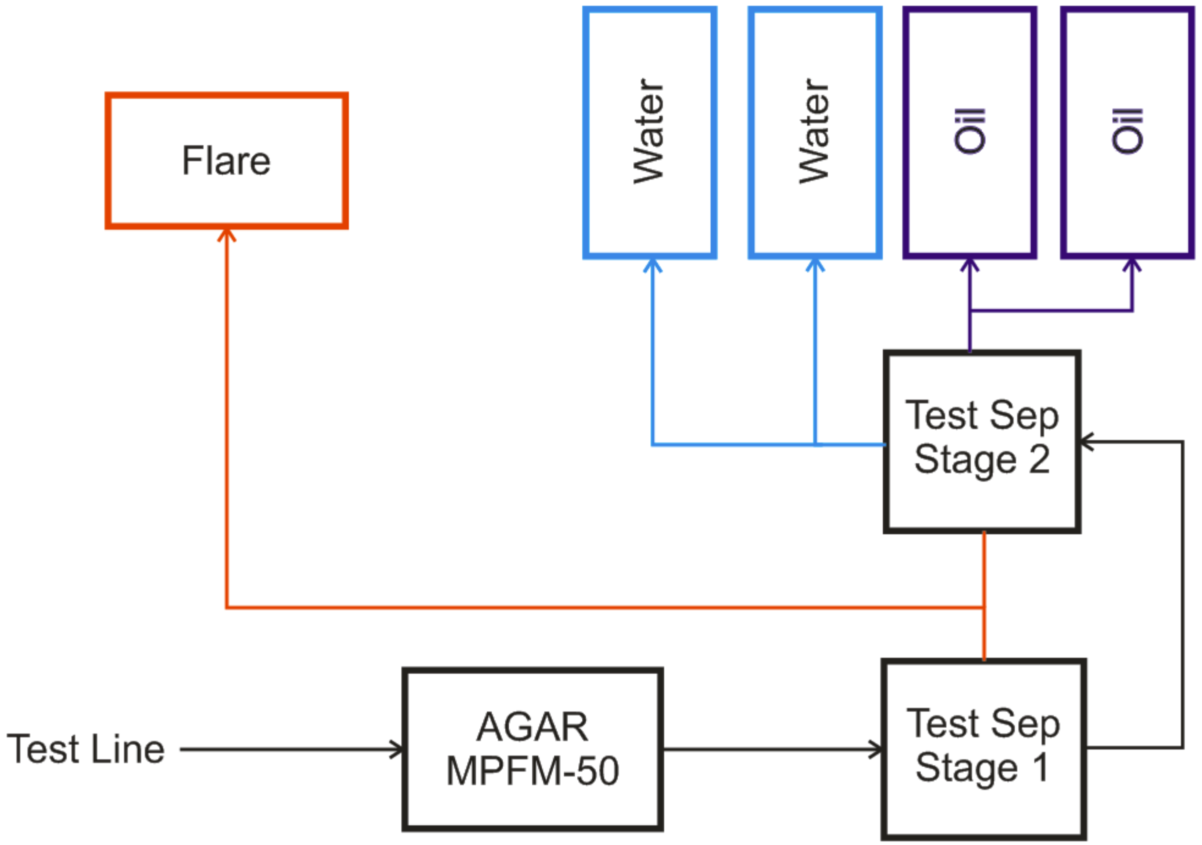
AER approval #9426R.

