Multiphase Metering and Well Rate Estimation Methods for Field Allocation

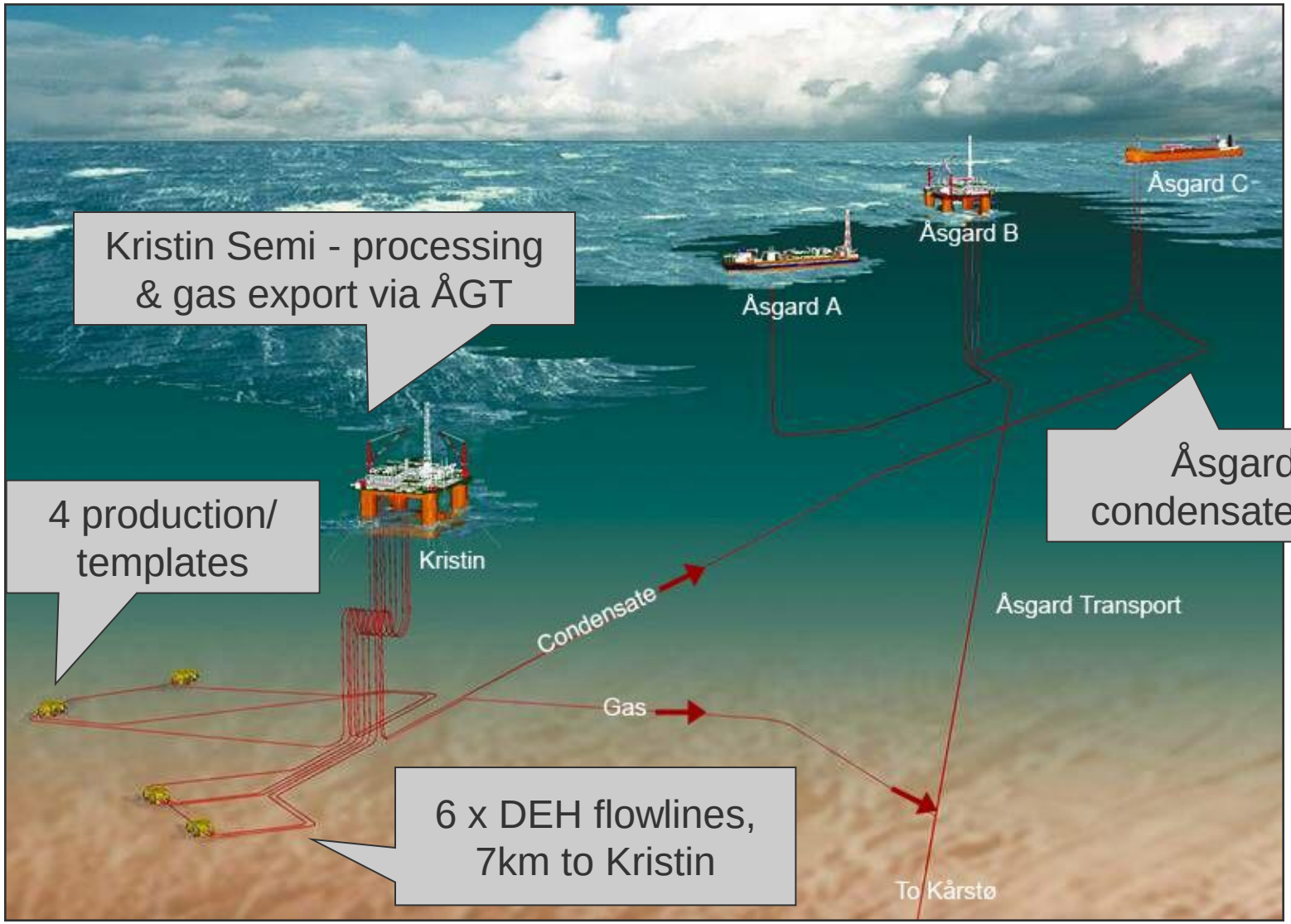
Arne Morten Dahl (Statoil, DPN OMN KH PTC KRI)

2014-06-05

Outline

- MPFM for field allocation, introduced by tie-in of Tyrihans to Kristin
- Original metering philosophy and allocation principle
- Events and challenges
- Remedial actions and changes
- Status metering and allocation 2014
- Future challenges technologies / opportunities

Kristin subsea infrastructure



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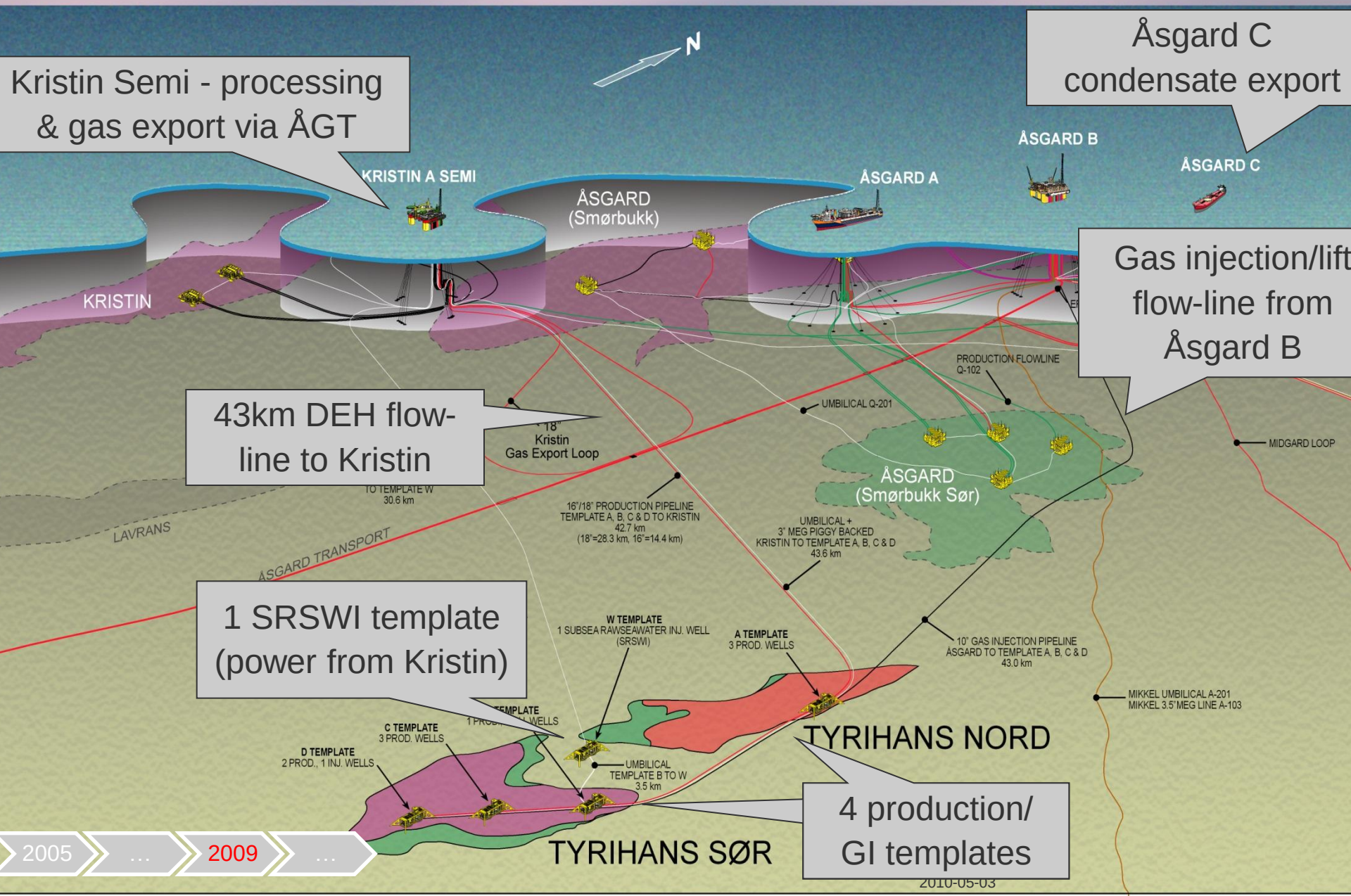
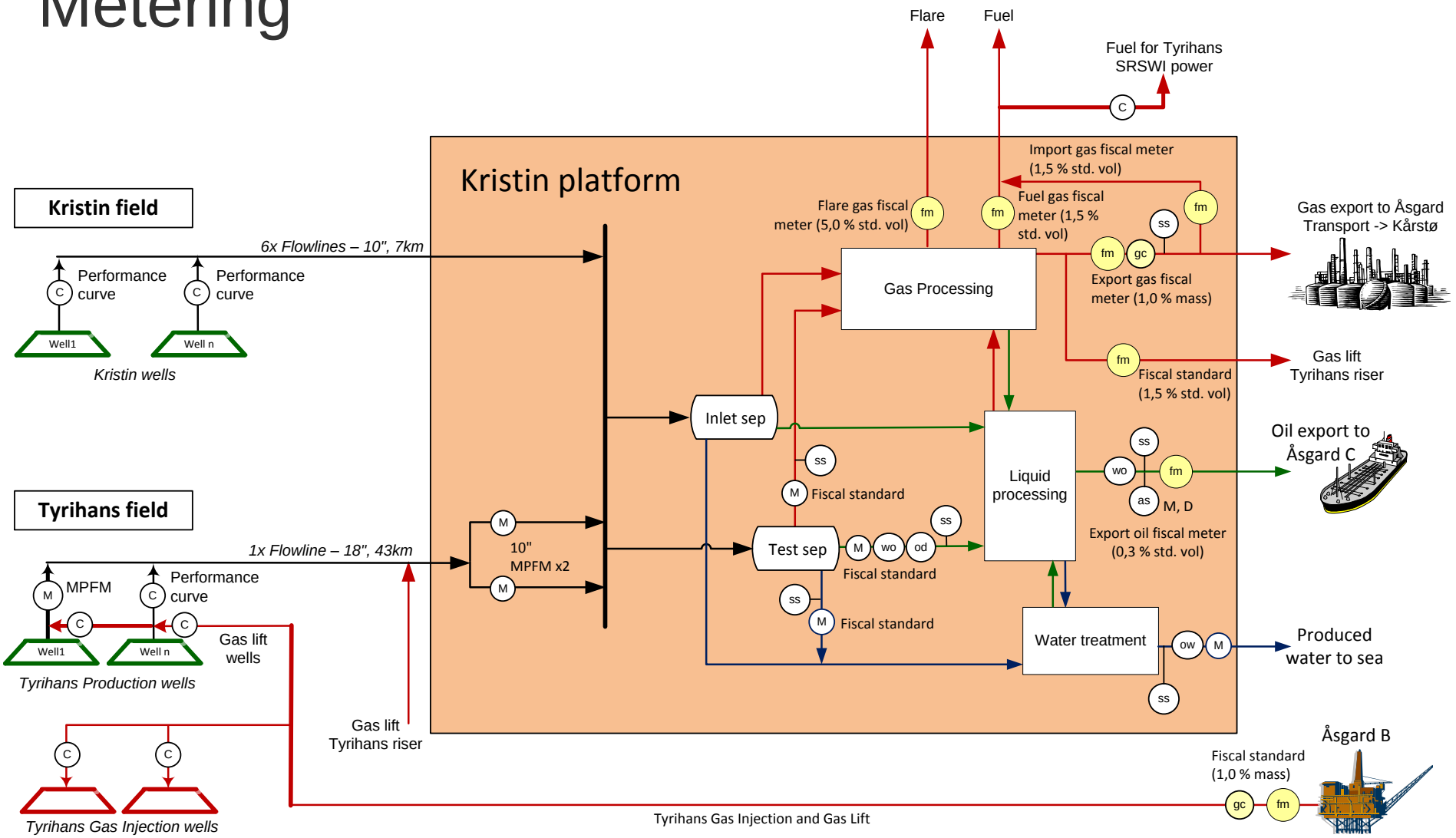
Tyrihans subsea infrastructure



