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Technical Paper

Multiphase Flowmeter Uncertainty – A Practical Methodology

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1 INTRODUCTION

Increased use of sub-sea tiebacks to existing platforms and infrastructure has led to an increased use of multiphase flow meters (MPFM's) for well and field initial measurements. These multiphase measurements are often used for the allocation of exported single phase products back to wells and /or fields. The measurement uncertainty of these multiphase flowmeters can have a substantial impact on the uncertainty of the allocated single-phase products. Where interconnected fields have differing owners, this can result in significant exposure for owners. In these circumstances it is essential that a realistic estimate of multiphase flowmeter uncertainty is obtained for planning, development, and operational purposes. This paper describes a practical methodology of assessing the uncertainty in multiphase flowmeter measurements corrected to standard conditions at the export location.

The method proposed is independent of multiphase meter type, it being based on:

a) verification of the MPFM against 'in-situ' single phase test separator metering,

b) manufacturers specified sensitivities to fluid property changes (to estimate 'drift' between verifications), and

c) process model conversion factors (to estimate uncertainty in the conversion of MPFM actual volume measurements to standard volume measurements at the export location).

2 FLOW MEASUREMENT CALCULATIONS

The MPFM provides three primary measurements: total liquid ($q_{liq,a}$) and gas ($q_{gas,a}$) volume flows at meter conditions and water liquid ratio (WLR). The oil volume flow ($q_{oil,a}$) at meter conditions is calculated as follows:

$$q_{oil,a} = q_{liq,a} \times (1 - WLR) \qquad (1)$$

Where $$WLR = {}^{q_{wat,a}}/_{q_{liq,a}} \qquad (2)$$

This returns the three phase actual volume flowrates at the location of the multiphase flowmeter. This is very useful information in its own right, however to use these measurements in an allocation system, it is normally required that the flowrates are converted to standard volume flowrates at the export location. That requires applying factors to each phase to account for the shrinkage / expansion of each phase during the processing of the produced hydrocarbons. Typical platform processing is shown in figure 1.

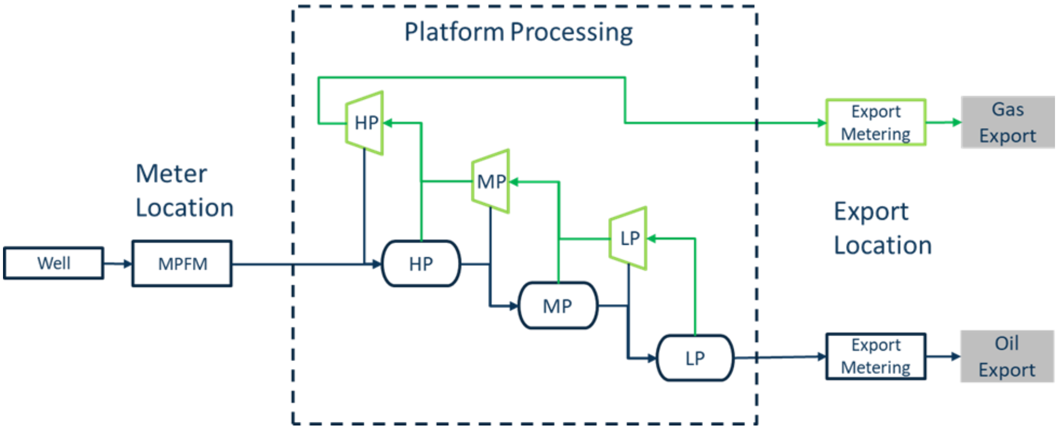


Fig 1 – Typical processing between MPFM and single-phase Export locations

The gas and oil volume flows, at meter conditions, are then converted to standard volume values at the single-phase export location, by the application of conversion factors, Gas Condensate ratio, and Solution Gas Oil ratio as per Annex B.1.3 of ISO/TS 21354 [1].