Niobrara & Bakken Installations

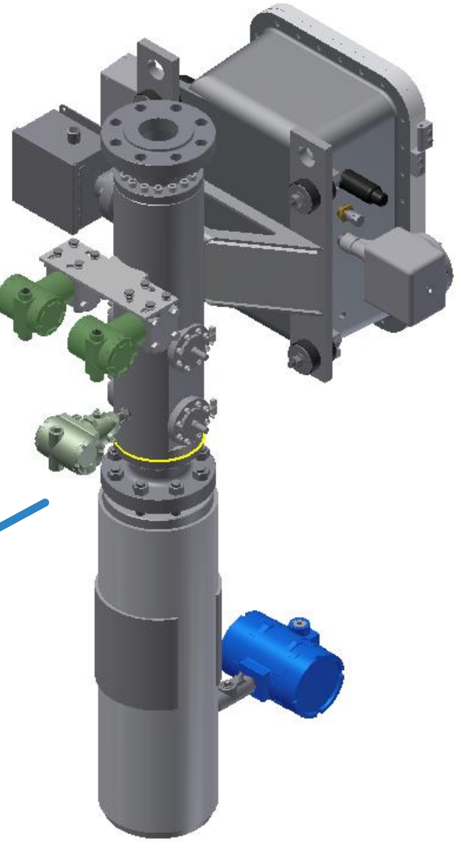
Niobrara Test Facility Arrangement



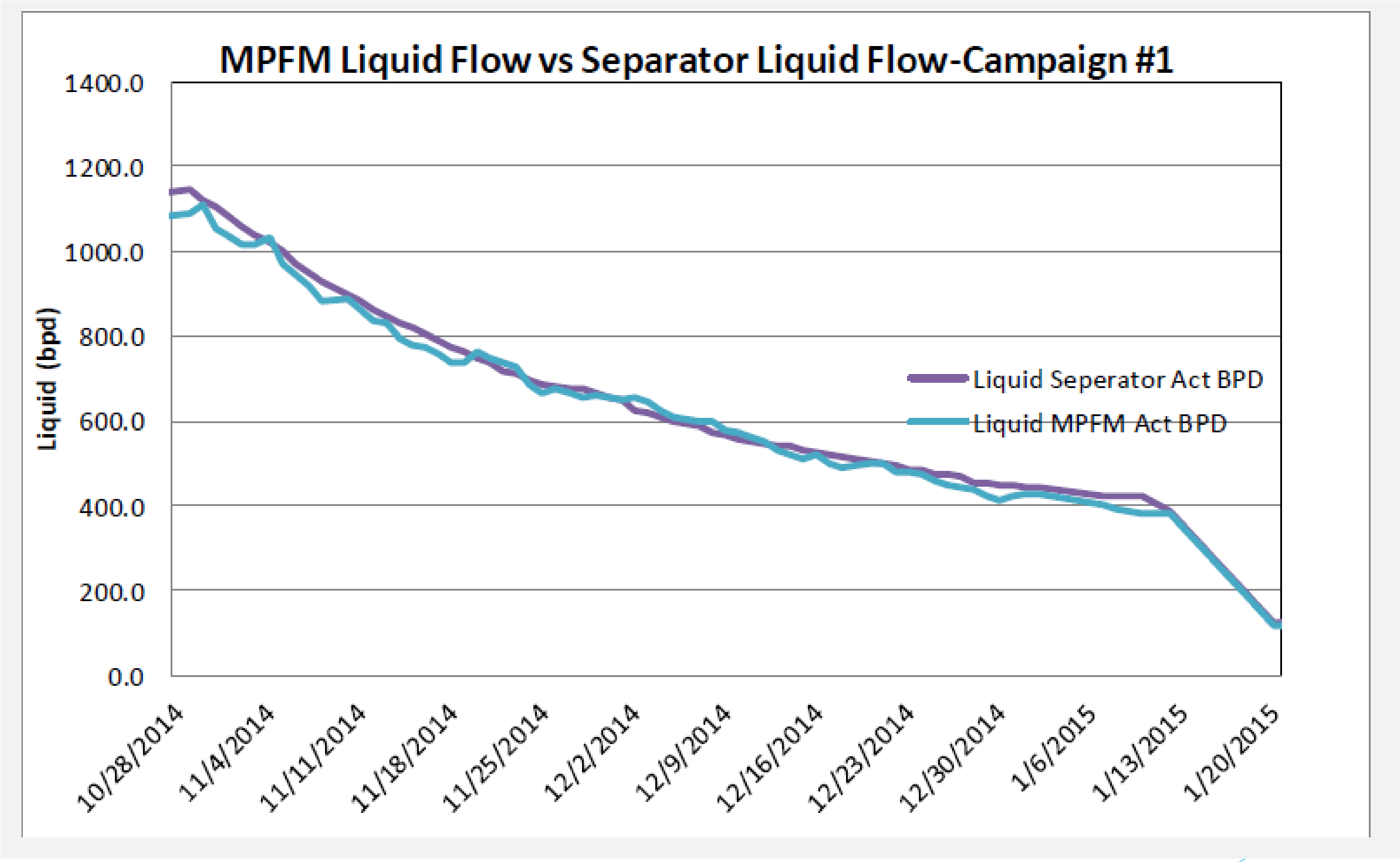
Niobrara Installation - Tank Comparative Testing

Test Information	AGAR MPFM-50			TANK Volume Reference			Volume Deviations		
Date	Oil Volume	Water Volume	Gas volume	Tank Oil Volume	Tank Water Volume	Gas meter	Oil Deviation	Water Deviation	Gas Deviation
	BBLS	BBLS	SCFD	BBLS	BBLS	MSF	%	%	%
5-Feb	80.91	587.13	316.81	81.70	N/A	336	1%	N/A	6%
6-Feb	80.69	584.01	320.50	78.30	568.0	350	3%	3%	8%
7-Feb	82.83	580.75	320.24	83.20	562.0	350	0%	3%	9%
8-Feb	81.99	577.41	318.38	81.70	578.0	346	0%	0%	8%
9-Feb	83.09	574.75	318.33	80.00	547.0	338	4%	5%	6%
10-Feb	75.10	506.58	286.22	76.70	514.0	316	2%	1%	9%
11-Feb	81.05	558.87	314.63	81.70	577.0	333	1%	3%	6%
12-Feb	84.36	552.28	314.84	80.60	N/A	341	5%	N/A	8%