2005 … 2009 …

Metering



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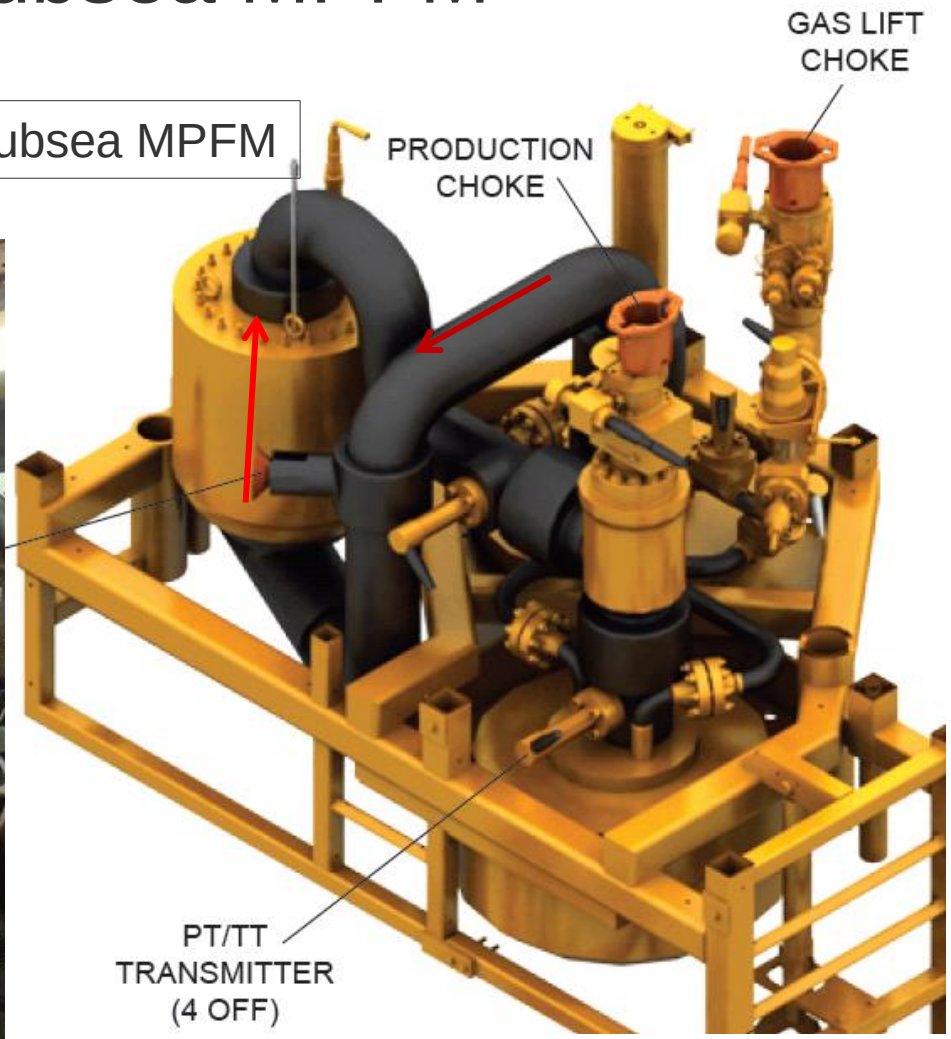
Tyrihans Topside and Subsea MPFM