Figure 2 describes the calculations performed in Annex B.1.3

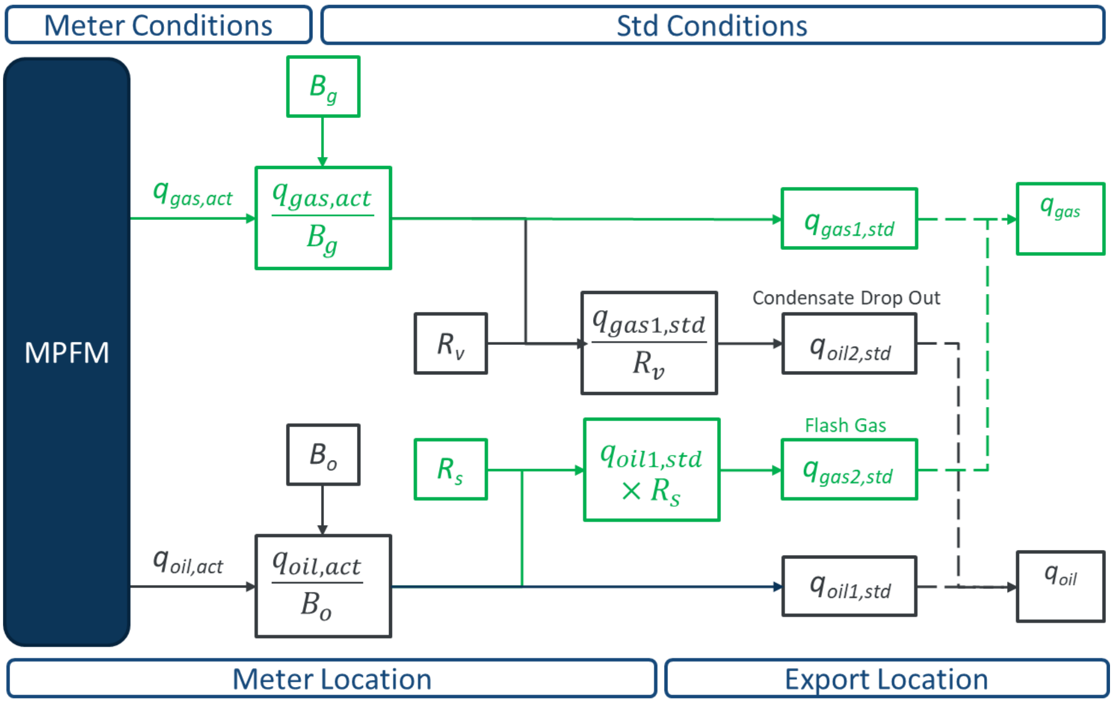


Fig 2 – Annex B.1.3 of ISO/TS21354

For gas, the 'Gas Conversion Factor' Bg (m^3/Sm^3), converts the actual gas volume measured by the MPFM to standard gas volume ($q_{gas1,std}$), at the export location, and accounts for any reduction in gas volume due to the drop out of heavy ends in processing between meter and export locations. The 'Gas Condensate Ratio' Rv (Sm^3/Sm^3), calculates the volume of condensate dropped out of the gas phase during processing ($q_{oil2,std}$).

Similarly for oil, the 'Oil Conversion Factor' *Bo* (m³/Sm³), converts actual oil volume measured by the MPFM to standard oil volume ($q_{oil1,std}$), at the export location, and accounts for any reduction in oil volume due to the flash of light ends in processing between meter and export locations. The 'Solution Gas Oil Ratio' *Rs* (Sm³/Sm³), calculates the volume of gas flashed off the oil phase during processing ($q_{gas2,std}$).

Finally, the volume of gas at the export location is calculated by summing the gas sourced from the metered gas phase ($q_{gas1,std}$), and the flashed gas ($q_{gas2,std}$). Similarly, the oil volume at the export location is the sum of the oil sourced from the metered oil phase ($q_{oil1,std}$), and the dropped out oil ($q_{oil2,std}$).

The following details the derivation of the gas and oil standard volumes at export conditions:

$$q_{gas,std} = q_{gas1,std} + q_{gas2,std} \quad (3)\ , \qquad q_{oil,std} = q_{oil1,std} + q_{oil2,std} \quad (4)$$

Expanding $q_{gas2,std}$ and $q_{oil2,std}$ in line with figure 2 returns the following:

$$q_{gas,std} = q_{gas1,std} + q_{oil1,std} \times R_s \quad (5)\ , \qquad q_{oil,std} = q_{oil1,std} + \frac{q_{gas1,std}}{R_v} \quad (6)$$

And expanding each of the gas and oil quantities in line with figure 2 returns:

$$q_{gas,std} = \left(\frac{q_{gas,act}}{B_g}\right) + \left(\frac{q_{oil,act}.R_s}{B_o}\right) \quad (7)\ , \qquad q_{oil,std} = \left(\frac{q_{oil,act}}{B_o}\right) + \left(\frac{q_{gas,act}}{B_g.R_v}\right) \quad (8)$$

Substituting equation 1 into equations 7 and 8 returns the gas and oil standard volume flowrates at the export location in terms of the primary MPFM measurements and conversion factors:

$$q_{gas,std} = \left(\frac{q_{gas,act}}{B_g}\right) + \left(\frac{q_{liq,act}.R_s}{B_o}\right) - \left(\frac{q_{liq,act}.WC.R_s}{B_o}\right) \quad (9)$$

$$q_{oil,std} = \left(\frac{q_{liq,act}}{B_o}\right) - \left(\frac{q_{liq,act}.WC}{B_o}\right) + \left(\frac{q_{gas,act}}{B_g.R_v}\right) \quad (10)$$

3 OVERVIEW OF UNCERTAINTY METHOD

3.1 Overview

Estimating the uncertainty of a MPFM directly is very difficult to achieve. Firstly, defining the relationship between all of the inputs and the single-phase flow measurements may be impossible due to the proprietary nature of the metering algorithms. Also even if the full algorithms are available the complexity of these may be such as to make a traditional analysis near impossible to achieve.

For these reasons a direct analysis of the MPFM is NOT proposed. Instead, this paper proposes that the uncertainty in the MPFM single phase flow rates be based upon periodic in-situ verification of the MPFM against the single-phase metering on the test separator exit lines. This method requires the test separator metering to be calibrated at an accredited laboratory. In this way the test separator metering functions as a transfer standard for each phase.

Of course this method can only estimate the MPFM uncertainty during a verification, hence additional terms are required to assess the effect of drift between verifications. Figure 3 shows the basic concept proposed.