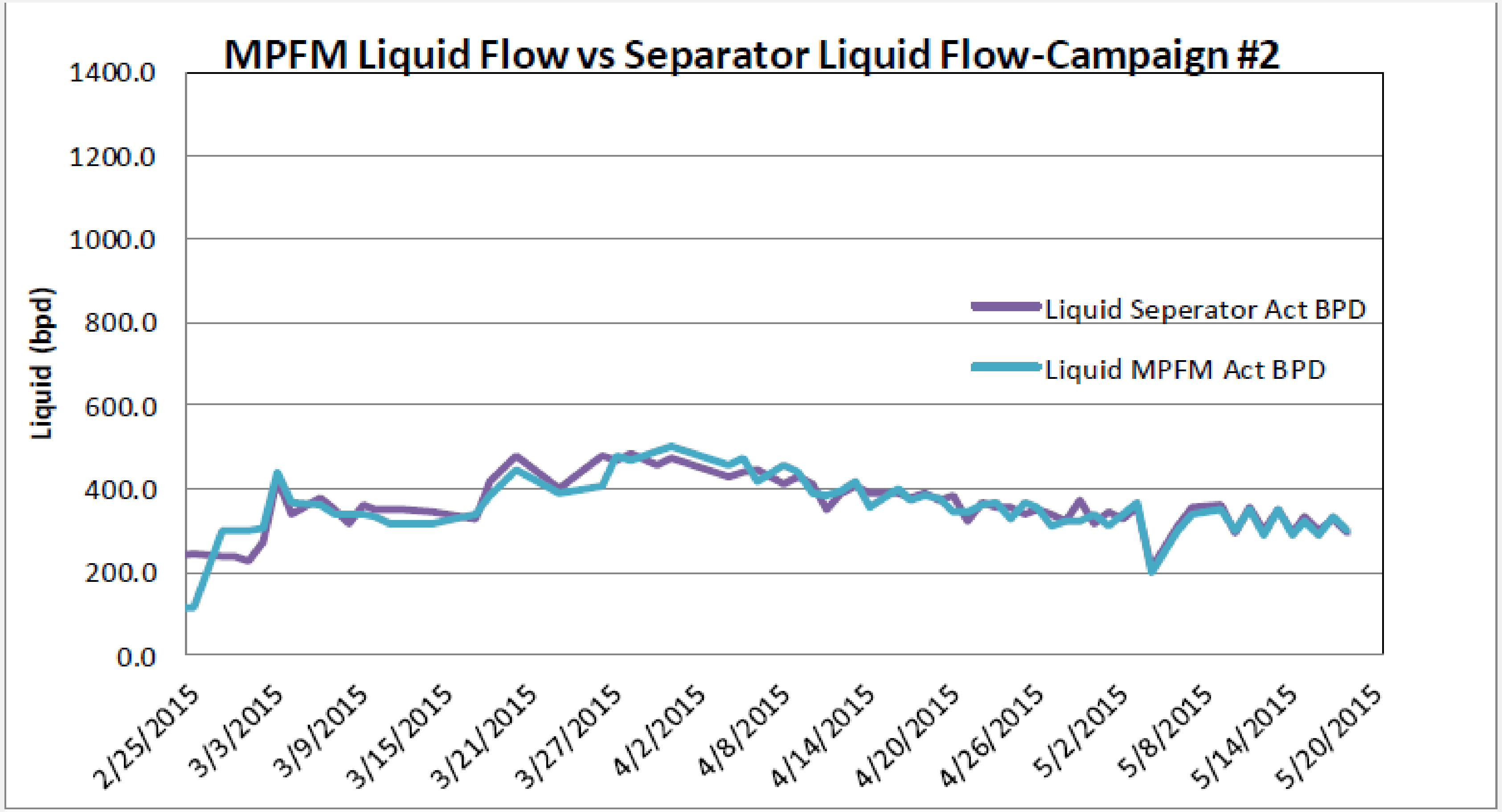
Eagle Ford - PAD A Meter



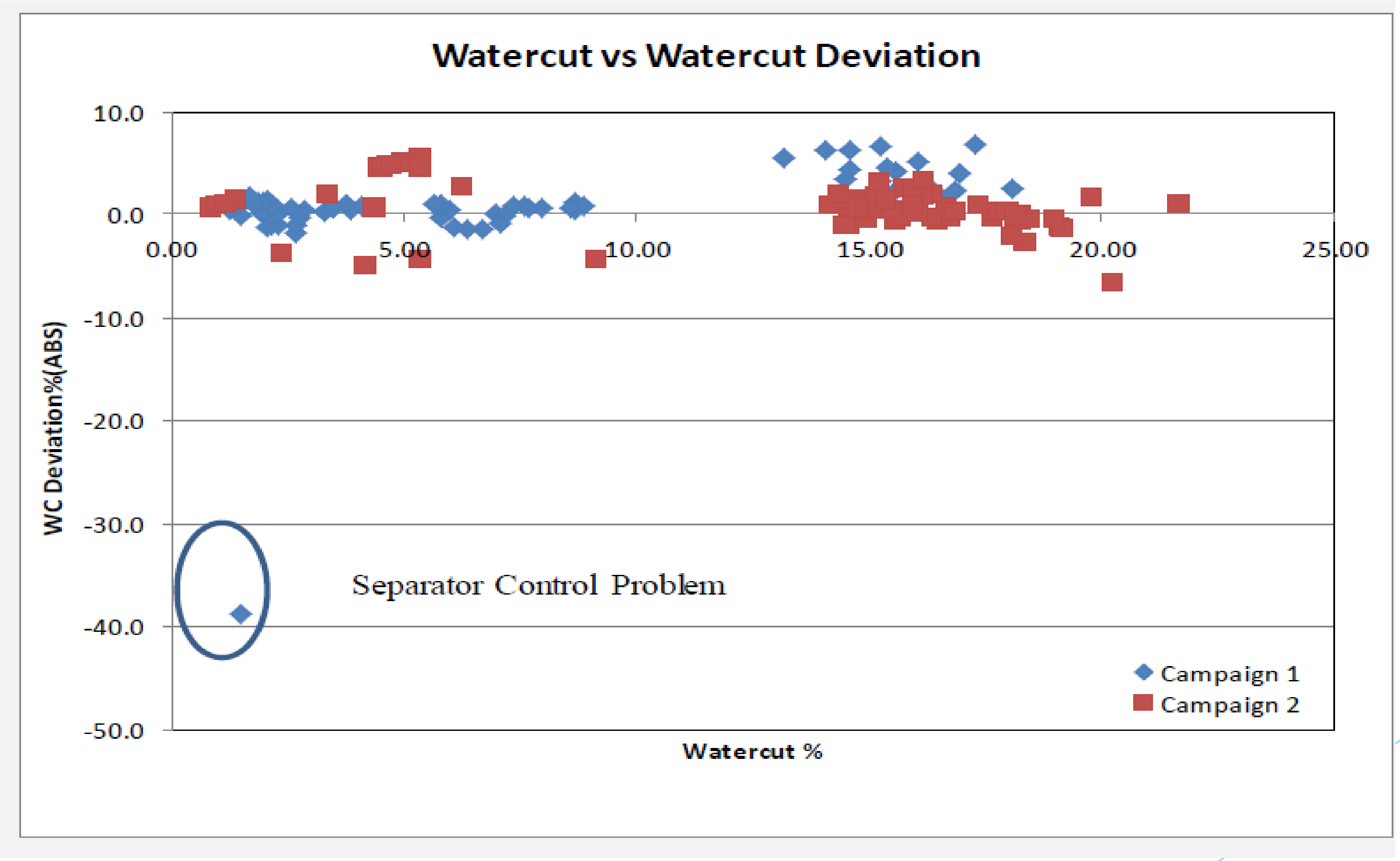
Eagle Ford High GVF MPFM



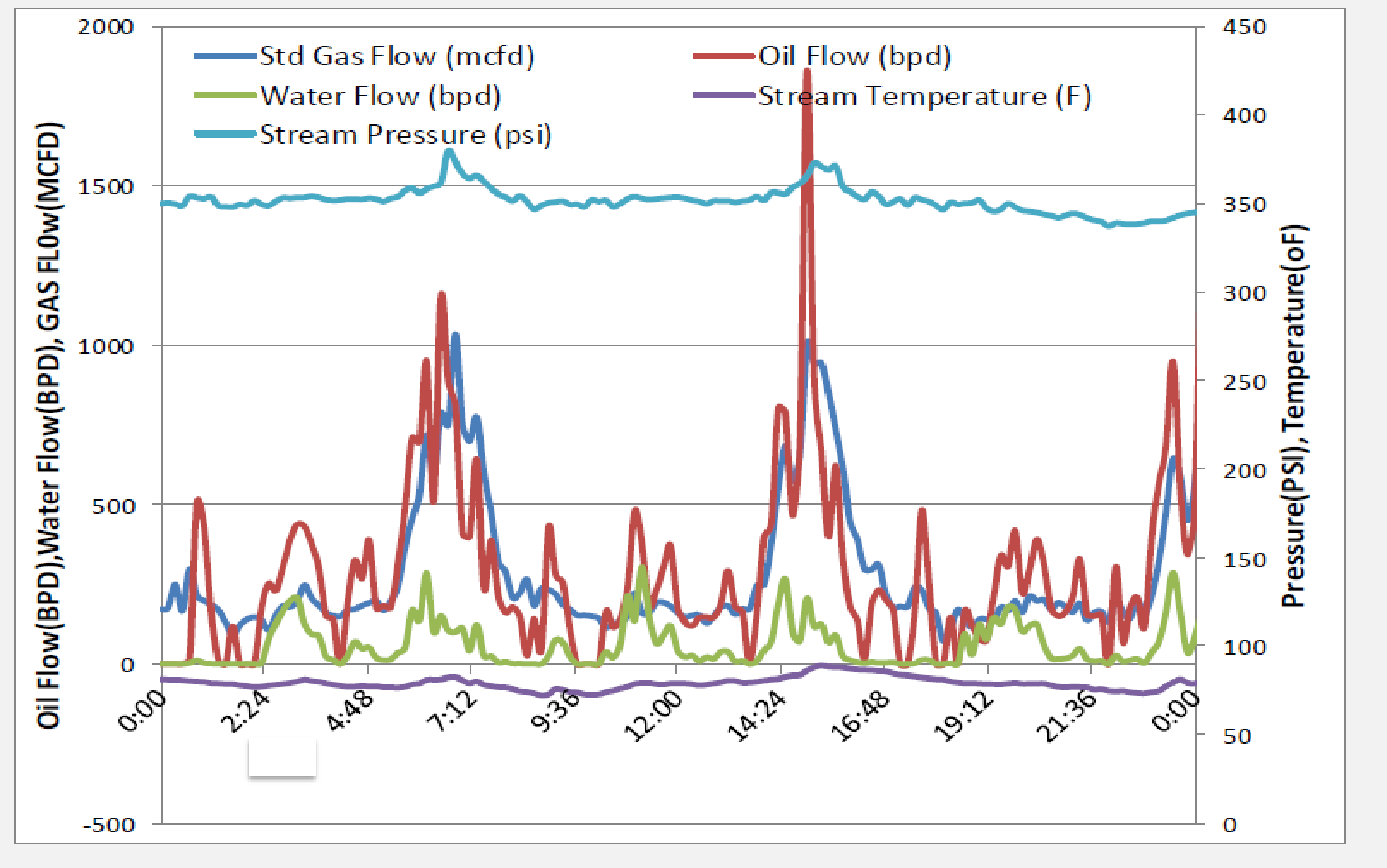
Eagle Ford High GVF MPFM