Topside MPFMs

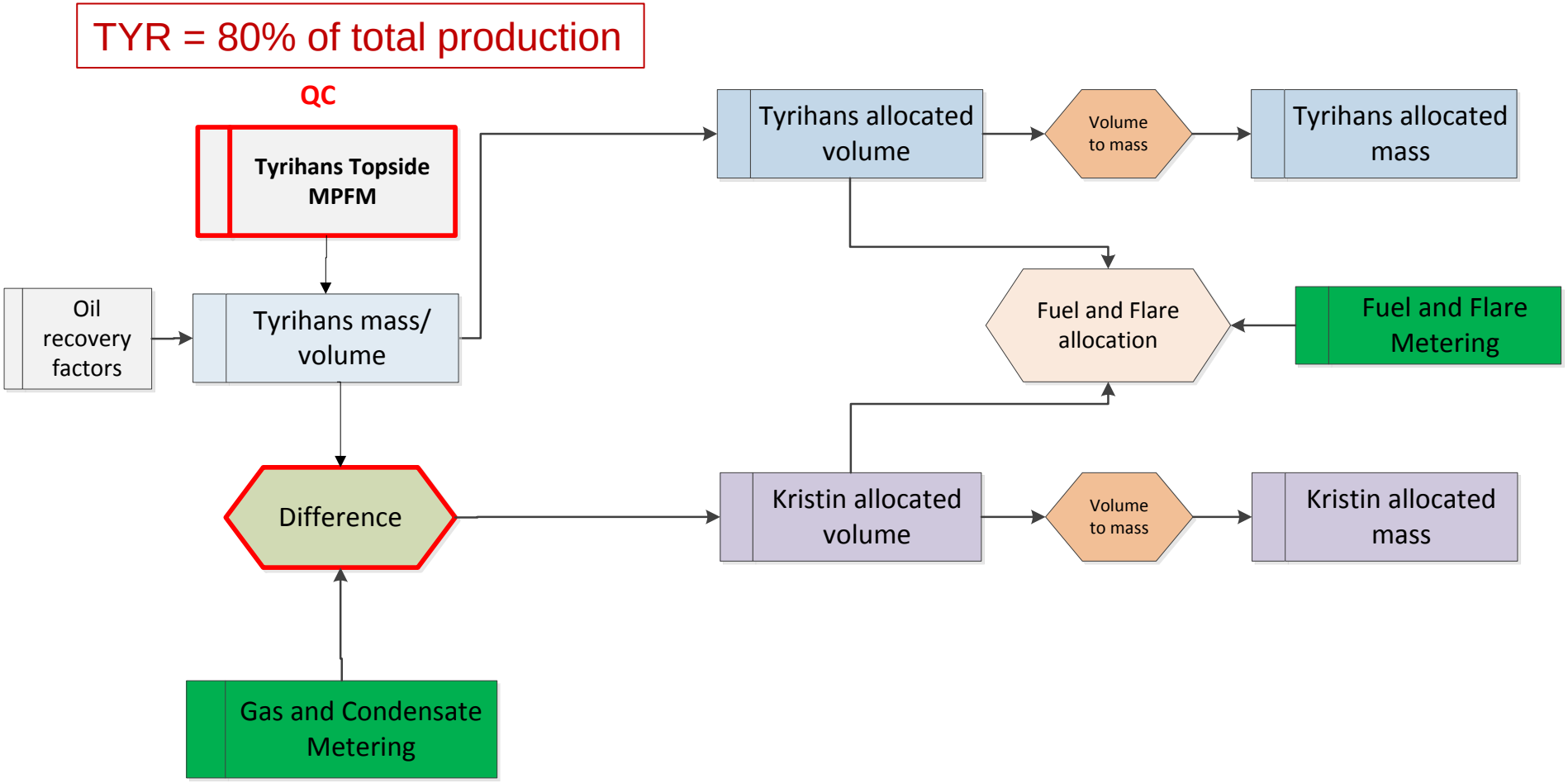
Subsea MPFM

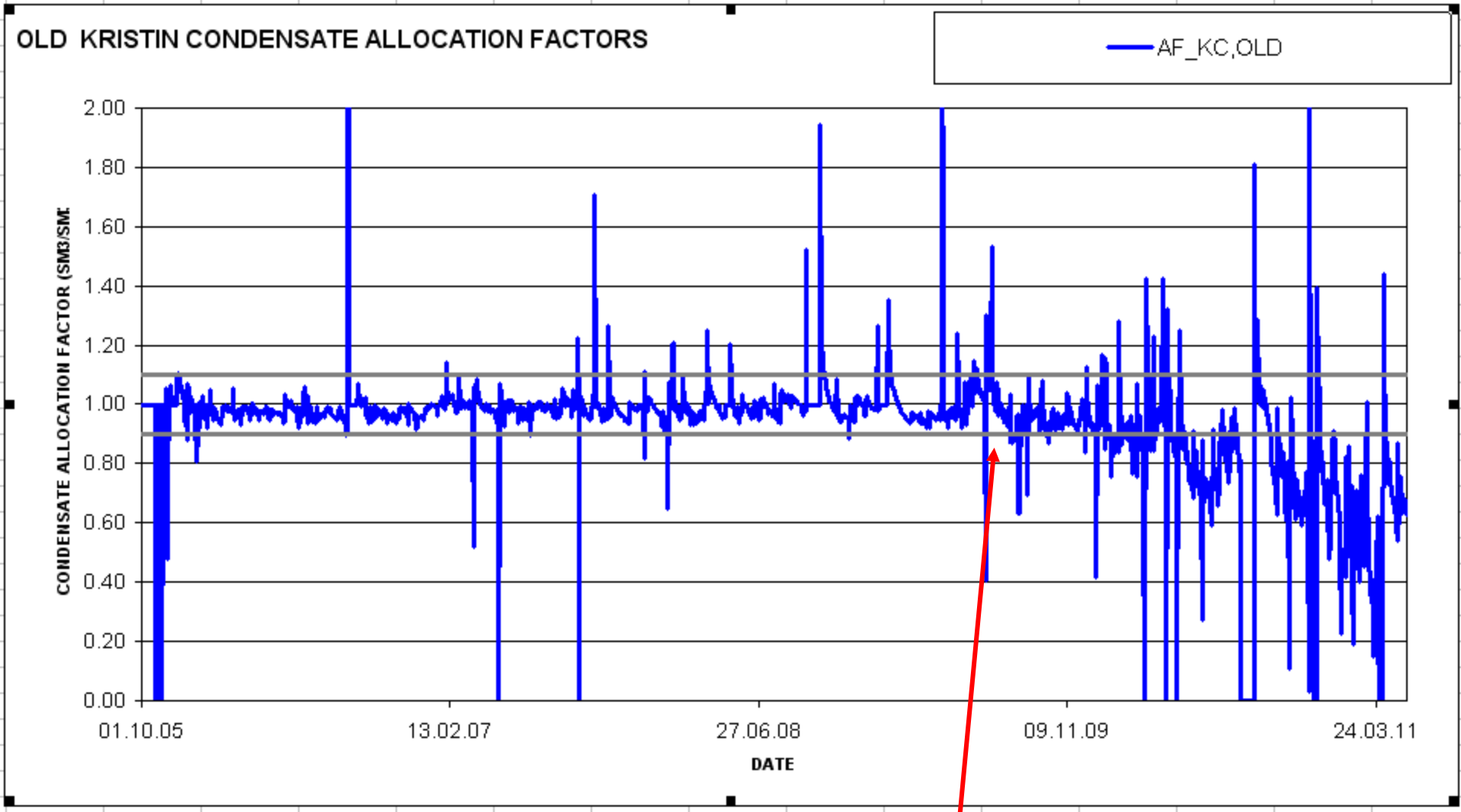


Main purposes of oil and gas allocation

- Fiscal allocation
  - Ownership allocation, distribution of the income
    - Oil and condensate mass
    - Gas energy
- Production Management
  - Detailed production monitoring and optimization
    - Allocated production and injection volumes for individual wells
- Reservoir Management
  - Reservoir simulation model history matching
    - Allocated production and injection volumes for individual wells

Original Allocation principle: Kristin as balance field (Kristin by difference – KBD)