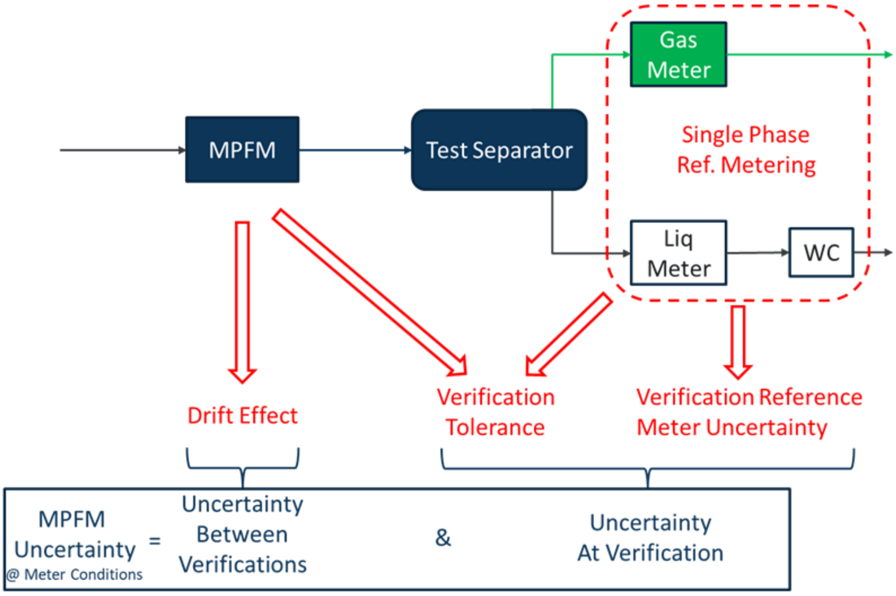


Fig 3 - Schematic of MPFM uncertainty analysis

3.2 Procedures Required

The uncertainty method requires that the following procedures are followed:

- That the multiphase flow meter (MPFM) is periodically verified against the test separator metering to a specified tolerance. Each primary measurement of MPFM must be individually verified. In the case of a 2-phase separator the gas and total liquid measurements can be verified against the appropriate separator leg meter, with the WLR being verified against the liquid leg sample analysis or water cut meter. In the case of a 3-phase separator, the total liquid measurement is verified against the combined water and oil leg meters, and the WLR is verified against the ratio of the water and oil leg meters.

- That the MPFM has its fluid parameters periodically updated with data from a representative pressurized line sample. Required frequency shall depend on the observed variation in process fluid properties (oil, gas, and water density) observed during operations.

3.3 Structure

The concept detailed in the previous section has been developed into the uncertainty structure as shown in figure 4.

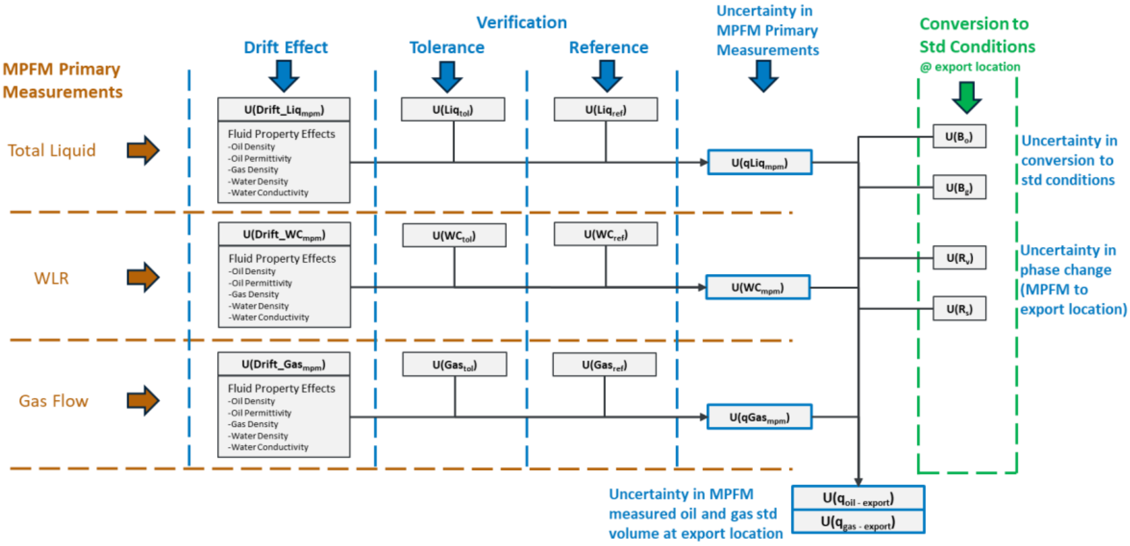


Fig 4 - MPFM Uncertainty Structure

As is shown in figure 4, the initial uncertainty analysis is performed on each of the MPFM's primary measurements i.e. Total liquid flow rate, Gas flow rate, and water liquid ratio. This includes an assessment of the effect of fluid property variation between PVT updates to estimate drift. This drift estimate is then combined with the verification tolerance and reference (test separator metering) uncertainties to return the uncertainties in the MPFM primary measurements. Finally, the MPFM primary measurement uncertainties are combined with the uncertainties in the conversion factors (conversion to standard volume, and phase change) to return the estimated uncertainty in oil and gas measurement at export conditions.

4 UNCERTAINTY ANALYSIS METHODOLOGY

The uncertainty attributed to the in-service verification of each of the MPFM's primary measurements is the combination of the following two terms,

a) the uncertainty of the reference measurement (test separator metering) and
b) the verification tolerance applied

4.1 Reference Measurement Uncertainty $U(Ver_{ref})$

The reference measurements depend on the type of test separator available (i.e. 2 or 3 phase), table 1 shows the options.