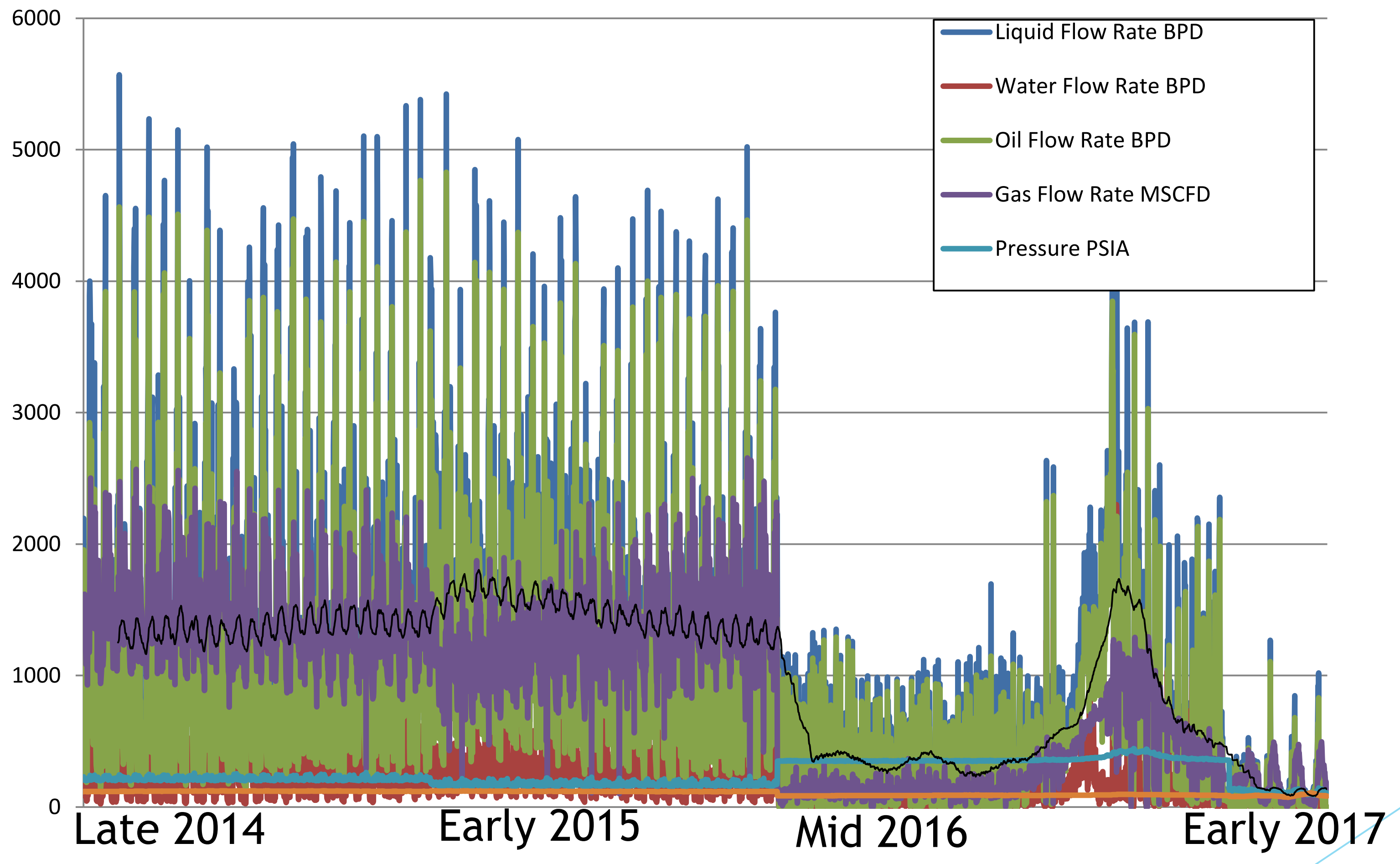
Eagle Ford High GVF MPFM



Eagle Ford High GVF MPFM

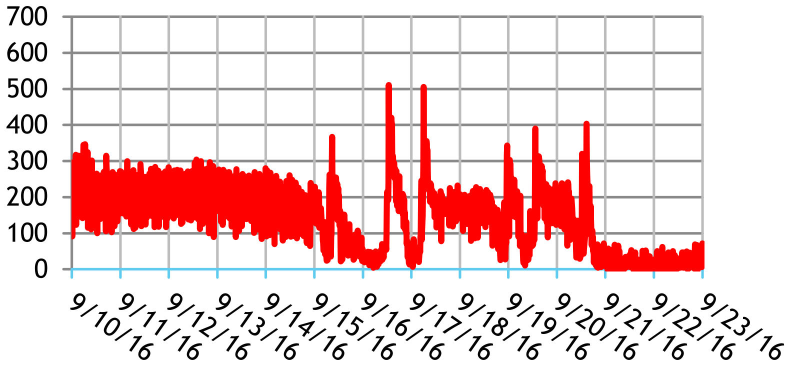


Eagle Ford High GVF MPFM -
Daily Flow Profile Comparison over Three Years

