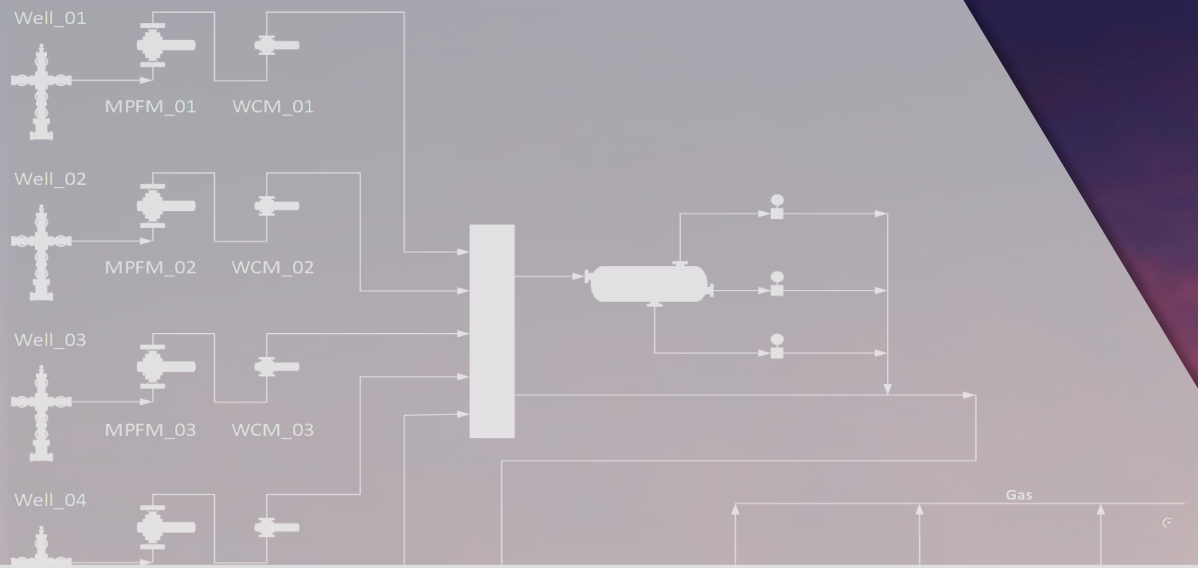


LiveFlo™
Multiphase Metering Solutions

# *Using Multi-Phase Flow Meters for Well Test Optimization in the new Digital yet Cost Sensitive Environment*

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**Haimo America Inc.**

APR, 2020

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- ❑ MPFM + AI in Well Testing
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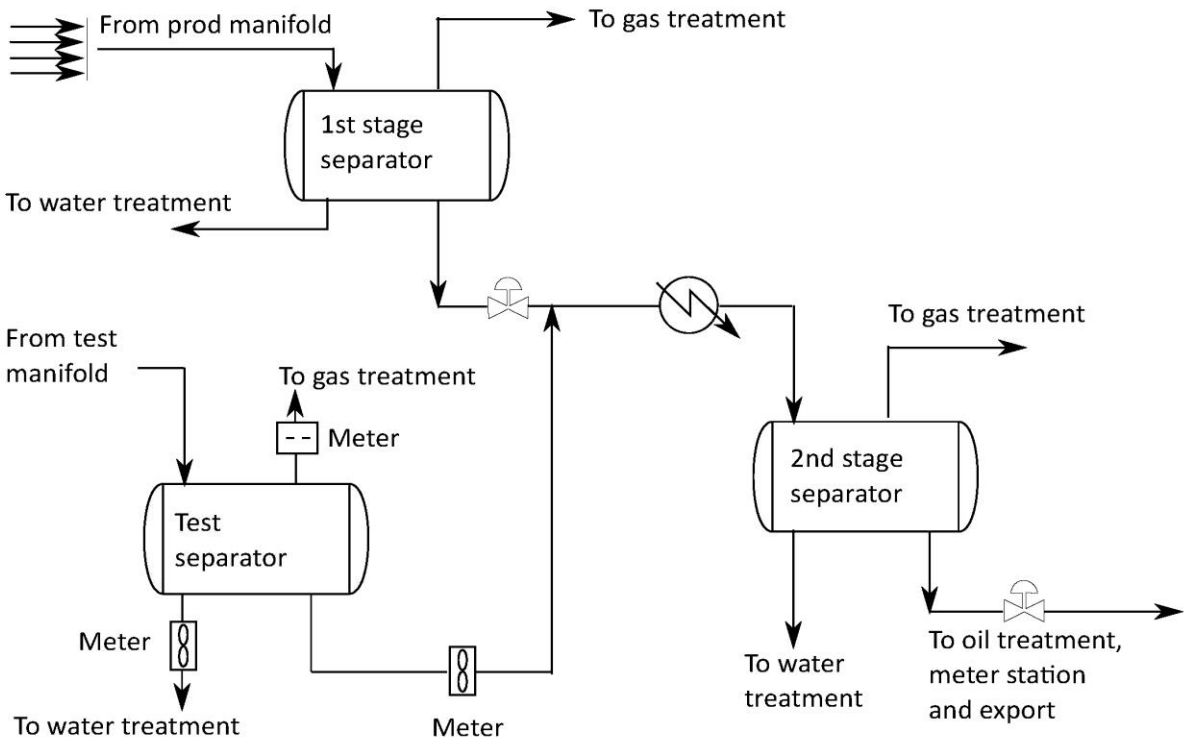
# Conventional Well Testing

**Various types of well testing is conducted throughout the lifetime of producing wells**

- In the petroleum industry,  a well test is the execution of a set of planned data acquisition activities. The acquired data is analyzed to broaden the knowledge and increase the understanding of the hydrocarbon properties therein and characteristics of the underground reservoir where the hydrocarbons are trapped….. The overall objective is identifying the reservoir's capacity to produce hydrocarbons, such as oil, natural gas and condensate. – *Wikipedia*
- A “well test” is simply a period of time during which the production of the well is measured, either at the well head with portable well test equipment, or in a production facility – *PetroWiki*
- Users of the well test data & information within the operator organization include amongst others Facilities, Production, Reservoir & Allocation Engineers, as also Hydrocarbon Accounting & senior management.