Table 1 Reference Measurements

MPFM Primary Measurement	2 Phase Test Separator	3-Phase Test Separator
Gas	Gas Leg Meter only	Gas Leg Meter only
Total Liquid	Liquid Leg Meter only	Oil meter + Water meter
Water Liquid Ratio	Sample Analysis or Water Cut Meter (Liquid Leg)	Water Meter/(Oil + Water meter)

Where a reference measurement is a single meter then the uncertainty is assessed in the normal method, or in the case of the water cut meter an assessment is made based on manufacturers information.
Where a reference measurement is a combination of meters then the meter uncertainties must be combined.

For the verifications to be viable it is essential that the estimated uncertainties for the three primary measurements are at least a factor of three lower than the verification tolerances detailed in the next section.

4.2 Verification tolerance $U(Ver_{tol})$

The verifications of each MPFM primary measurement will be deemed successful if its value lies within a specified tolerance limit of the reference measurement. This tolerance value must be achievable hence it is recommended that this tolerance be set to no less than the performance level specified by the MPFM manufacturer for the expected operating conditions.

4.3 In-service drift U(Drift) – Fluid Property Effects

Between MPFM verifications and PVT updates, any change in measured fluid properties from those configured within the MPFM will result in a drift of the MPFM primary measurements. Hence, the effect of fluid property variation is applied in the uncertainty analysis as a ‘drift’ term.

The MPFM is configured with fluid property information (oil density, gas density, water density, oil permittivity, water conductivity etc.) that is representative of the multiphase stream being measured. Integrated PVT software or tables are then used to adjust these parameters (e.g. densities) to correct for operational changes in pressure and / or temperature.

However, if the base properties of the in-service fluids (e.g. water salinity or oil composition) change from the configured values, then errors will be introduced into the calculated / reported flowrates. It is normal practice to update these physical properties (e.g. via fluid sample analyses) on a periodic basis, so that no significant errors develop. However between updates, an allowance must be made for the additional uncertainty introduced by any such drifts. This requires information on

a) the sensitivity of the MPFM’s primary reading (liquid flow rate, gas flow rate and WLR) to changes in the key physical properties,
b) and an estimate of the likely changes in these key physical properties between configuration updates.

The sensitivity information should be available from the MPFM manufacturer, and be based on laboratory testing of the meter type.

Changes in physical fluid properties for new wells / fields should be based on well fluid forecasts, however for older wells, changes in fluid properties can be based on a review of historic fluid properties, where a history is available.

The uncertainty due to varying fluid properties between verifications can then be estimated by multiplying the sensitivity and estimated change between verifications. An example for the effect of oil density on total liquid measurement is given below:

$$u(\Delta\rho_{oil}) = \Delta\rho_{oil} \times c_{\rho\ oil} \quad (11)$$

The overall drift uncertainty for total liquid flow is then estimated by combining all the fluid property uncertainties by root sum square as shown below:

$$u(Liq_{MPFM}\_Drift) = \sqrt{u(\Delta\rho_{oil})^2 + u(\Delta\rho_{gas})^2 + u(\Delta\rho_{wat})^2 + u(\Delta\varepsilon_{oil})^2 + u(\Delta\sigma_{wat})^2} \quad (12)$$

4.4 Uncertainty in MPFM Primary Measurements (U(q_{liq}), U(q_{WC}), U(q_{gas}))

The uncertainties calculated in sections 4.1 to 4.3 are combined by root sum square to return the uncertainties for each MPFM primary measurement.

$$U(MPFM_{pm}) = \sqrt{U(drift)^2 + U(Ver_{ref})^2 + U(Ver_{tol})^2} \quad (13)$$

4.5 Uncertainty in Conversion Factors (U(Bg), U(Bo), U(Rv), U(Rs))

Conversion factors are required to convert the actual volume flowrates at meter location to standard volume flowrates at the export location as discussed in the flow measurement calculation section.

Conversion factors are derived by a thermodynamic simulation of the process, encompassing the process from the MPFM location to the point at which the single-phase flowrates are required, typically at the location of the export metering or at the end of the production chain. Conversion factors are derived for a range of typical operational conditions. These include pressures, temperatures, and flowrates at the MPFM and at intervening process equipment included in the process model, and fluid compositions at the MPFM.

Determining the inherent uncertainty in the process model derived conversion factors is not a straight forward task, hence this method does not attempt to do this. Instead the uncertainty in the conversion factors has been estimated based on the range of factors returned for the typical operating conditions. It is understood that the factors calculated offline are often used in a matrix or look-up table, so that the applied factor is interpolated based on a measured meter and/or vessel conditions. Hence the estimated uncertainty derived by this method is likely to be larger than the actual uncertainty i.e. this method is conservative it returns a worst-case scenario.

4.6 Combination of Uncertainties

The final stage of the analysis is to combine the primary measurement uncertainties along with the conversion factor uncertainties.

This has been performed as per ISO5168[2], GUM[3], using equations 9 and 10 which calculate the standard volume gas and oil flowrates at the export location from the MPFM primary measurements and conversion factors.