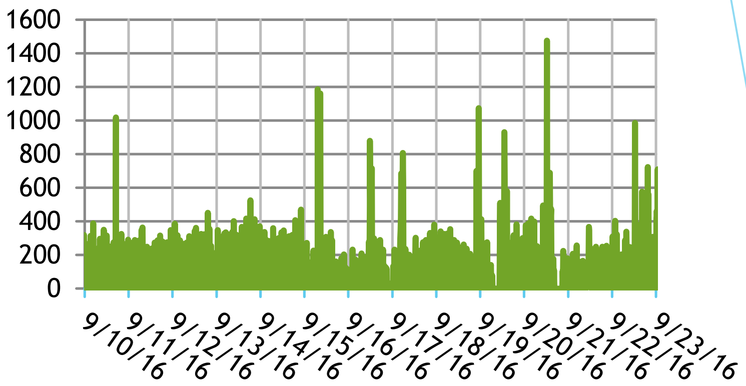


Eagle Ford MPFM – Identification of Water Migration

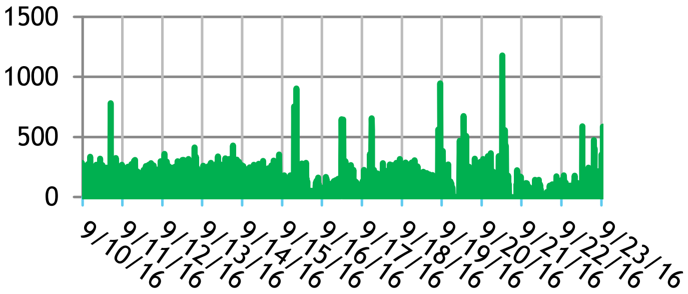
Std Gas Flow (mcfd)



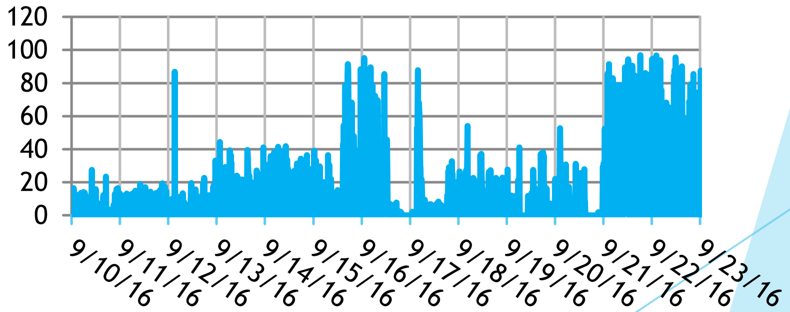
Liquid flow (bpd)