# Daily Well Testing - Allocation & Prod. Mgt

**Daily tests are conducted during production phase to obtain average daily production of oil, gas and water**



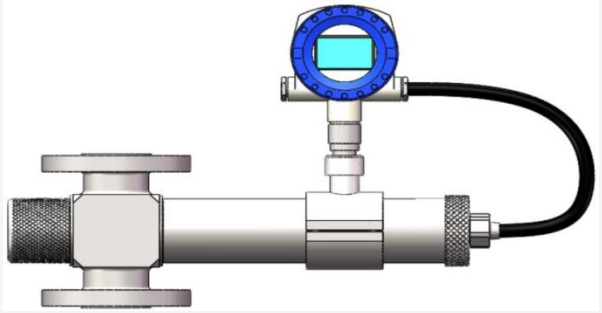

"Daily" test procedures usually require the rates of liquid, gas, pressure and temperature to be stable 24 hours or other fixed period.

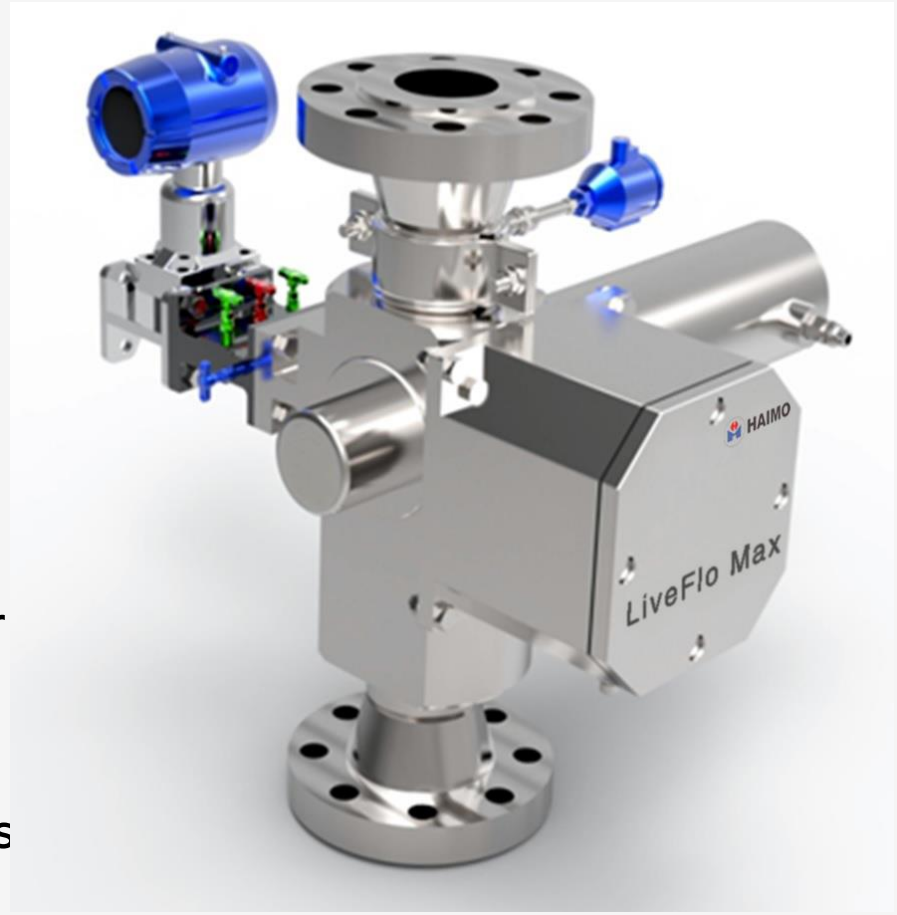
Due to "unstable" production conditions, and delays introduced by test separators, extended testing period is often required, sometimes reaching 5-7 days.

Costs associated could be very high.

*Periodic well tests on the production plant is the conventional way to get an estimated or theoretical production contribution per phase fraction per well per month. This plant is receiving a multi phased flow of oil and gas from many wells via a manifold. Flow from one well at a time is taken to the test separator (shaded). The output flow rates are measured for each phase fraction.*
*From: Wikipedia – Allocation*