The standard volume gas uncertainty is calculated as follows:

$$u(q_{gas,std}) = \sqrt{\begin{array}{c}\left(\frac{\theta q_{gas,std}}{\theta q_{liq,act}}.u(q_{liq,act})\right)^2 + \left(\frac{\theta q_{gas,std}}{\theta WC}.u(WC)\right)^2 + \left(\frac{\theta q_{gas,std}}{\theta q_{gas,act}}.u(q_{gas,act})\right)^2 \\ + \left(\frac{\theta q_{gas,std}}{\theta B_o}.u(B_o)\right)^2 + \left(\frac{\theta q_{gas,std}}{\theta B_g}.u(B_g)\right)^2 + \left(\frac{\theta q_{gas,std}}{\theta R_s}.u(R_s)\right)^2\end{array}} \qquad (14)$$

Where

$$\frac{\theta q_{gas,std}}{\theta q_{liq,act}} = \frac{R_s}{B_o} - \frac{WC.R_s}{B_o} \quad , \quad \frac{\theta q_{gas,std}}{\theta WC} = \frac{q_{liq,act}.R_s}{B_o} \quad , \quad \frac{\theta q_{gas,std}}{\theta q_{gas,act}} = \frac{1}{B_g}$$

$$\frac{\theta q_{gas,std}}{\theta B_o} = -\frac{q_{liq,act}.R_s}{{B_o}^2} + \frac{q_{liq,act}.WC.R_s}{{B_o}^2} \quad , \quad \frac{\theta q_{gas,std}}{\theta R_s} = \frac{q_{liq,act}}{B_o} - \frac{q_{liq,act}.WC}{B_o}$$

$$\frac{\theta q_{gas,std}}{\theta B_g} = -\frac{q_{gas,act}}{{B_g}^2}$$

And standard volume oil flow uncertainty is calculated as follows:

$$u(q_{oil,std}) = \sqrt{\begin{array}{c}\left(\frac{\theta q_{oil,std}}{\theta q_{liq,act}}.u(q_{liq,act})\right)^2 + \left(\frac{\theta q_{oil,std}}{\theta WC}.u(WC)\right)^2 + \left(\frac{\theta q_{oil,std}}{\theta q_{gas,act}}.u(q_{gas,act})\right)^2 \\ + \left(\frac{\theta q_{oil,std}}{\theta B_o}.u(B_o)\right)^2 + \left(\frac{\theta q_{oil,std}}{\theta B_g}.u(B_g)\right)^2 + \left(\frac{\theta q_{oil,std}}{\theta R_v}.u(R_v)\right)^2\end{array}} \qquad (15)$$

Where

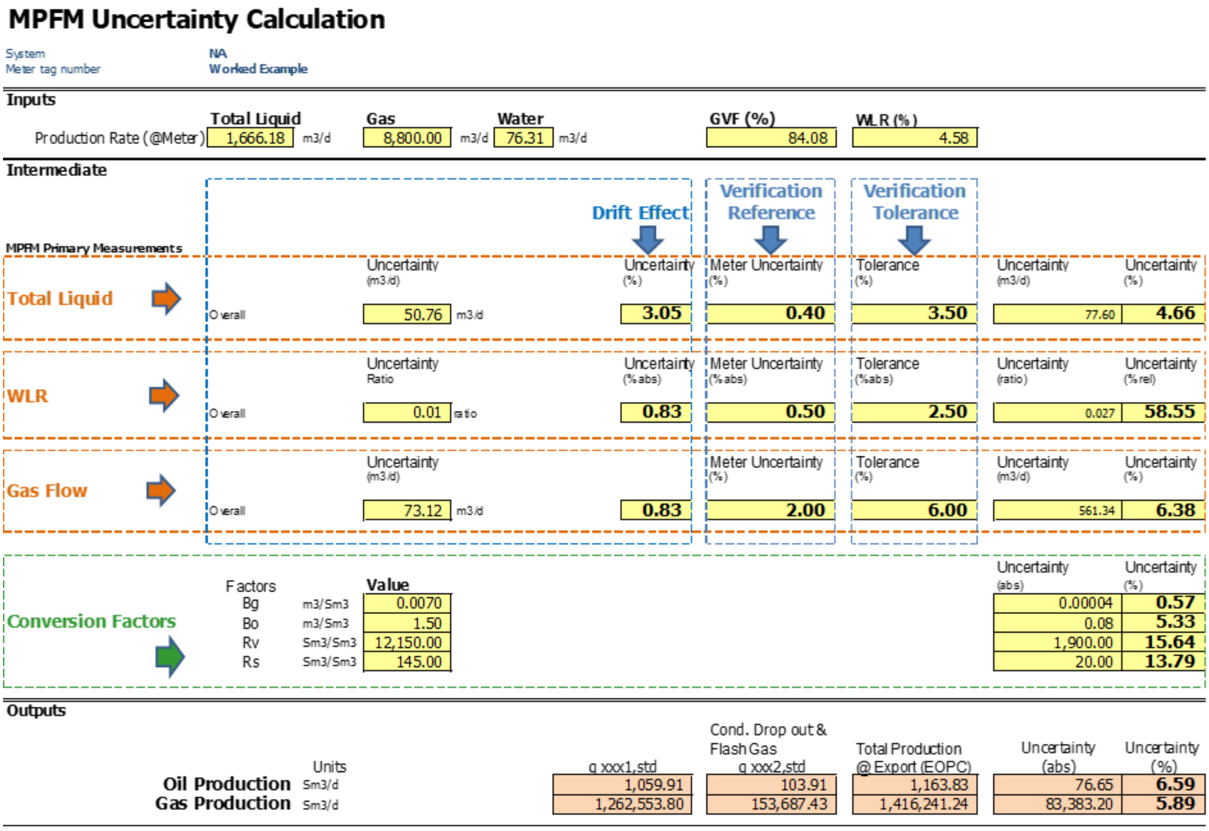
$$\frac{\theta q_{oil,std}}{\theta q_{liq,act}} = \frac{1}{B_o} - \frac{WC}{B_o} \quad , \quad \frac{\theta q_{oil,std}}{\theta WC} = -\frac{q_{liq,act}}{B_o} \quad , \quad \frac{\theta q_{oil,std}}{\theta q_{gas,act}} = \frac{1}{B_g.R_v}$$