Allocation factor = Allocated volume/theoretical volume

Tyrihans start-up

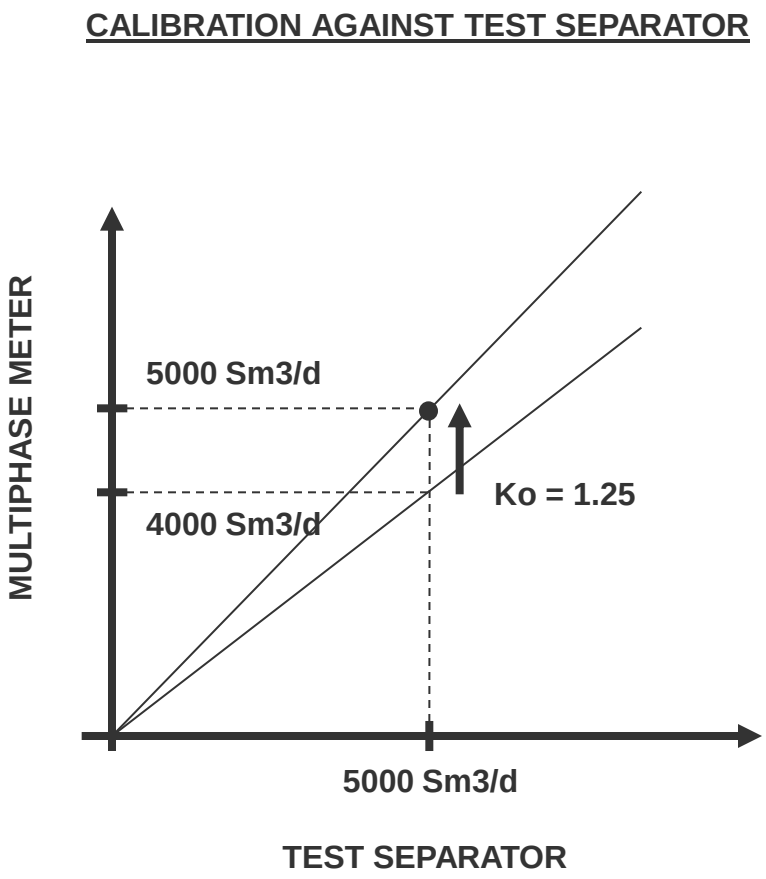
Troubleshooting Allocation System

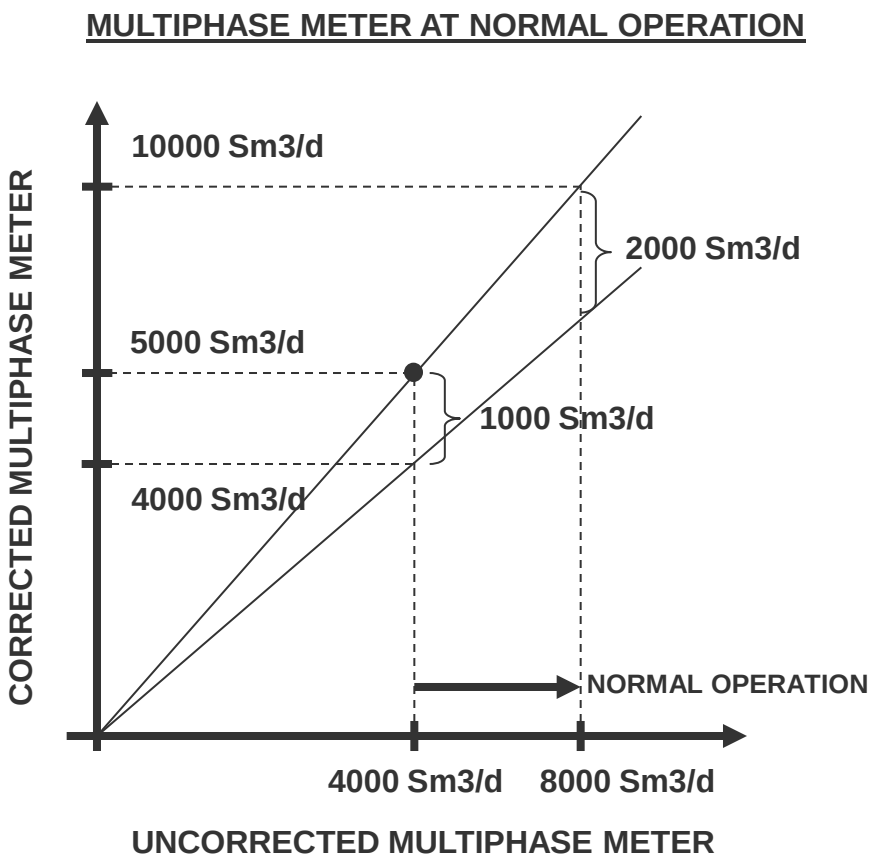
The original field allocation system does not reproduce the results from field tests.

Main issues seem to be:

- Test separator readings high compared to export rates
- Topside MPFM mass correction is not linear as a function of rate under calibration
- Unable to calibrate topside MPFMs against the test separator at normal operational conditions
- Problem with gas measurements at high rates
- Allocation principle with Kristin as balance field

Multi phase flow meter calibration principle





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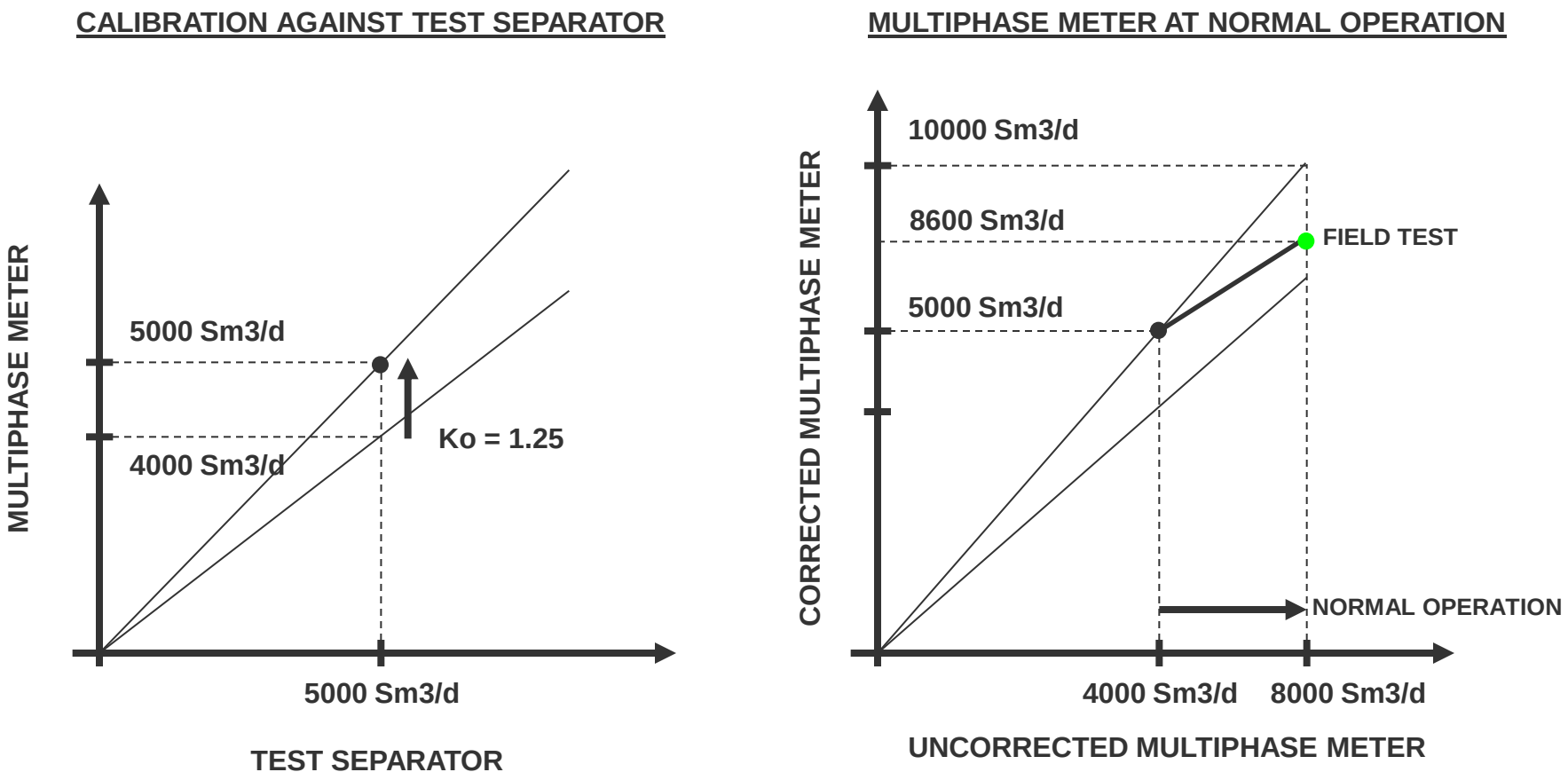
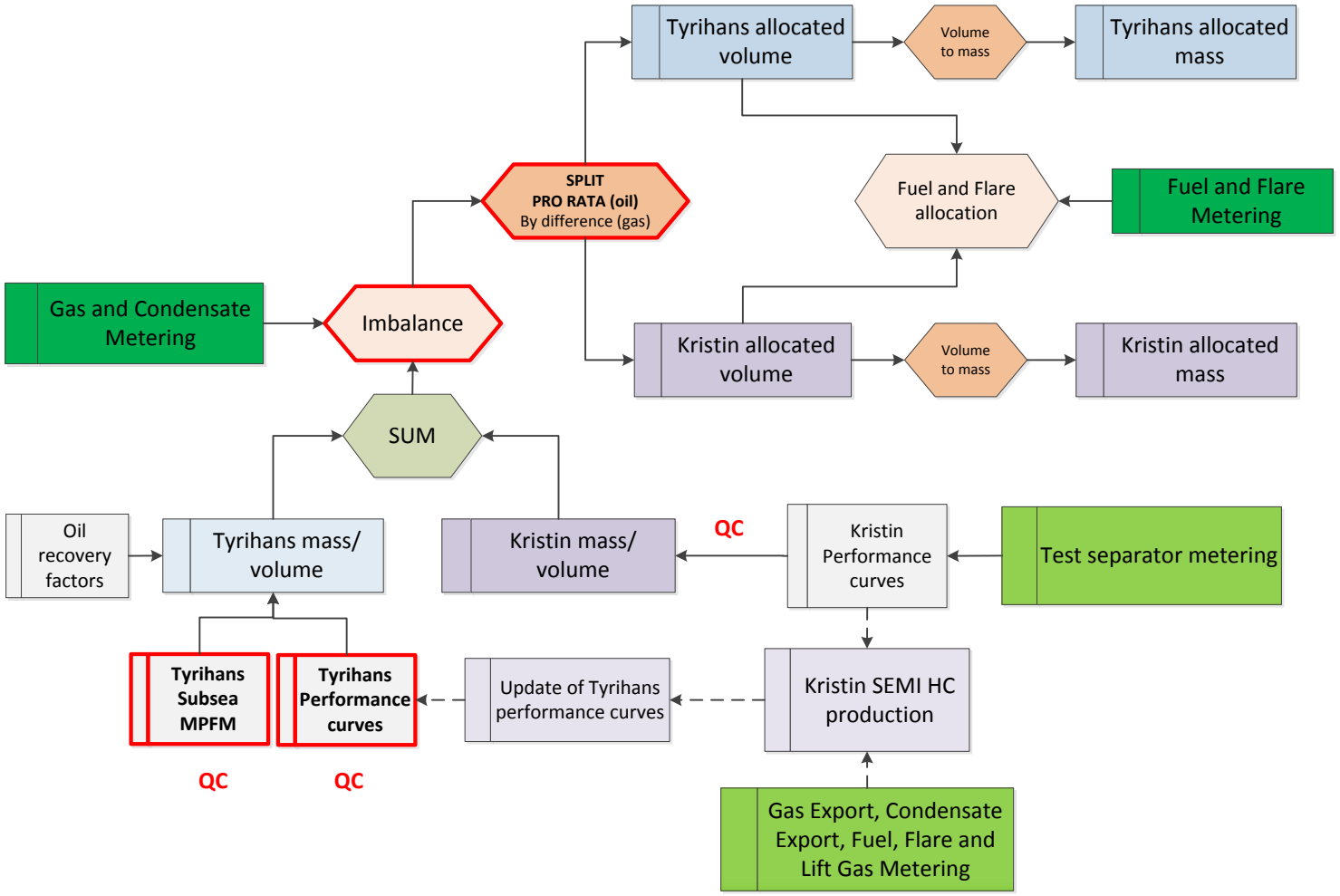
Multi phase flow meter calibration principle