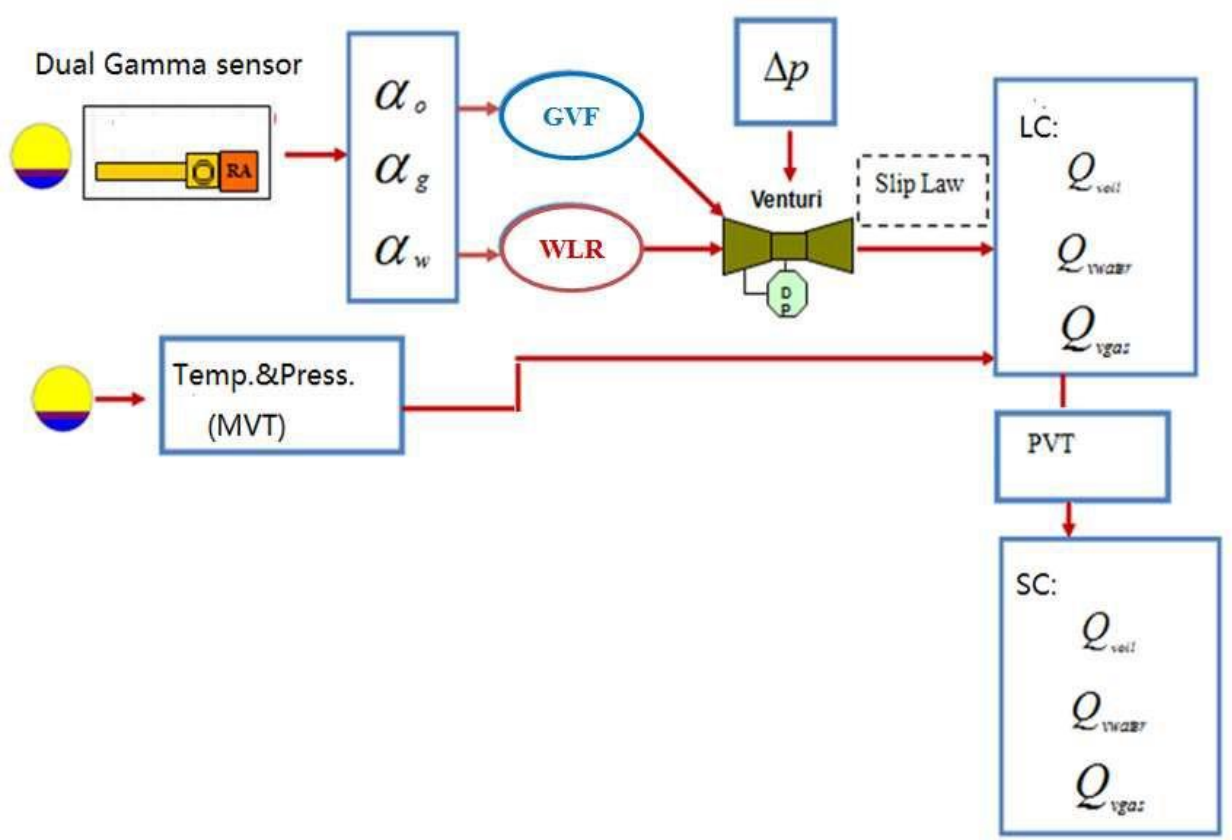
# Multiphase Meter Technology






- Multiphase Flow Meter (MPFM): Continuous flow measurement of oil, gas and water w/o phase separation
- A wet gas meter (WGM) is a multiphase meter that operates with >95% gas volume fraction (GVF)
- A 3-Phase Water Cut Meter (WCM) is a simplified multiphase meter measuring only GVF and WLR, without measuring flow rate
- MPFM/WGM/WCM typically have turn down ratio of 10:1, but higher turn down is possible too with the use of two different sizes of venturis within one meter skid, allowing for wider rangeability
- Very low pressure drop across the meters

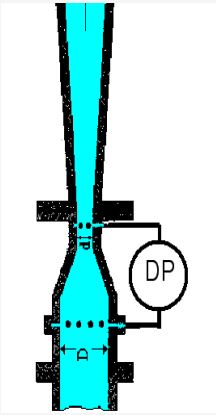
# Multiphase Meter Technology




## Calculation / Formulas

$$Q_{Total} = C \times \sqrt{\frac{\Delta p}{r_{mix}}}$$

**From Venturi**




$$r_{mix} = (1 - GVF) \times [r_o + WLR \times (r_w - r_o)] + (GVF \times r_g)$$

$$Q_{gas} = Q_{Total} \times GVF$$
$$Q_{liq} = Q_{Total} \times (1 - GVF)$$

$$Q_{water} = Q_{liq} \times WLR$$
$$Q_{oil} = Q_{liq} \times (1 - WLR)$$

- Core components are the venturi, dual energy gamma sensor and multivariable transmitter
- Total Flow Rate is measured by the venturi while Gas Volume Fraction and Water Liquid Ratio is determined by the Gamma Ray Detector System
- Oil, water & liquid flow rates are then calculated accordingly

# Why are Multiphase Meters the better alternative?

- Monitoring oil, gas and water rates of individual wells is the key to reservoir management and production optimization
- Real-time & accurate data is fundamental to smart field development
  - *Gravity-based test separators cannot provide real-time data*
  - *Multiphase Flow Meters: small; fewer components; high frequency real-time data*
- MPFMs were historically applied to offshore development due to their small size, but high costs prevented onshore application in the past. However technological advances in the past 10 -15 years has lead to significant cost reduction as compared to test separators and with considerably more benefits than the test separators

# Advantages

- ✓ Inline meter, no moving parts - low OPEX & maintenance
- ✓ No phase separation required, zero flaring
- ✓ Wellhead installlation can replace conventional testers / separators and associated safety devices; reduces CAPEX / OPEX in both greenfield & brownfield developments.
- ✓ Small footprint, Simple installation, low weight and safe operation
- ✓ High mobility, Low pressure-loss across meter, Low power consumption
- ✓ Replaces portable well tester; additional QHSE benefits by eliminating venting, driving hazards, and HC inventory transport, Safer & highly Cost Effective Solution
- ✓ Reduced testing time - excellent dynamic response to change in well flow, leads to higher test frequency
- ✓ Reliable, high frequency real-time, repeatable and accurate measurements ( $\pm$2% absolute on water cut & $\pm$5 to10% relative for the liquid & gas flow rates)

# Separator v/s MPFM

## Reduce the Amount of Big Vessels

Configuration: 54" x 10' x 1440# psi 3-phase
Flow Rate: 21,880 BPD Total Liquids @ 1 min Retention, 84 MMSCFD Gas @ 1000# psi
Delivered: July 2018, Eagle Ford, TX, US

