Operating Experience with Multiphase Meters at Who Dat and Delta House Fields

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Overview Who Dat and Delta House

• Who Dat current production: 24,000 STB/D, 55 MMSCF/D, 8,000 BWPD.
  – First oil 12/2011, first subsea MPM meters 9/2013
  – Current total wells: 10 (9 MPM meters)
  – Cumulative: 46 MMSTB oil, 82 BCF, 7.5 MMBBL Water

• Delta House Current rate: 92,000 STB/D, 200 MMSCF/D, 1,000 BWPD
  – First oil 4/2015, first subsea MPM meters 4/2015
  – Current total wells: 11 (10 MPM meters)
  – Cumulative: 38 MMSTB oil, 94 BCF, 0.3 MMBBL Water

• Individual well production allocated using MPM meters going forward
Overview MPM Meter Technology

• Multiphase & Wetgas (Dual Mode)
• Venturi – Total mass flow
• 3D Broadband – tomographic measurement
  – Phase fractions of oil, gas and water
  – Gas-volume-fraction (GVF)
  – Water-liquid-ratio (WLR)
  – Liquid/gas distribution within the pipe
• Gamma densitometer – mixture density
• Salinity probe – water salinity
Who Dat

Status: 6 flowlines, 4 manifolds, 10 wells, 7 producing horizons
Fluid type: from wet gas to 16 API oil and everything in-between
Delta House

**Status:** 8 flowlines, 6 manifolds, 11 wells, 6 producing horizons

**Fluid type:** condensate, volatile oil and black oil

**Long term:** exploration in the area will result in additional tie-backs
MPM Meter Installation

• Application Design
  – 3”; Duplex
  – 10 kpsi; -30F to 250 F
  – Beta ratio 0.55 or 0.7

• Installation
  – Installed on manifold side in jumpers
  – Flanged in jumpers (no welding), preservation of meter & electronic
  – vertical upwards flow
  – Novolastic insulation around dP taps
  – ROV protection cage
Allocation Philosophy

• Well production is allocated from LACT and sales gas meters directly back to standard oil and gas readings from subsea MPMs.

• Test separator not used for tier 1 allocation

• Test MPMs every 180 days (Delta House) or 360 days (Who Dat) by comparing with separator readings
Uncertainty Breakdown

Each uncertainty ‘element’ must be evaluated in setting acceptance criteria.

**Meter**
- Technology, Flow Models, software, Flow loop testing

**Configuration**
- PVT quality, EoS models, comingling, reservoir changes, EoR

**Conversion**
- PVT quality, production process, comingling
PVT Configuration Challenges

• Conversion from MPM measured gas rates to LACT/sales gas standard condition

• Differences between PVT configuration (look-up tables) in MPM vs actual fluid composition

• Single stage flash (MPM) to model multi-stage flash separation (DH)
Allocation Benefits vs. Conventional Well Test

• Daily test data yield better accuracy
  – MPM sensitive to small daily changes while conventional well test are carried out weekly or monthly

• Reduced downtime
  – No need to put each individual well to the test separator every 1-3 months (by either shutting-in wells in the same flowline or moving wells into the other flowline)
  – No need to perform well tests when the well is on rapid decline or with choke changes
Reservoir Benefits: GOR sensitive wells

• In 2 wells at Who Dat, GOR is sensitive to withdrawal rate

• Simple trending/monitoring of GOR led to flow rate adjustments to conserve energy in the reservoir

• One of the 2 wells was producing 6000 STB/D and 25 MMSCF/D, causing a 100 psi/month decline. After reducing the rate to 3000 STB/D, gas rate reduced to 8 MMSCF and pressure decline was eliminated

• By reducing the rate, simulation projected an increase of 5+ MMSTB reserves
GOR Sensitive Well Examples

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Reservoir Benefit: Co-mingled Wells

- MPMs allow accurate determination of production distribution between co-mingled producing zones
- Able to use the operational flexibility of the smart sleeves to well test each zone individually
- Two particular wells where production is co-mingled and each well produces from 2 different reservoirs
- With better understanding of the reservoirs we were able to increase booked reserves by 2 MMSTB

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Reservoir Benefit: Reservoir Modeling

- Continuous WLR and GOR data are key history match parameters that are not very accurate using conventional data testing.
- More reliable data improves the quality of the reservoir models and so enhance the accuracy of production forecast and decision making.
Operational Benefit: Production Optimization

• Before the use of MPM’s, well optimization required a determination of productivity based on the last well test to provide a target downhole flowing pressure to reach a desired production rate.

• Because of reservoir depletion, new target downhole flowing pressures were required weekly in order to maintain target production rates.

• MPM is now used as the primary rate measurement in the optimization process. An MPM rate target can sometimes be appropriate for months.

• The meters are also used as the primary rate measurement in well ramp-up where the meter combined with the DHPT gauge are monitored through the ramp-up.
Operational Benefit: Surface Meters

• MPM was used as a diagnostic tool to help identify one separator oil reading that was 40% lower than reality in Delta House and one separator oil reading that was 25% too high than reality in Who Dat
Challenge: Meter Sizing

- All of our meters in service were designed to have a 0.7 Venturi beta ratio based on initial estimates.

- Some of the wells have declined to less than 1000 STB/D liquid, which is below the minimum pressure differential (dP).

- MPM of those wells can read a positive rate when the wells are shut in and zero rate when the wells are flowing when the differential pressure is less than 50 millibar (minimum operating differential pressure).

- dp cut-offs were reduced to ‘expand’ meter envelope outside of normal measurement range (operation as low as 10 mbar).

- Where possible, it is recommended to account for the entire life of the well in order to optimize the MPM sizing. In some cases, 0.55 beta meters may work.
Challenge: Water Properties for High WLR Wells

• Water properties play a significant role to oil and water readings in water continuous wells (WLR > 50%), water salinity ranges from 30,000 ppm to 150,000 ppm.

• Failing to put correct water conductivity / water density in the meter can result significant uncertainties when dp is less than 50 millibar.

• Integrated MPM meter salinity probe has been used to actively compensate changing water properties in water continuous flow.
Challenge: Double Choke Problem

• The standard oil, gas and water readings at the MPM depend upon the pressure and temperature at the meter

• When the meter condition changes, even though actual rate is constant (no change in drawdown), the standard oil and gas readings could change.

• Most of time, this happened when we have a subsea choke and a surface choke, so we called it double choke problem
MPFM Value: Accuracy, Diagnostics, Reservoir Surveillance

• Accuracy
  – All 19 meters in service average 5% uncertainty with validation and occasional calibration.
  – Measured water flow rates consistent with overboard water volumes. Identifies water source in intelligent and commingling subsea wells without shut-in’s.

• Diagnostics
  – Meters are used as tool to QC sales gas and separator meter measurements
  – In-situ capabilities for trouble shooting=>QC on meter hardware, software and PVT configurations
  – Use recalculation tool to test updated field configurations prior to calibration
  – Remote access for raw data retrieval, diagnostics, updates. No offshore personnel required even for commissioning meters for the first time.

• Reservoir Surveillance
  – Continuous MPM readings are valuable tools to identify rate sensitive wells as we can then enhance ultimate recovery by reducing production rate
  – MPM’s can identify the production ratio and fluid phase behavior between different zones in commingled wells when the sleeves are shifted to enhance understanding of commingling zones and increase ultimate recovery
  – MPM’s can provide valuable water cut and gas oil ratio behavior for reservoir modeling to enhance model quality and reliability for better decision making