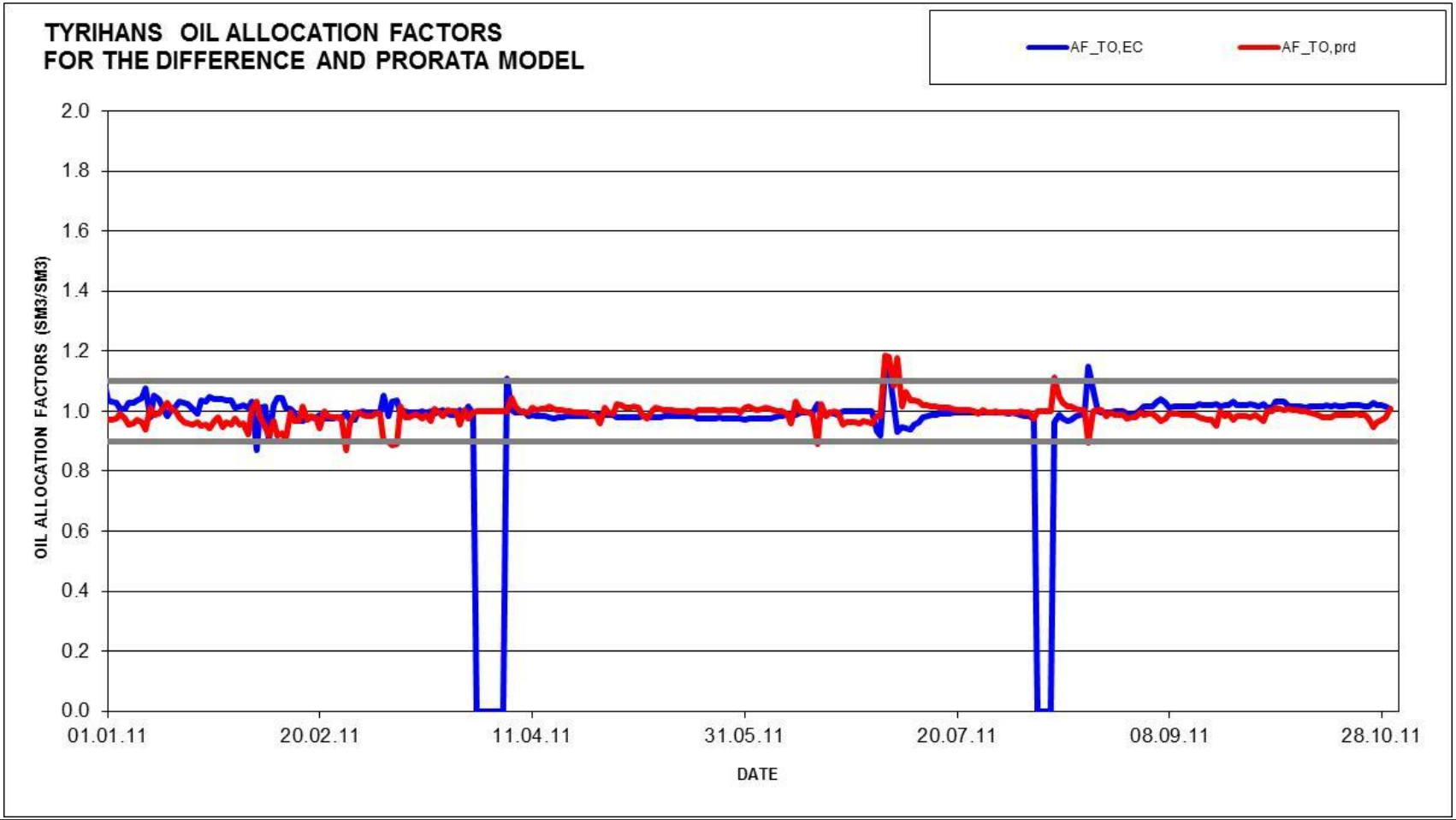
New allocation method:
1) Subsea HC mass, 2) ProRata principle



Allocation quality control

- Kristin Flowline tests Campaign (KFC) –> Tyrihans by Difference (TBD)
- Topside MPFM “calibration”
  - Topside MPFM rates with updated correction factors, trends
- Sum Tyrihans subsea MPFM and PC theoretical rates, trends
- Sum Kristin PC theoretical rates, trends
- Allocation factors
- Expected allocation results
  - Kristin GOR from history matched reservoir simulations
- Single field tests
  - Shut down one field, produce the other field through topside process fiscal metering

Allocation factors 2011



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Summary:
Challenges in Kristin-Tyrihans Allocation

- Tyrihans topside multiphase flow meters (MPFM) disqualified for allocation
  - Cannot be calibrated against test separator at normal operating conditions due to test separator rate limitation
  - Can be corrected against result for Tyrihans from Kristin Flowline tests (KFC) but limited validity
- Sum Tyrihans subsea multiphase flow meters: backup method
  - One or more subsea multiphase flow meters not in working order (backup for backup!)
- Extensive use of well performance curves (PC) both on Kristin (by design) and Tyrihans (backup for subsea MPFMs)
- Single field tests that require shut-down of either Kristin or Tyrihans are costly and do not show the mixing effect of the two fields.
- Field allocation requires extensive monitoring and follow-up
- Allocation accuracy dependent on test separator performance (availability, accuracy…..)