## Save Overall Cost on Centralized Facilities

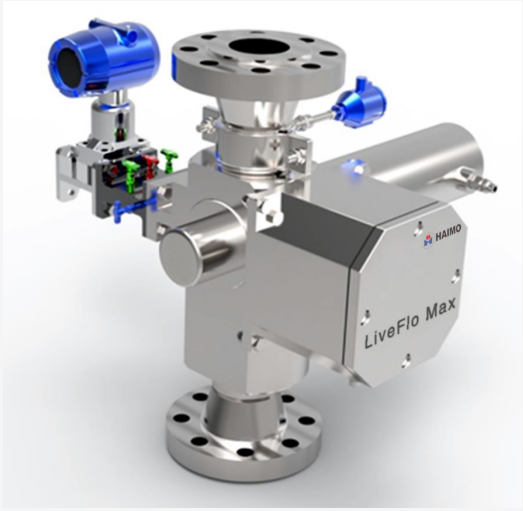
Configuration: 8' x 20' x 125# psi Heater Treater ; 8' x 20 x 75# psi FWKO
Flow Rate: 3,500 BPD Total Liquids @ 5 min Retention, 450 MSCFD Gas
Delivered: March 2018, Permian Basin, Texas, US

## With MPFMs

**Continuous Data with 24/7 Realtime Monitoring and Remote Control**

# Onshore & Offshore Applications

Water Cut Meter




Inline MPFM / WGM

Single / Dual venturi Skid-Type MPFM as Production Measurement Center

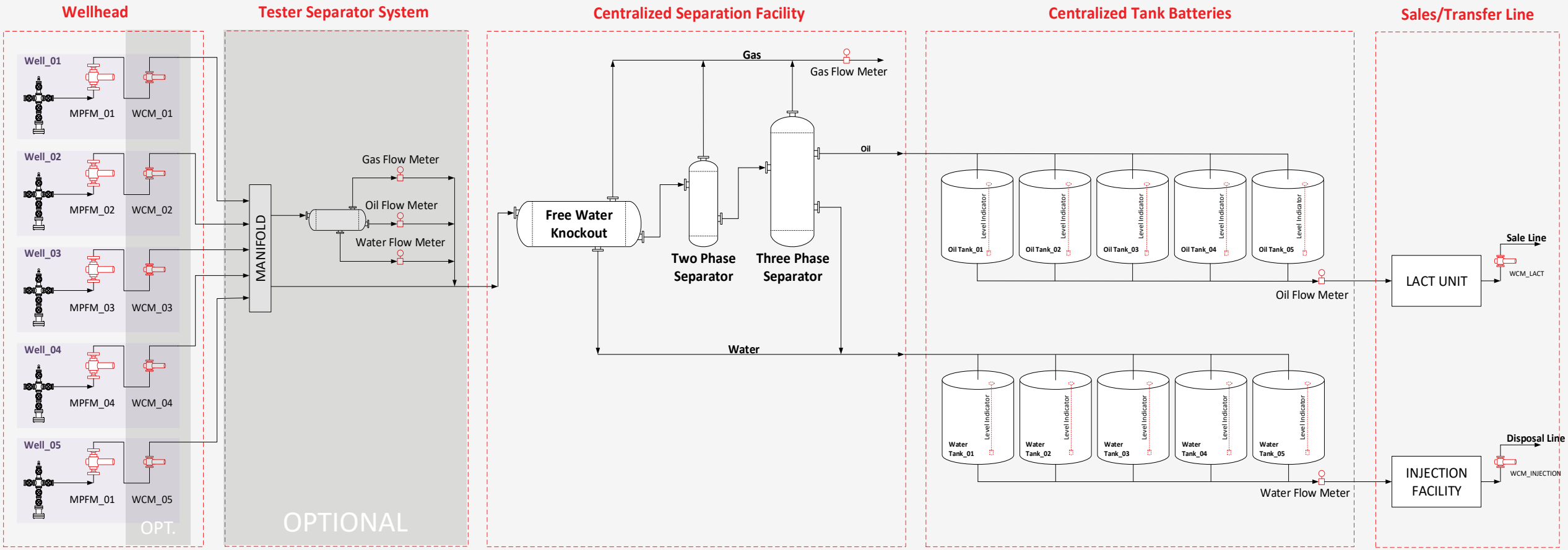
| Model | Size | WLR Range | GVF Range | Capacity |
|---|---|---|---|---|
| Water Cut Meter | 1.5 - 4 inch | 0-100% | 0-90% | Liquid Prod.: 100-14,000 BPD |
| Inline MPFM<br>Inline WGM | 1.5 - 8 inch<br>1.5 - 16 inch | 0-100% | 0-95%<br>90-100% | Liquid Prod.: 100-58,000 BPD<br>Gas Prod.: 2000acfd-4mmacfd |
| Skid Based unit | 1.5 - 16 inch | 0-100% | 0-100% | Liquid Prod.: 100-350,000 BPD |