$$\frac{\theta q_{oil,std}}{\theta B_o} = -\frac{q_{liq,act}}{{B_o}^2} + \frac{q_{liq,act}.WC}{{B_o}^2} \quad , \quad \frac{\theta q_{oil,std}}{\theta R_v} = -\frac{q_{gas,act}}{B_g.{R_v}^2} \quad , \quad \frac{\theta q_{oil,std}}{\theta B_g} = -\frac{q_{gas,act}}{{B_g}^2.R_v}$$

5 UNCERTAINTY EXAMPLES

The following figures show examples of a MPFM uncertainty analyses.

The first example is for a single MPFM operating in a GVF of 84% and WLR of 5%. The MPFM is verified against a local 2 phase separator, with water cut calculated for a flow proportional sample analysed using the Karl fisher method.



MPFM Uncertainty Calculation

System NA
Meter tag number Worked Example

Inputs

	Total Liquid		Gas		Water		GVF (%)	WLR (%)
Production Rate (@Meter)	1,666.18	m3/d	8,800.00	m3/d	76.31	m3/d	84.08	4.58

Intermediate

MPFM Primary Measurements				Drift Effect	Verification Reference	Verification Tolerance		
Total Liquid		Uncertainty (m3/d)		Uncertainty (%)	Meter Uncertainty (%)	Tolerance (%)	Uncertainty (m3/d)	Uncertainty (%)
	Overall	50.76	m3/d	3.05	0.40	3.50	77.60	4.66
WLR		Uncertainty Ratio		Uncertainty (%abs)	Meter Uncertainty (%abs)	Tolerance (%abs)	Uncertainty (ratio)	Uncertainty (%rel)
	Overall	0.01	ratio	0.83	0.50	2.50	0.027	58.55
Gas Flow		Uncertainty (m3/d)			Meter Uncertainty (%)	Tolerance (%)	Uncertainty (m3/d)	Uncertainty (%)
	Overall	73.12	m3/d	0.83	2.00	6.00	561.34	6.38

Conversion Factors	Factors		Value	Uncertainty (abs)	Uncertainty (%)
	Bg	m3/Sm3	0.0070	0.00004	0.57
	Bo	m3/Sm3	1.50	0.08	5.33
	Rv	Sm3/Sm3	12,150.00	1,900.00	15.64
	Rs	Sm3/Sm3	145.00	20.00	13.79

Outputs

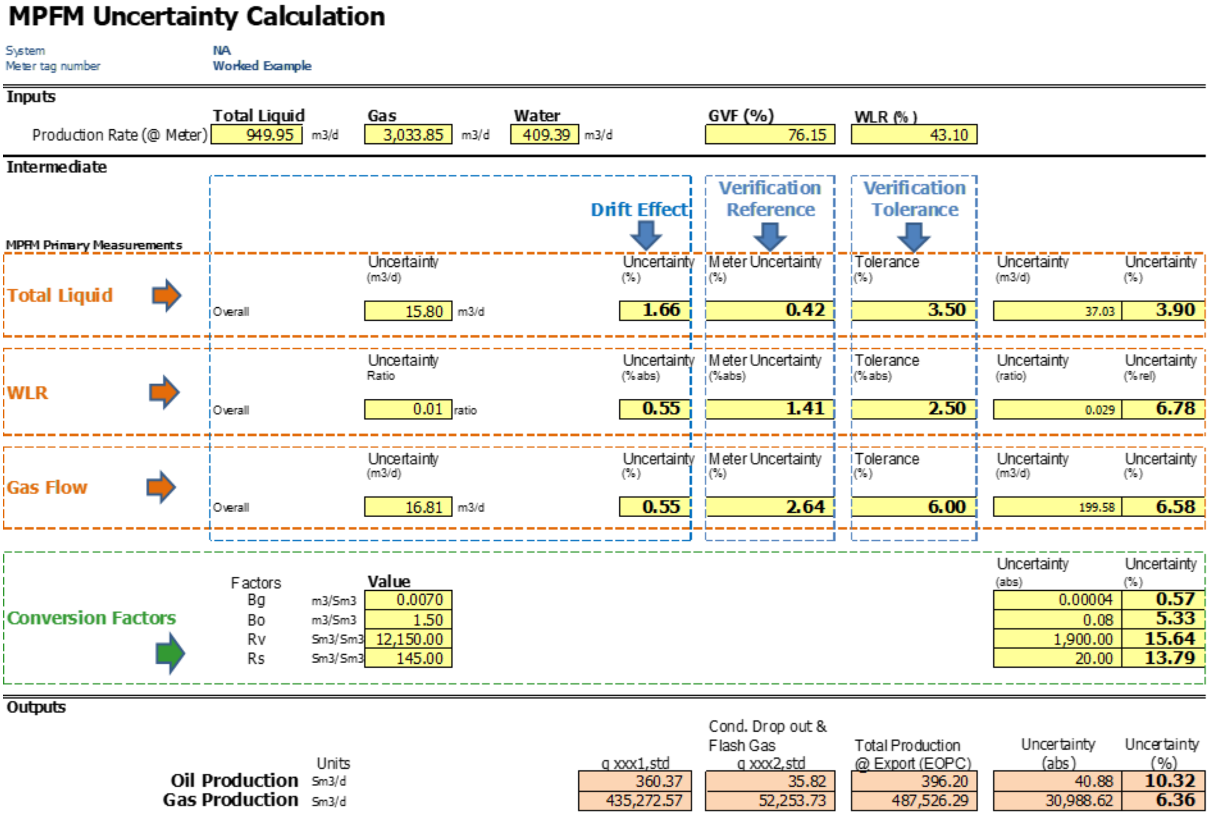
	Units	q xxx1,std	Cond. Drop out & Flash Gas q xxx2,std	Total Production @ Export (EOPC)	Uncertainty (abs)	Uncertainty (%)
Oil Production	Sm3/d	1,059.91	103.91	1,163.83	76.65	6.59
Gas Production	Sm3/d	1,262,553.80	153,687.43	1,416,241.24	83,383.20	5.89