Future challenges / concerns

- Replacing existing subsea MPFMs (present vendor)
  - Long delivery time, dependent on available choke modules
  - Reliability (will they fail again?)
- Low pressure production (LPP) from 2014
  - Change in topside process conditions (PVT, ORF-factors, etc.)
  - Test separator capacity change
  - Performance of subsea MPFM change under LPP conditions?
- Topside MPFM – GVF approaching 95% (reduced accuracy, reduced validity of corrections factors…..)
- Possible additional 3rd party tie-ins
  - Change in metering philosophy
  - Change in allocation procedure
  - Change in topside process conditions (PVT, ORF-factors, etc.)

Future technologies / opportunities

- Virtual metering
  - Replace direct measurements by indirect analysis and modelling
  - Replace/complement MPFMs
  - «Model based allocation». Calculations based on online data model of the subsea system, updating based on sensor changes

Figure: ©FMC

2005 … 2009 2010 2011 2012 2013 2014 …

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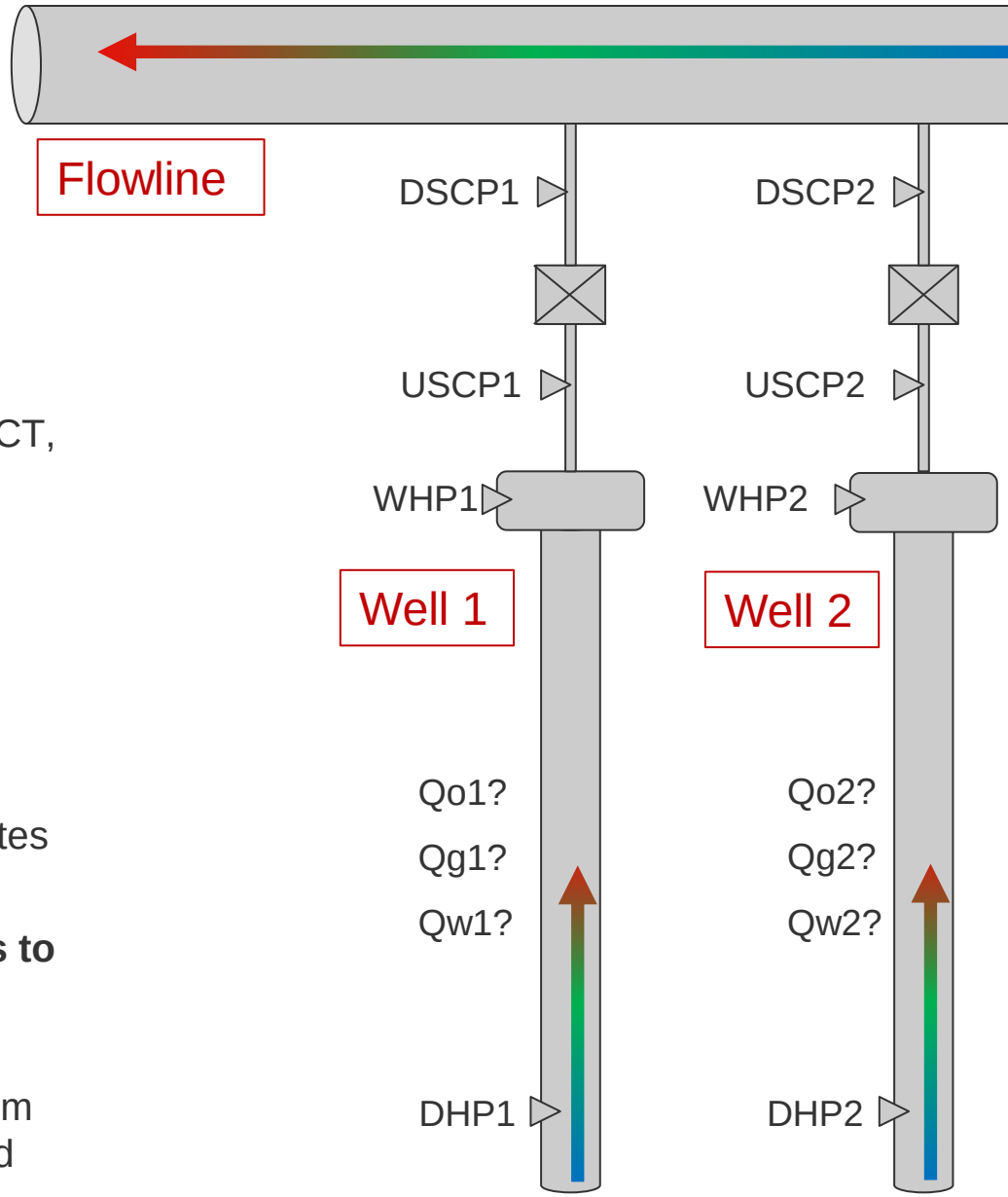
Tyrihans VM case



- Many parameters are measured in Tyrihans production system
  - WHP, WHT, USCP, USCT, DSCP, DSCT, DHP, DHT, DHP1, DHP2, etc.
- Topside at Kristin Semi some important parameters are also measured
  - Corrected topside MPFM rates, KFC rates, total Tyrihans fluid densities

- Use all this measured data to provide estimates on well rates
- **VM is a collection of mathematical models to estimate well rates accounting for most available data**
- iVM is the software tool where the VM problem is solved and where the results are presented

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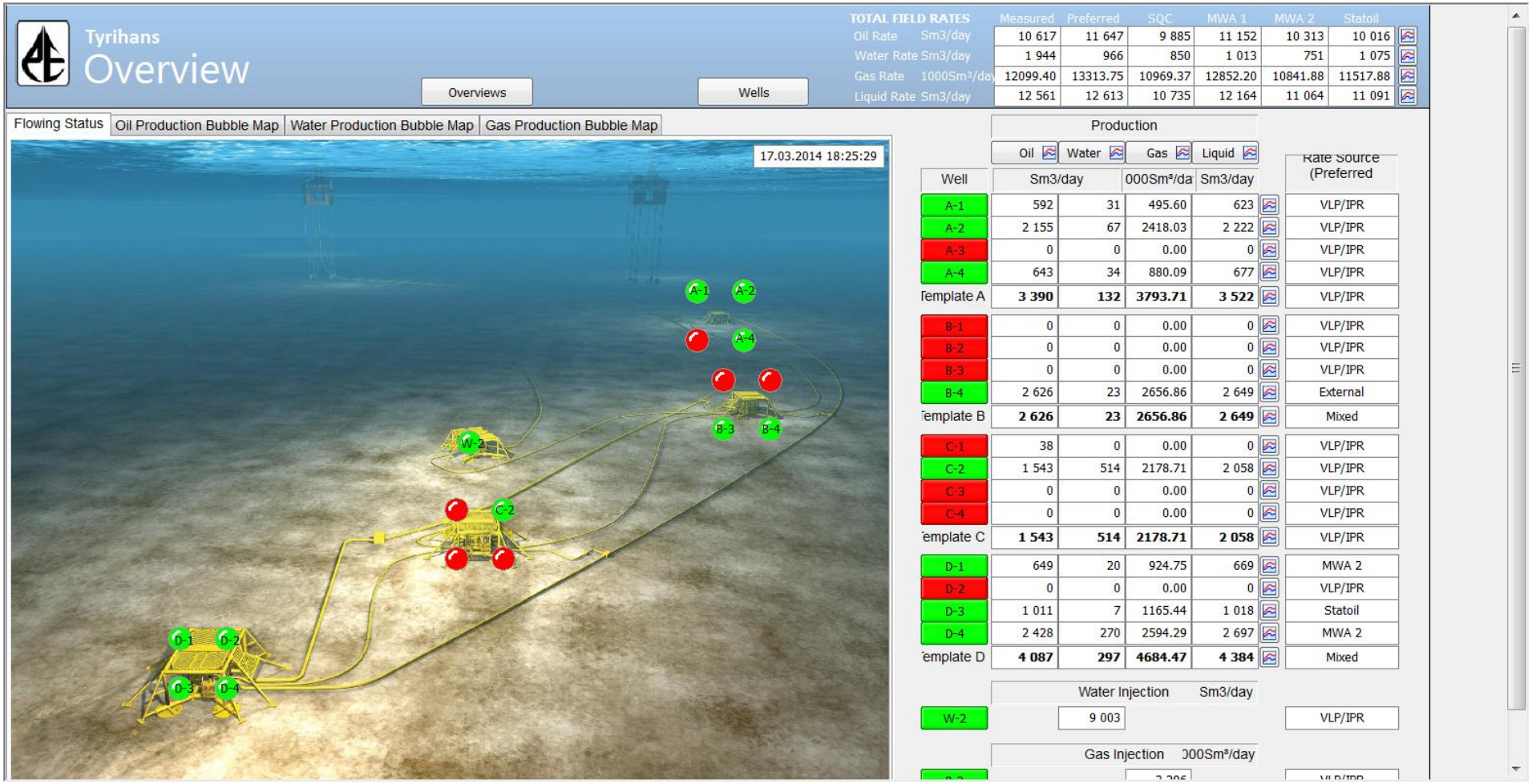
Petex iVM field overview