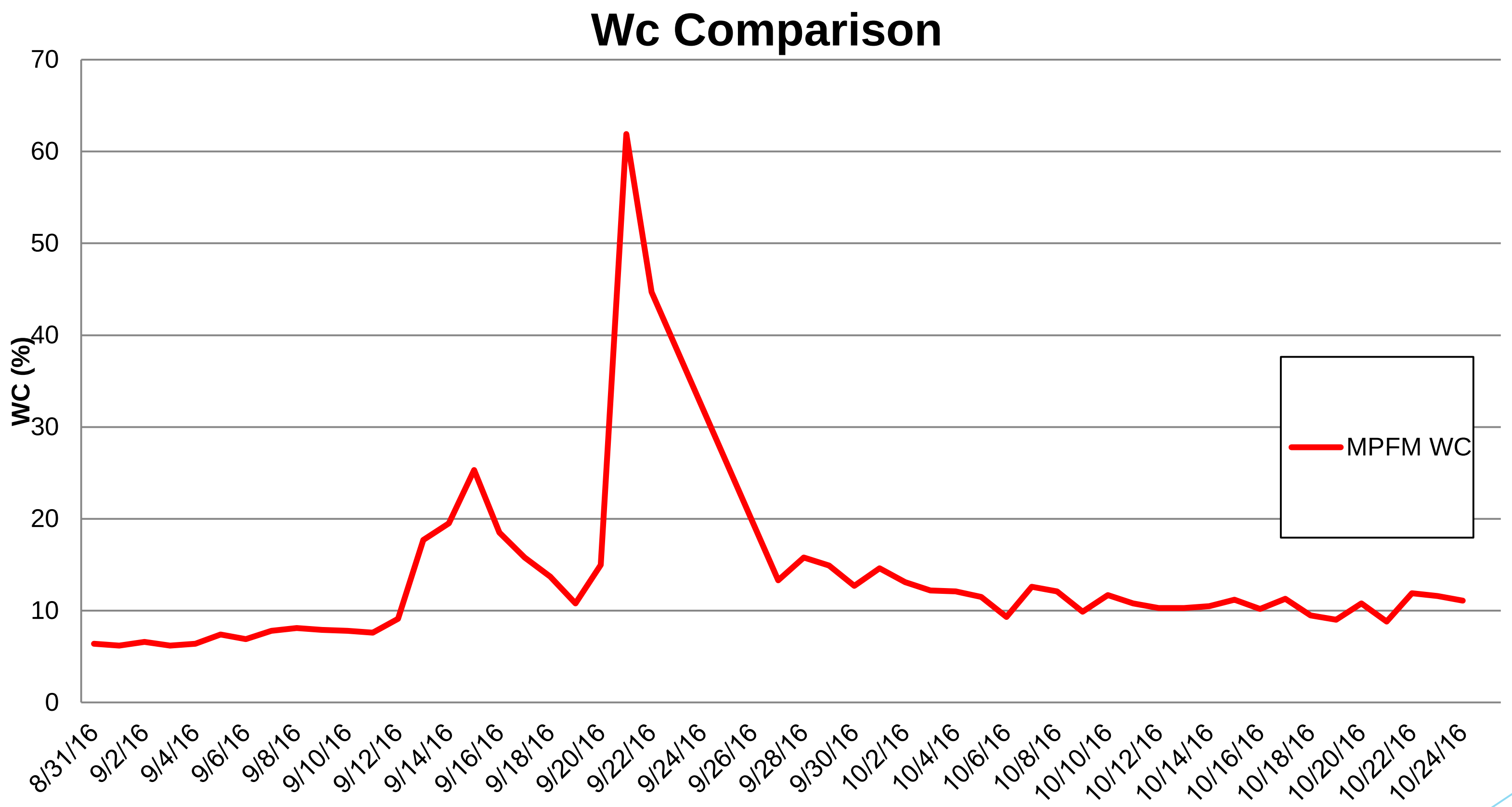
Oil Flow (bpd)



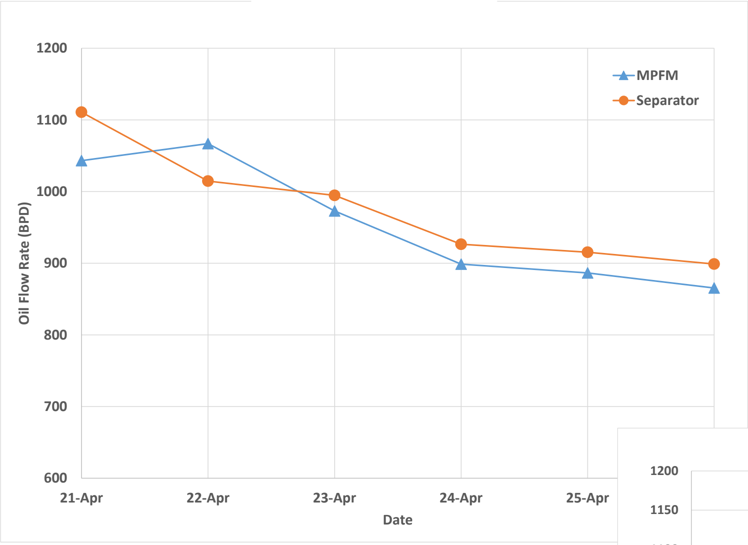
Water Cut (%)