# Flowback and Mobile Testing Applications

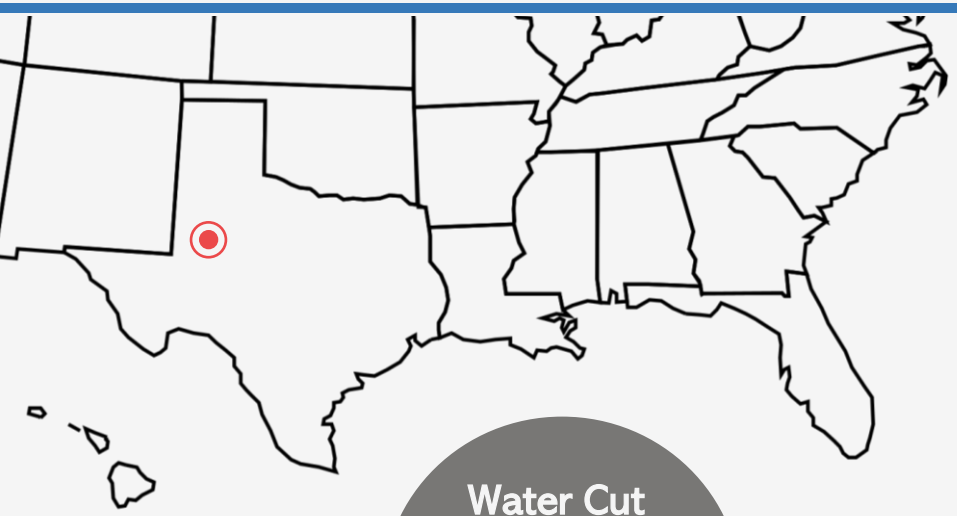
- Real-time flowback data aids **choke management, sand monitoring and surging controls.** Additionally early production data helps compare actual productivity vs. plan
- Wells are brought on stream at a lower cost and with a faster turnaround time
- The meter can be deployed when monitoring the flowback on all the different stages:
  - Early Stage – P, T, gas surging, total flow rate etc.;
  - Mid Stage – P, T, Q of oil, gas and water, surging etc.
  - Late Stage – P, T, Q, surging, early demob etc.
- Safety assurance plus quick indication of any upset condition or unexpected incident

# Permanent Closed-Loop Field Check Applications

Below is a typical MPFM installation layout for multi-well pad with a centralized surface processing facility. As shown, during the early production stage when the well is still flowing, for the purpose of crosscheck, the tester separator system is normally installed with a manifold system. Alternatively, we could install the MPFM inline with the WCM for crosscheck and to save footprint and cost as well.



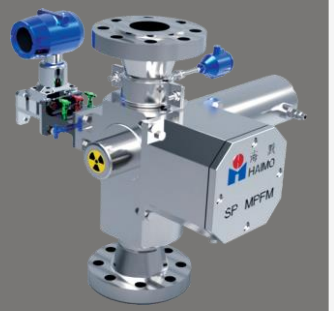
# Performance Validation example - U.S. Permian Basin

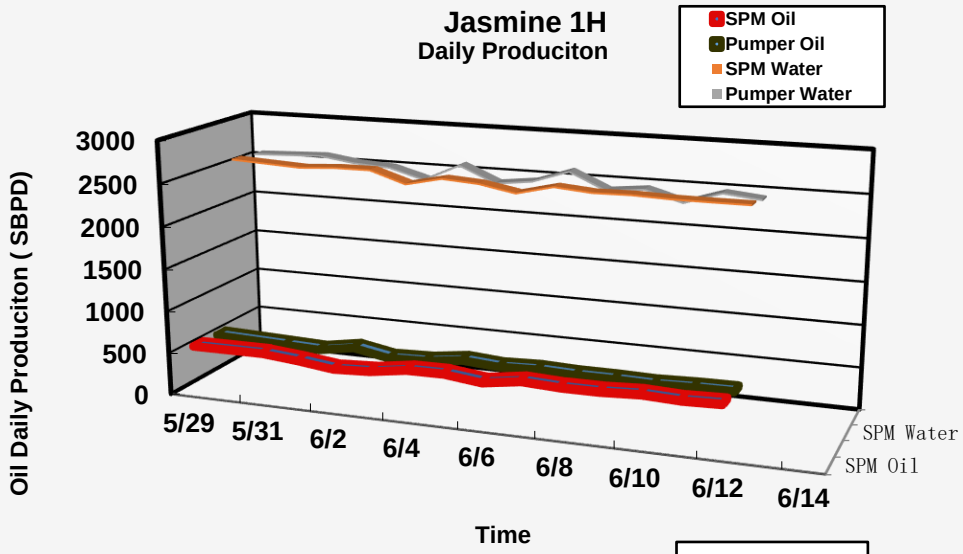


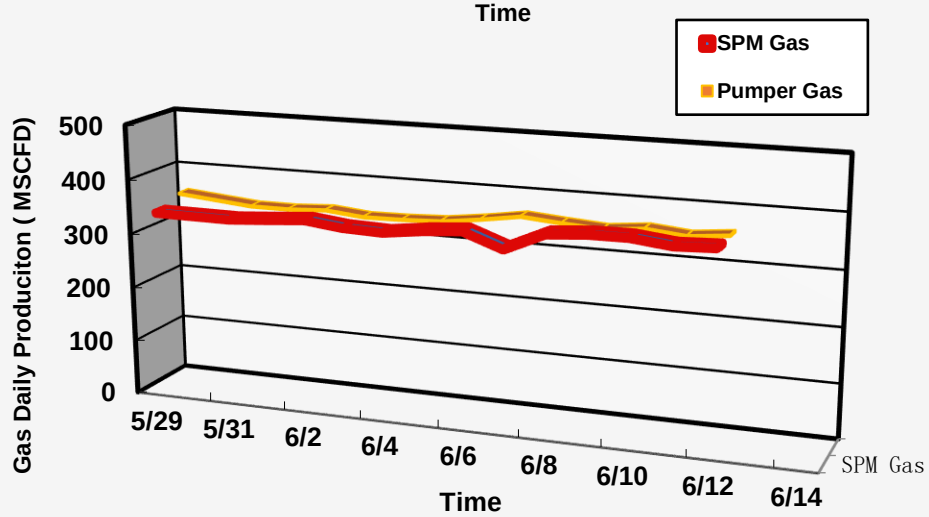
**Water Cut Absolute Error**

**1.2%**

- **Location:** Permian Basin, TX
- **Well Type:** Horizontal Well
- **Water cut:** 82%-87%
- **GOR:** 620-680