Figure: ©Petroleum Experts



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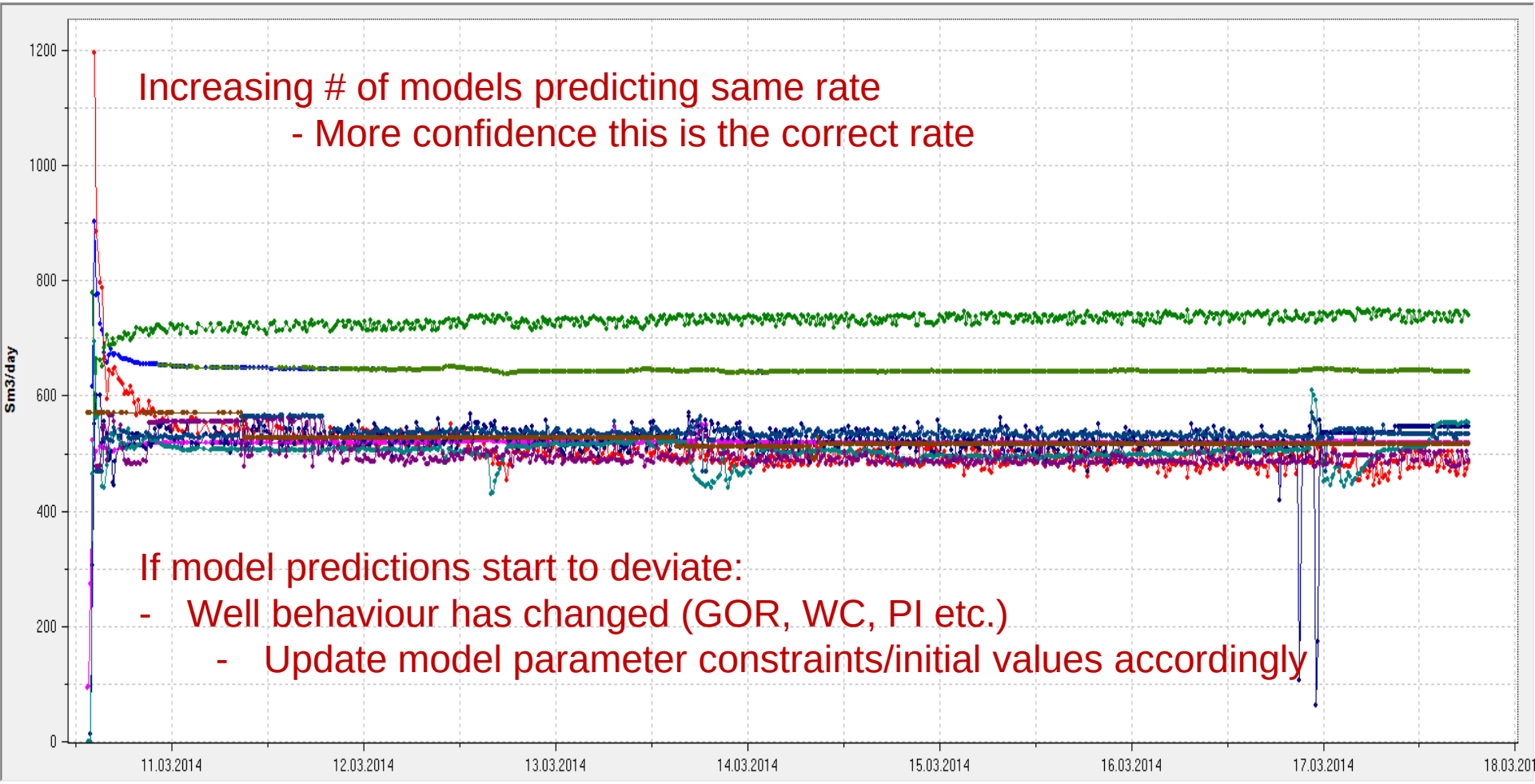
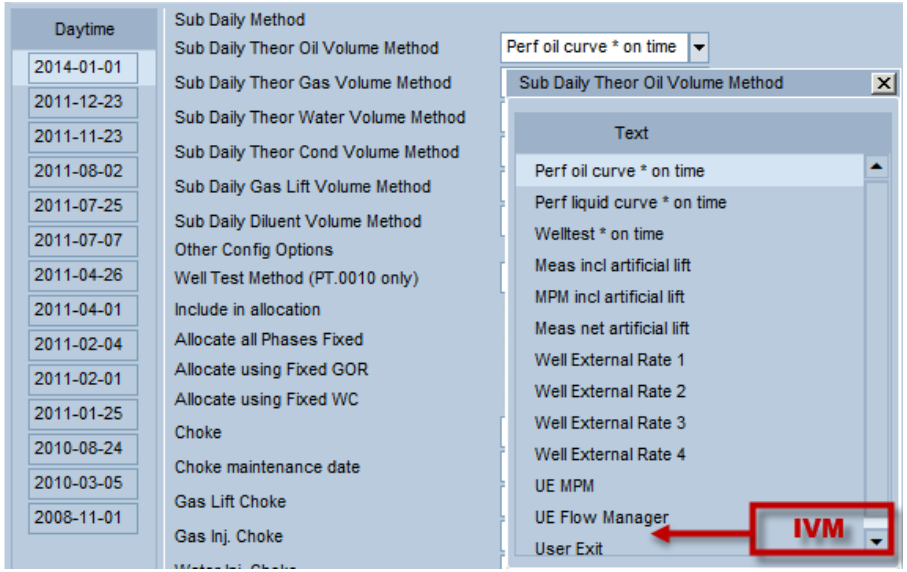
iVM rate estimation techniques

Figure: ©Petroleum Experts



Current status / experience Tyrihans iVM

- System installed late 2013
- Q1-2014
  - QC / troubleshooting software, models, model updating, data transfer and system stability
  - System currently running continuously updating results
- Q2-2014
  - Further QC and software improvements
  - Implement writing iVM rates to production database (EC)
    - Enables IVM rates available for input to allocation, replacing performance curves / subsea MPFM where applicable



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There's never been a better time for good ideas

Acknowledgements:

- Trygve Kløv
- Kurt Haugnæss
- Even Lillemo
- Yngve H. Belsvik
- Kolbjørn Kyllo

(all Statoil)