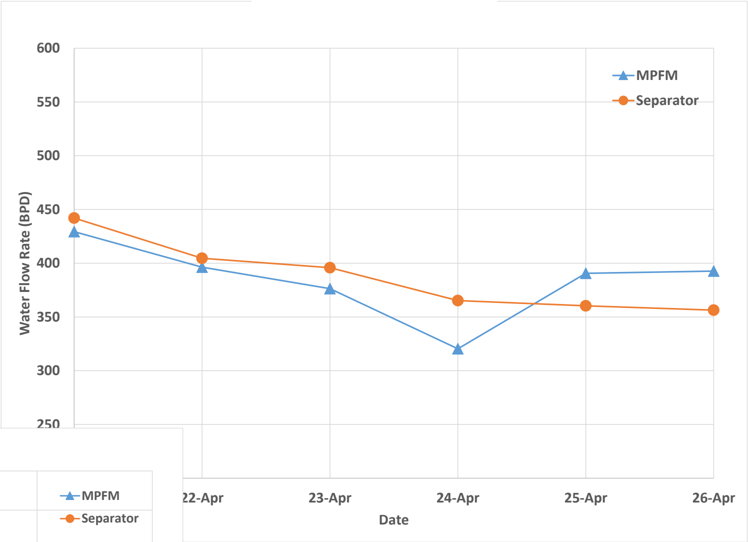


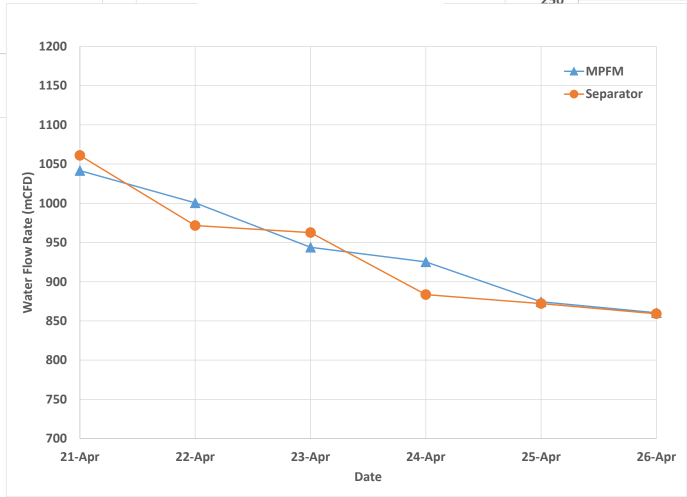
Eagle Ford MPFM – Identification of Frack Water Migration



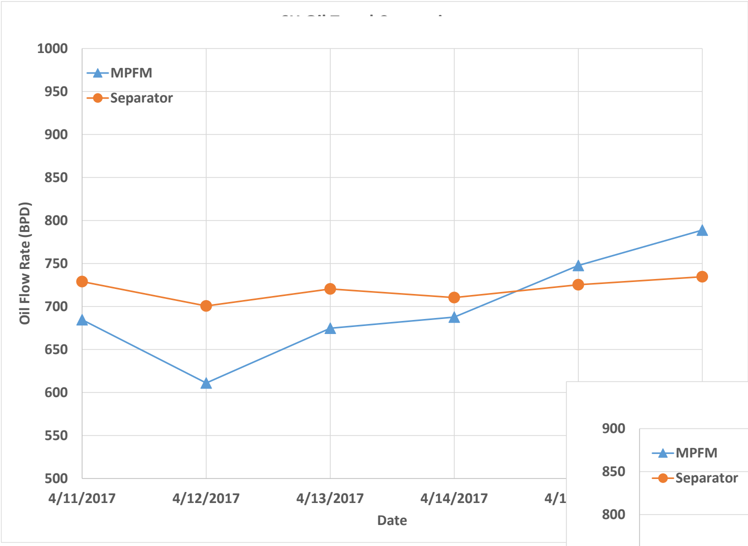
Eagle Ford – from Initial Evaluation to Operation- PAD A, Well 1 Comparative Trends

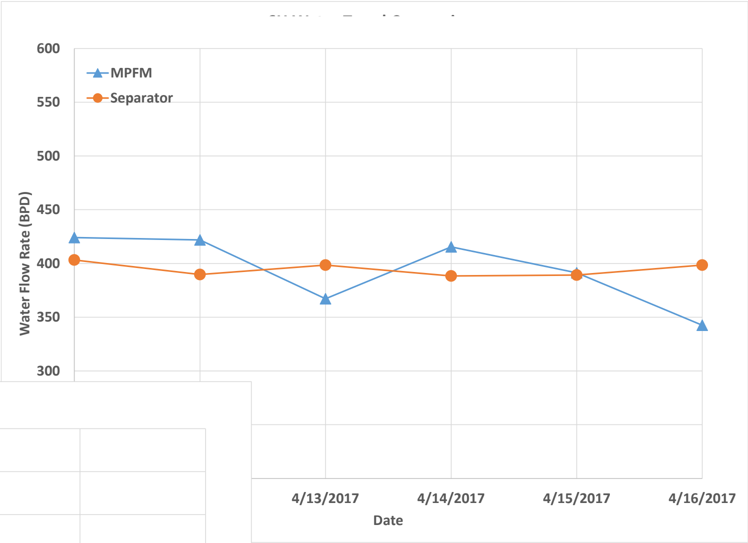


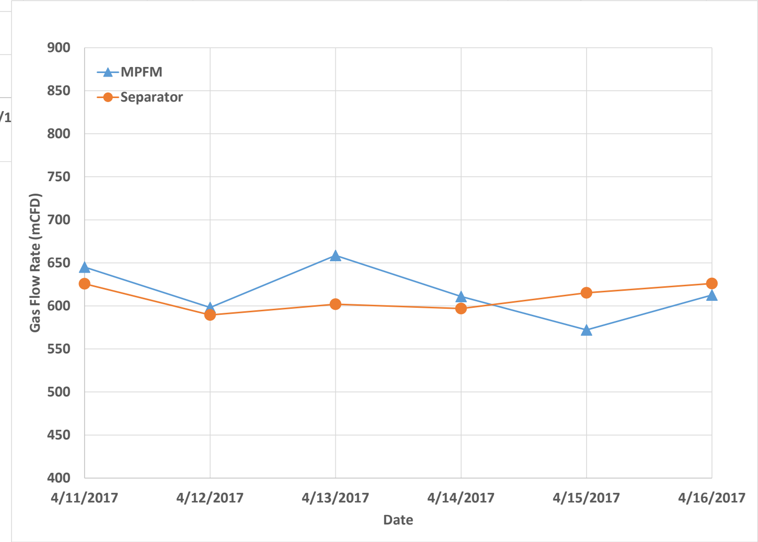




Eagle Ford – from Initial Evaluation to Operation PAD A, Well 2 Comparative Trends