## Relative Error

**2.9%** Oil

**1.6%** Gas

**2.3%** Water

**2.4%** Total

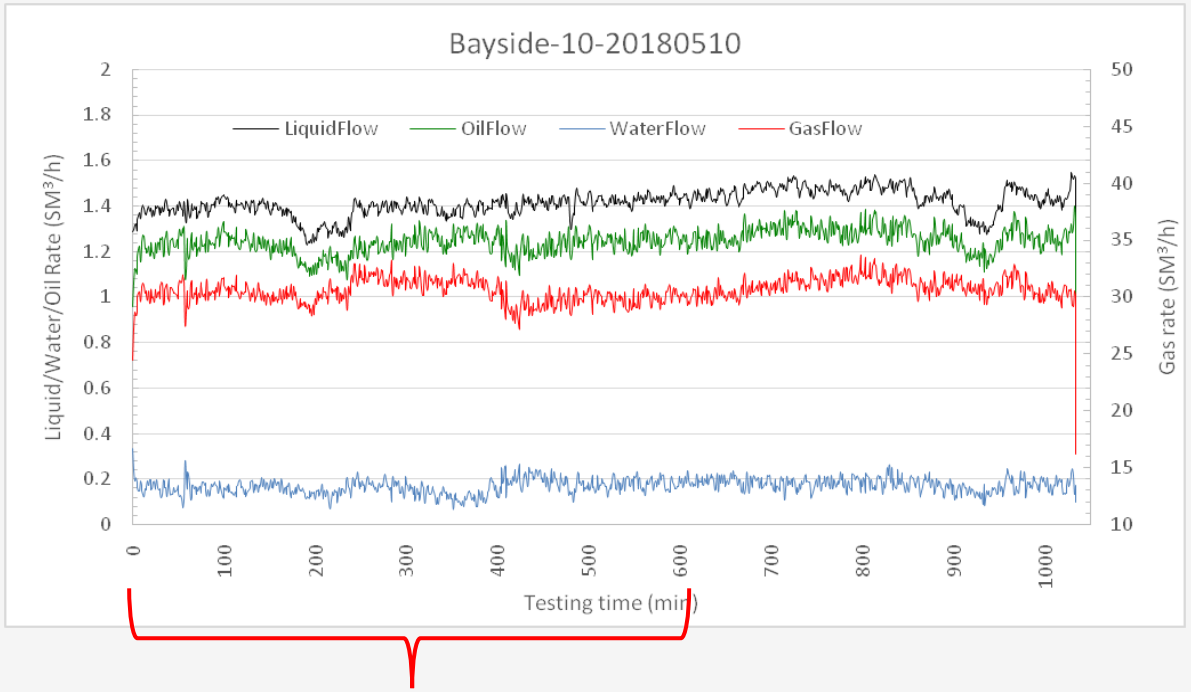
# MPFM + AI

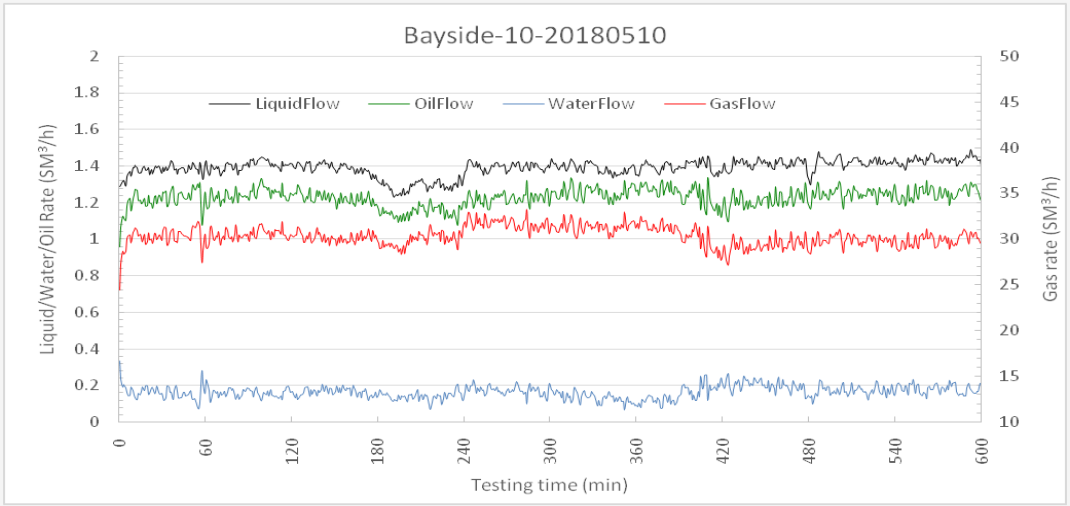
As a company, Haimo has provided the industry with high quality MPFMs for over 25 years, and we understand the need for optimizing daily tests, especially when there are cost constraints.

Recent  data science and artificial intelligence advances has allowed us to develop an AI-based well test optimization approach, based on thousands of multiphase flow loop tests.

- AI can recognize subtle changes in flow patterns and determine if these flow patterns are stable or not, which cannot be recognized by human eyes quickly, particularly with complex flow patterns.
- Flow patterns usually remain “stable” once reached in the absence of human interferences such as separation, choke change etc. even when slugging takes place.
- The well test optimizer was tested on real well test data in order to determine the practicality and potential time saving if applied.
- Multiple evaluations are applied to assure test result validity (multi-regression, extension of testing, etc.)