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Arne M. Dahl
Principal Engineer Prod Tech,
Kristin Petek
KH PTC KRI
amda@statoil.com
Tel: +4792660405

www.statoil.com

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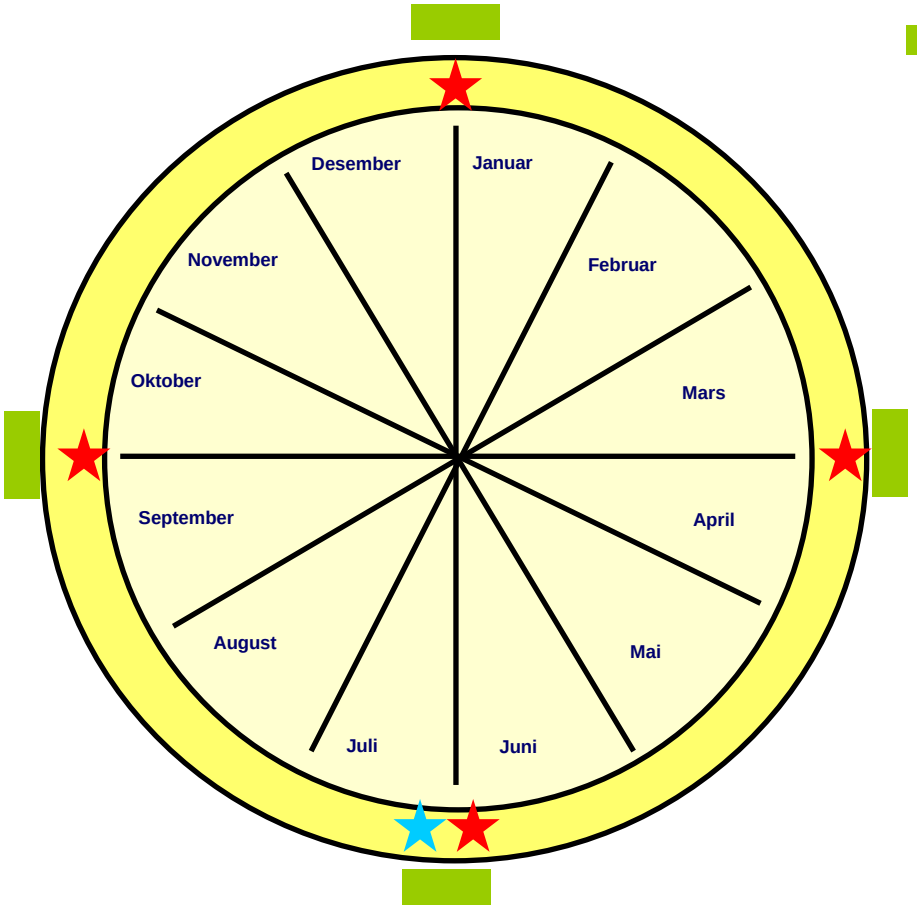
Backup slides

Allocation input and sources

- TYH HC mass
  - TYH total mass (Subsea MPFM and Performance Curves)
  - TYH total water mass fraction (Test separator)
- PVT
  - TYH total HC composition (GOR) (“KFC” – KRI flowline separator tests)
  - TYH total HC molecular weight pr component (Recombined PVT-samples)
  - Tyrihans gas molecular weight (ISO 6976)
  - Oil recovery factors (ORF) (Hysys process simulation)
  - Tyrihans oil density (Hysys process simulation)
  - Kristin condensate density (Hysys process simulation)
- Well rate estimates
  - Kristin theoretical condensate volume (Performance Curves, “KFC” – KRI flowline separator tests)
  - Tyrihans theoretical oil volume (Subsea MPFM and Performance Curves)
- Fiscal metering
  - Total export oil and condensate (Fiscal export meters)
  - Total export, fuel and flare gas (Fiscal export meters)

PVT sampling KRI/TYH
Basis for ORF-calculations and allocation



- Process simulations (ORF update)
- Sampling of TYH mixed well stream + condensate & export gas
  - When necessary due to fluid changes (new wells, wells shut down etc.)
  - Approx. every three months
- Annual sampling of KRI wells / flowlines
- Reallocation is performed when ORF is updated

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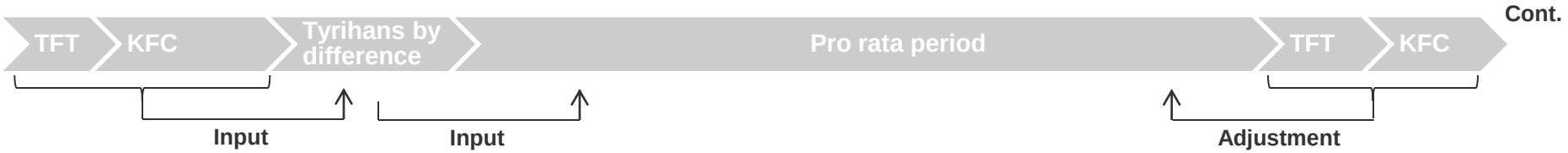
TFT = Tyrihans Flowline Tests
KFC = Kristin Flowline Tests Campaign

Allocation workflow



- **Tyrihans total water mass fraction** based on TFT
- **Kristin production** based on KFC

- «Tyrihans by difference» (one production day)
  - **Tyrihans production** based on total production and KFC/TFT
  - **Tyrihans GOR** and **WCT** determined

- «Pro rata period» (normally 14+ days)
  - Based on latest «Tyrihans by difference»
  - **Pro-rata principle** to compensate for Tyrihans GOR/WCT development and Kristin depletion effects (not captured by performance curves)
  - Tyrihans GOR (total HC composition) adjusted if necessary (observed trends)

- After next TFT and KFC;
  - Previous **«pro rata period» adjusted based on new test results**

Future technologies / opportunities

- Install new subsea MPFMs (new vendor)
  - Long delivery time, need mechanical fitting, cost
  - Increased subsea power requirement
- Subsea PVT sampling (Mirmorax)
  - Representative fluid sampling per well, input to PVT for MPFM calibration / allocation
  - Need mechanical modifications

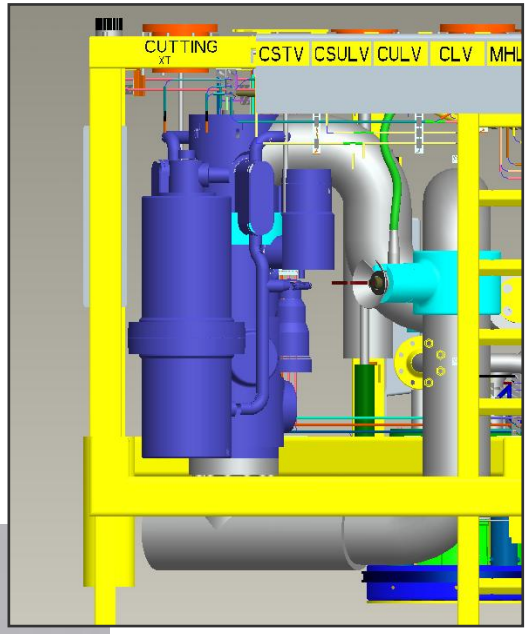


Figure: ©FMC

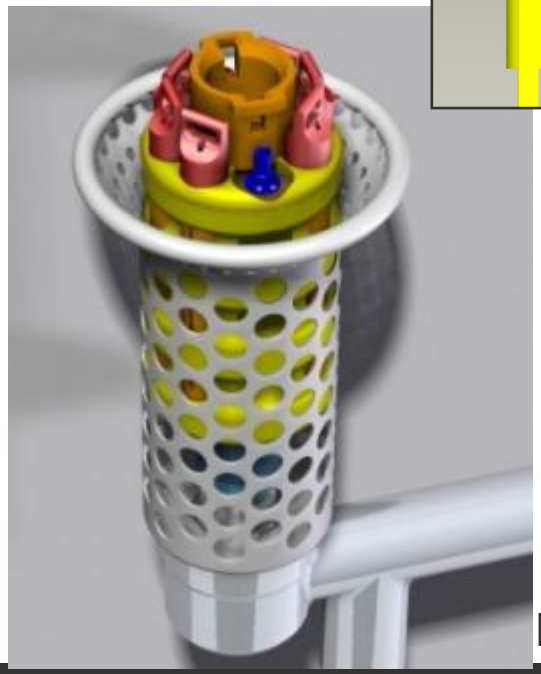


Figure: ©Mirmorax

Future technologies / opportunities

- Multi-diciplinary integrated modelling
  - Integration of Reservoir simulation to Topside process simulations for history matching and future forecast of ORF
    - Possibility for more frequent update of ORF calculations by utilizing input from reservoir simulations
    - Possibility for less frequent update of ORF based on Lab sample measurements due to knowledge of future development

Figure: ©Petrostreamz

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Tyrihans virtual metering case

- For Tyrihans the following applies:
  - The Tyrihans field was developed with limited metering flexibility
  - No access to the test separator for individual wells
  - Subsea multiphase flow meters (MPFMs) failing
  - Calibration of subsea MPFMs against measured data not possible
  - Accuracy of uncalibrated subsea MPFMs is questionable
    - PVT - liquid and gas density has changed since installation
    - Additional corrections due to drifting and change in meter behavior
- Virtual metering (VM) techniques can provide estimates for well rates that are not measured or inaccurately measured
- The confidence in virtually metered rates should be higher than any other type of estimates