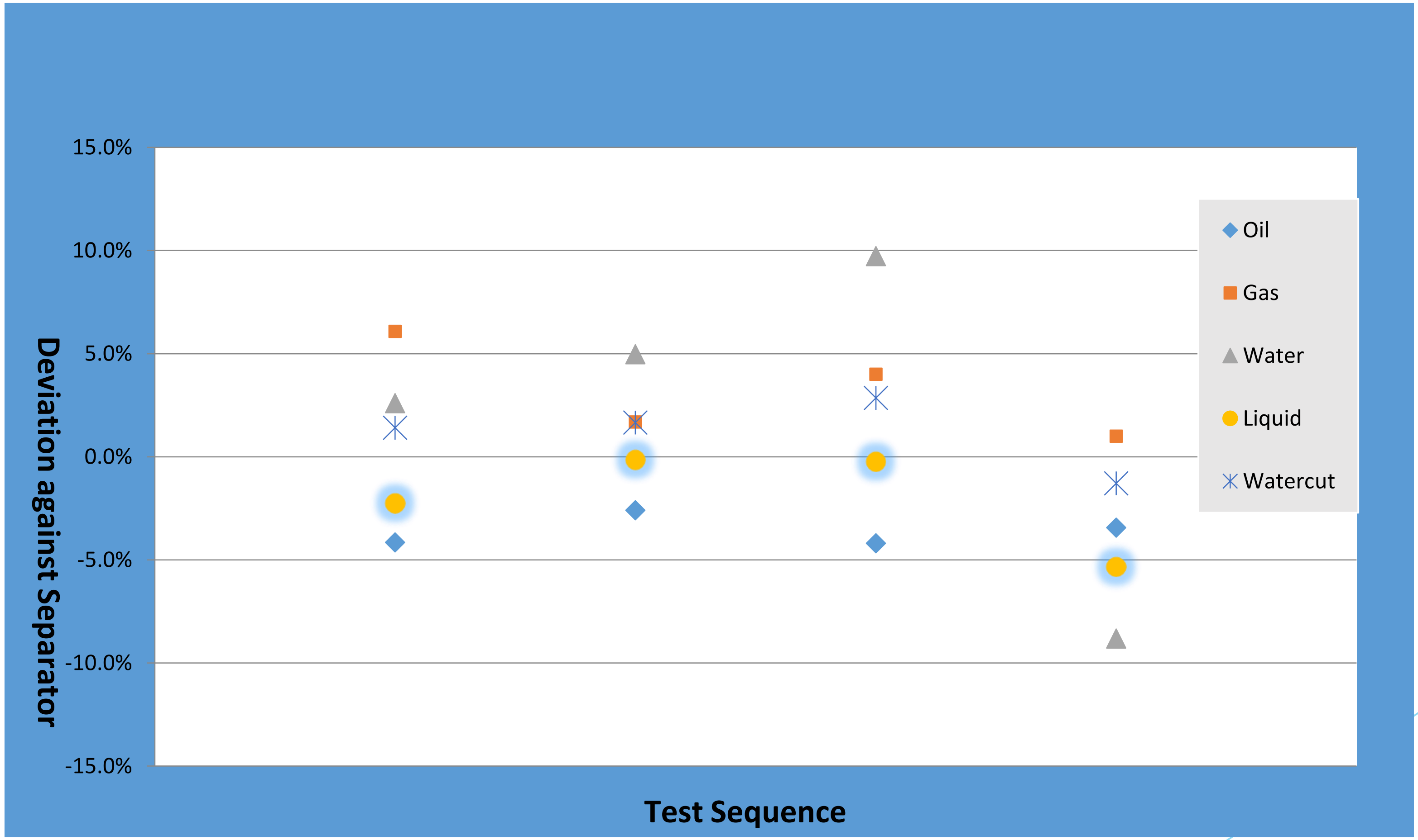




Eagle Ford - Well Test Summary Comparison over 5 days, after flow back separator hand over

Test Dates	AGAR GAS	AGAR OIL	AGAR WATER	AGAR LIQUID	AGAR WC	TEST GAS	TEST OIL	TEST WATER	TEST LIQUID	TEST WC	Gas	Oil	Water	Liquid	WC
	mcf	bbl	bbl	bbl		mcf	bbl	bbl	bbl						
4/16-4/21	5173	5215	2198	7413	29.7%	4877	5441	2142	7584	28.3%	6.1%	-4.2%	2.6%	-2.3%	1.4%
4/06-4/11	4109	4768	2469	7237	34.1%	4041	4895	2352	7247	32.5%	1.7%	-2.6%	5.0%	-0.1%	1.7%
4/21-4/26	4801	4616	2097	6713	31.2%	4617	4818	1911	6730	28.4%	4.0%	-4.2%	9.7%	-0.2%	2.8%
4/11-4/16	2979	3377	1750	5127	34.1%	2950	3497	1919	5416	35.4%	1.0%	-3.4%	-8.8%	-5.3%	-1.3%

Eagle Ford MPFM Summary of Phases and Fractions Uncertainties for 5 Days Tests Real-Time Data – PAD A



Eagle Ford MPFM Summary of Phases and Fractions Uncertainties for 5 Days Tests Real-Time Data – PAD B

Well A - Aug 1 - Separator Deviation			
Gas %	Liquid %	Oil %	Watercut Absolute %
-1.3	3	-0.6	1.3

Well B - Aug 2 - Separator Deviation			
Gas %	Liquid %	Oil %	Watercut Absolute %
3.5	-2.1	4.8	1.5

Conclusions & Recommendations

- In choosing a method for field evaluation, special care needs to be taken to validate the pre-test reference assumptions, and take corrective action if deemed necessary
- A comprehensive field test will examine the MPFM performance in all stages of well's life, since each of these stages will have distinctive dynamic flow characteristics
- Constant communication and collaboration between technology provider and E&P company is key for successful implementation