# Well Production Testing with Optimizer

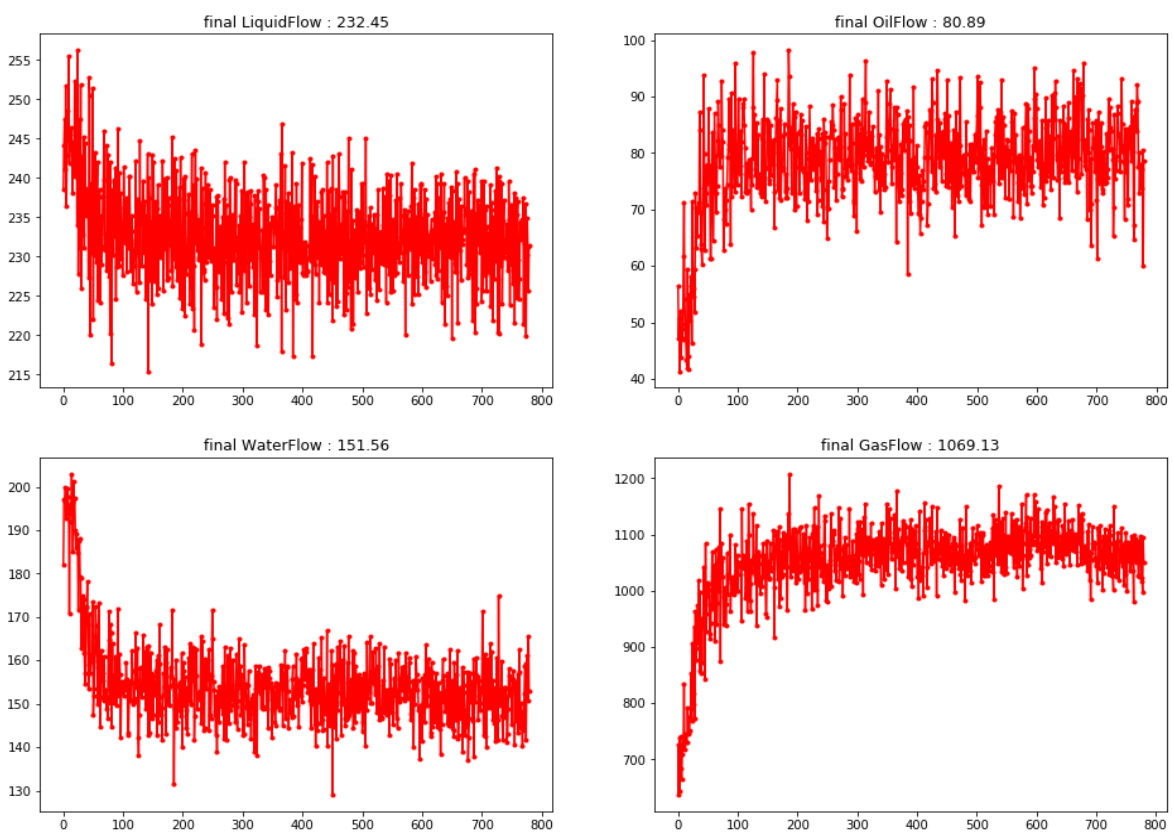


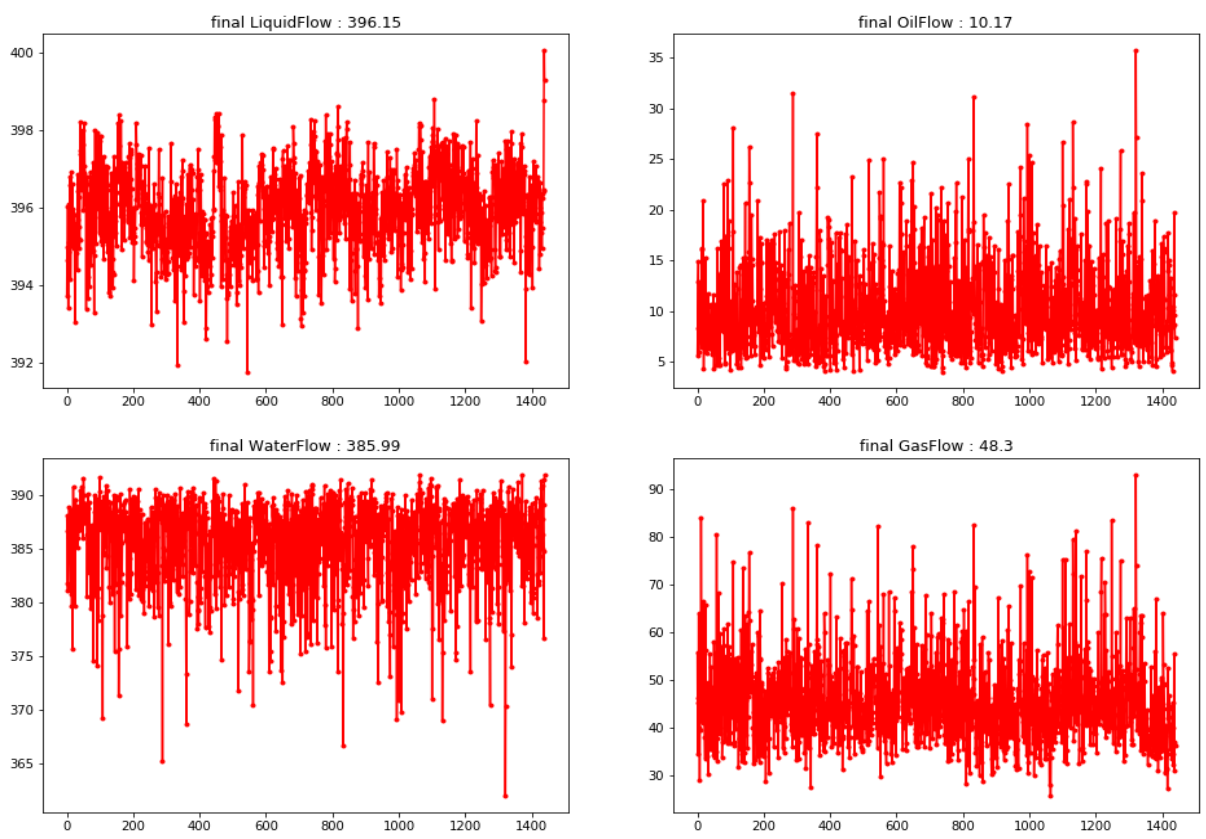

Total test time = 1040 min, @ 2% error, 350 minutes can be saved

# Well Test Optimizer in Production Optimization (With True Realtime Data)*

## Onshore Daily Testing




**Reaching "stability" at 282 min. Testing can be stopped at 342 min.**

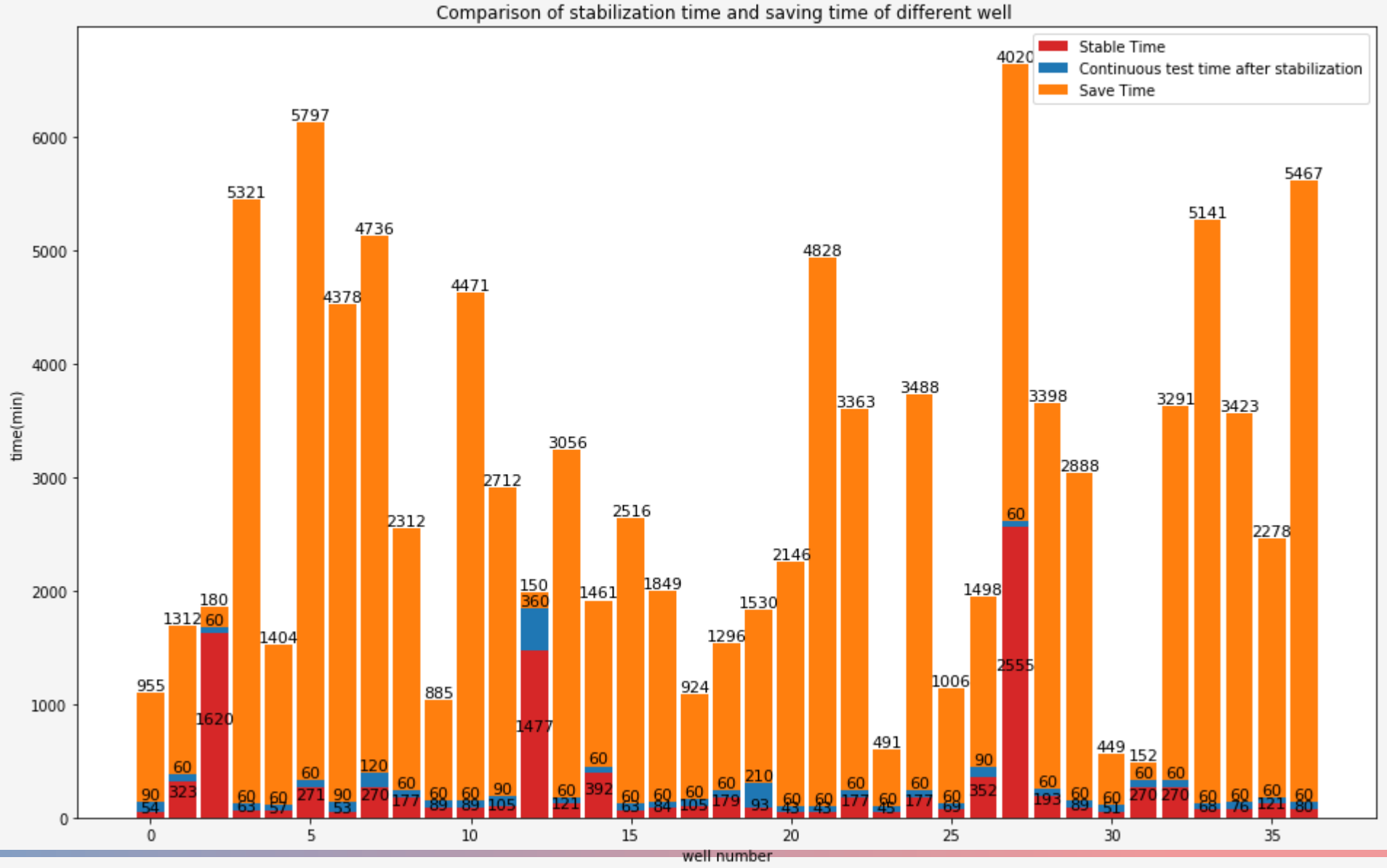



**Reaching "stability" at 49 min. Can stop at 89 min.**

(Technical paper was presented by Haimo at the SPE Workshop: Multiphase and Wet Gas Flow Measurements in Conventional and Unconventional Data Driven Environment, 28-29 January 2020, Galveston, Texas)

# Another Optimizer validation – 37 offshore wells

- After WTO first recognizes/marks the start of “stable” flow condition, 80% wells required only 60 min. additional time to confirm “stability”
- 10% wells required 90 min additional time to confirm “stability”
- WTO commands stop test 120 min after start of “stability”
- In this field, the average time can be saved is 2160 min.



# Conclusions

**Various types of well testing is conducted throughout the lifetime of petroleum producing wells. “Daily” tests form the bulk of all well testing.**

- MPFMs offer a superior option to test separators for well testing with reference to measurement uncertainties, data availability, test frequency, CAPEX & OPEX as also safety & ease of operations.
- MPFM is recommended, not only for saving test time, but also for the many other benefits associated with its use & deployment.
- Further MPFM data combined with Artificial Intelligence can detect and determine flow stability that cannot be detected by human eyes, especially with flow pattern variations.
- Accordingly, the optimizer program application can be deployed with the meter to help save test time in as much as 90%. The time saved and free equipment availability can be better utilized for testing more critical wells and for testing more frequently. It can also help resolve testing equipment shortage issues and fulfill mandatory testing requirements.
- Value delivery from the technology: Cost savings in equipment and time; freedom of prioritizing tests; real time decision making; HSE risk reduction; better options for production management.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