Fig. 5 - Uncertainty Example (GVF 84%, WLR 5%)

The uncertainty in gas production at the export location (or EOPC) is estimated at 5.89%. This is lower than the uncertainty in the gas flow at the MPFM (6.38%). These seems counter intuitive however it can be explained when we consider that not all the gas at the export location was in the gas phase at the MPFM, in fact in this example more than 10% of the gas at the export location was in the liquid phase at the MPFM. As the uncertainty in the liquid phase is lower than the gas phase then it is possible for the gas to export to have a lower uncertainty than the gas measured at the MPFM. It should be noted that the tolerance for the gas meter verification (6%) is at the limit for a practical verification (i.e.it is the minimum 3 times the uncertainty of the gas leg test separator meter uncertainty (2%).

The uncertainty in the oil production at the export location (or EOPC) is estimated at 6.59%. This is higher than the uncertainty in the total liquid flow at the MPFM. This is due to several factors, firstly the high relative uncertainty in the WLR, and secondly that a significant quantity (approx. 10%) of the oil at export was measured as gas at the MPFM. As the MPFM has a higher uncertainty for gas than liquid this again results in an increase in uncertainty. And finally, the high uncertainty in the 'Oil Conversion Factor' (Bo).

The second example is for a single MPFM operating in a GVF of 76% and WLR of 43%. The MPFM is verified against a local 2 phase separator, with water cut measured by an on-line water cut meter.



MPFM Uncertainty Calculation

System NA
Meter tag number Worked Example

Inputs

	Total Liquid		Gas		Water		GVF (%)	WLR (%)
Production Rate (@ Meter)	949.95	m3/d	3,033.85	m3/d	409.39	m3/d	76.15	43.10

Intermediate

MPFM Primary Measurements

		Uncertainty		Drift Effect Uncertainty	Verification Reference Meter Uncertainty	Verification Tolerance Tolerance	Uncertainty	Uncertainty
Total Liquid	Overall	15.80 (m3/d)	m3/d	1.66 (%)	0.42 (%)	3.50 (%)	37.03 (m3/d)	3.90 (%)
WLR	Overall	0.01 (Ratio)	ratio	0.55 (% abs)	1.41 (%abs)	2.50 (% abs)	0.029 (ratio)	6.78 (% rel)
Gas Flow	Overall	16.81 (m3/d)	m3/d	0.55 (%)	2.64 (%)	6.00 (%)	199.58 (m3/d)	6.58 (%)

Conversion Factors	Factors		Value	Uncertainty (abs)	Uncertainty (%)
	Bg	m3/Sm3	0.0070	0.00004	0.57
	Bo	m3/Sm3	1.50	0.08	5.33
	Rv	Sm3/Sm3	12,150.00	1,900.00	15.64
	Rs	Sm3/Sm3	145.00	20.00	13.79

Outputs

	Units	q xxx1,std	Cond. Drop out & Flash Gas q xxx2,std	Total Production @ Export (EOPC)	Uncertainty (abs)	Uncertainty (%)
Oil Production	Sm3/d	360.37	35.82	396.20	40.88	10.32
Gas Production	Sm3/d	435,272.57	52,253.73	487,526.29	30,988.62	6.36

Fig. 6 - Uncertainty Example (GVF 76%, WLR 43%)

The uncertainty in the oil production at the export location (or EOPC) (10.32%) is substantially higher than the liquid measured at the MPFM (3.90%). This is due to the combination of high water liquid ratio (43%) and the high relative uncertainty in the WLR measurement (6.78%) and the high 'Oil Conversion Factor' (Bo) uncertainty (5.33%).

6 DISCUSSION

This methodology can return realistic uncertainties for MPFM measurements at the export / allocation location. This supports measurement network design decisions such as, the need for a MPFM , and if needed where it should be located and what type is best suited.

However this method of assessing MPFM uncertainty is dependant on several factors which must be considered before being applied to a proposed or actual installation. These include :

- The requirement for an 'in-situ' test separator, with suitably calibrated single-phase measurements. For MPFM's which do not have this facility, this requirement can be met by a mobile test rig. For MPFM's installed either sub-sea or on a satellite platform, this option is unlikely to be available. In these circumstances a 'remote' test separator can be used if the uncertainty in the conversion factors (test separator to MPFM) are incorporated into the verification reference uncertainty.

- The uncertainty in the test separator single phase metering must be well understood, this will require the metering to be periodically calibrated at an accredited flow laboratory and installed on-site in a suitable manner.

- The 'Drift' estimate is reliant upon manufacturer supplied 'Fluid Property Sensitivities', the quality of this data will be dependent upon the assessments performed by the manufacturer.

- The uncertainty in process model conversion factors has been estimated based on the range of factors returned over the anticipated range of process operating conditions. This is a pragmatic approach to estimating the uncertainty. It is anticipated that the estimated uncertainty is likely to be an overestimate, hence maintaining a conservative approach.

The methodology also has several limitations which must be recognised and accepted:

- Factors other than fluid property effects which can contribute to 'Drift' are not considered, such as erosion / corrosion, contamination etc. However the effect of any biases caused by such effects would be 'effectively' calibrated out during verifications against the test separator. This emphasises the need for regular reverification if the uncertainties estimated by this method are to remain representative.

- The analysis assumes that each of the MPFM primary measurements (total liquid rate, water cut and gas rate) are independent variables (i.e. uncorrelated). This is a simplification as the primary measurements will have some level of correlation due to each being derived from inter-related equipment. However the impact of this correlation on the estimated oil and gas production uncertainties is likely to be relatively minor.

7 NOTATION

MPFM	Multi Phase Flow Meter
HC	Hydrocarbons
EOPC	End of Production Chain
$q_{liq,a}$	Total liquid flowrate at MPFM at metered conditions
$q_{gas,a}$	Gas flowrate at MPFM at metered conditions
$q_{wat,a}$	Water flowrate at MPFM

$q_{oil,a}$	Oil flowrate at MPFM at metered conditions
WLR	Water Liquid Ratio measured by MPFM
$q_{gas1,std}$	Gas Std Volume flowrate at export location (source: gas at MPFM)
$q_{oil2,std}$	Oil Std Volume flowrate at export location (source: gas at MPFM)
$q_{oil1,std}$	Oil Std Volume flowrate at export location (source: oil at MPFM)
$q_{gas2,std}$	Gas Std Volume flowrate at export location (source: oil at MPFM)
$q_{gas,std}$	Total Gas Std Volume flowrate at export location (source: HC's at MPFM)
$q_{oil,std}$	Total Oil Std Volume flowrate at export location (source: HC's at MPFM)
Bg	Gas Conversion Factor (m^3/Sm^3)
Rv	Gas Condensate Ratio (Sm^3/Sm^3)
Bo	Oil Conversion Factor (m^3/Sm^3)
Rs	Solution Gas Oil Ratio (Sm^3/Sm^3)
$U(Ver_{ref})$	Reference Measurement Uncertainty (in verification of MPFM Primary Measurement)
$U(Ver_{tol})$	Tolerance applied (in verification of MPFM Primary Measurement)
$U(Drift)$	Uncertainty due to MPFM Primary Measurement 'Drift' between verifications
$U(\Delta\rho_{oil})$	Uncertainty in MPFM total liquid measurement due to variations in in-service oil density
$U(Liq_{MPFM}\_Drift)$	Uncertainty in MPFM total liquid measurement due to variations in in-service fluid properties
$U(\Delta\rho_{gas})$	Uncertainty in MPFM total liquid measurement due to variations in in-service gas density
$U(\Delta\rho_{wat})$	Uncertainty in MPFM total liquid measurement due to variations in in-service water density
$U(\Delta\varepsilon_{oil})$	Uncertainty in MPFM total liquid measurement due to variations in in-service oil permittivity
$U(\Delta\sigma_{wat})$	Uncertainty in MPFM total liquid measurement due to variations in in-service water conductivity
$U(MPFM_{pm})$	Uncertainty in MPFM primary Measurement
$U(Bg)$	Uncertainty in Gas Conversion Factor
$U(Rv)$	Uncertainty in Gas Condensate Ratio
$U(Bo)$	Uncertainty in Oil Conversion Factor
$U(Rs)$	Uncertainty in Solution Gas Oil Ratio
$U(q_{gas,std})$	Uncertainty in Total Gas Std Volume flowrate at export location (source: HC's at MPFM)
$U(q_{oil,std})$	Uncertainty in Total Oil Std Volume flowrate at export location (source: HC's at MPFM)
$\Delta\rho_{oil}$	Estimated change in oil density between MPFM verifications
$C\rho_{oil}$	Sensitivity of MFPM total liquid measurement to change in oil density

8 REFERENCES

[1] ISO/TS 21354: 2020 ‘Measurement of multiphase fluid flow’

[2] BS ISO 5168: 2005 ‘Measurement of fluid flow – Procedures for the evaluation of uncertainties’

[3] JCGM 100: 2008 ‘Evaluation of measurement data – Guide to the expression of uncertainty in measurement’