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STANDARDIZATION WITHIN MULTIPHASE METERING

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Author:
E. Dykesteen
Norwegian Society for Oil and Gas Measurement and Fluenta as, Norway

Organiser:
Norwegian Society of Chartered Engineers
Norwegian Society for Oil and Gas Measurement
Co-organiser:
National Engineering Laboratory, UK

STANDARDIZATION WITHIN MULTIPHASE METERING

Eivind Dykesteen, Fluenta a.s.

SUMMARY

On an inititive from the Norwegian Society for Oil and Gas Measurement (NFOGM) a 'Handbook of Multiphase Metering' has been developed. The handbook is intended to serve as a guide for both users and manufacturers of multiphase meters, and provide the industry with a common basis for terminology, specifications etc. in the field of in-line multiphase measurement systems. The handbook should not be regarded as a final document. Rather, it is hoped that it will initiate more international work in which the issues and topics raised here can be further developed. This paper contains extracts from the 'Handbook of Multiphase Metering'. The intention of this is to provide the reader with a picture of the scope and objective of the handbook, and further to introduce some of the more important recommendations of the handbook with respect to e.g. performance specifications, testing and qualification of multiphase meters.

BACKGROUND

The idea of developing a Handbook of Multiphase Metering was first presented at NFOGM's first annual meeting in april 1993. The idea received a very positive responce, and as a consequence the NFOGM board took the initiative to form a working group consisting of members from oil companies, manufacturers and r&d.

The committee was formed as a Norwegian working group. This was not to exclude others, but because it was felt that it was immature to start work on an international level. For this reason also the mandate for the group was restricted to drafting of a handbook for the industry, rather than drafting of an international standard.

The initiative to draft a Handbook of Multiphase Metering was presented as introduction to discussion group at the North Sea Flow Measurement Workshop in 1993. These discussion groups supported the need for a handbook, and agreed that drafting of an international standard was immature.

The NFOGM working group completed a draft version of the handbook early 1995. This draft version was presented at the NFOGM annual meeting in April, and a one month deadline for comments was given. Comment have been treated by the working group and a final document was prepared. The Handbook of Multiphase Metering is now available from the NFOGM secretariate.

This paper contains extracts from the 'Handbook of Multiphase Metering'. The intention of this is to provide the reader with a picture of the scope and objective of the handbook, and further to introduce some of the more important recommendations of the handbook with respect to e.g. performance specifications, testing and qualification of multiphase meters.

The members of the NFOGM working group has been:

Eivind Dykesteen	Fluenta
Bernt Helge Torkildsen	Framo Engineering
Hans Olav Hide	MultiFluid International
Jens Grendstad	Kongsberg Offshore
Dag Flølo	Sandsli Drift
Harald Danielsen	Statoil
Håkon Moestue	Norsk Hydro
John Amdal	Saga Petroleum

THE OBJECTIVE OF THE HANDBOOK

The need for multiphase flow measurement in the oil and gas production industry has been evident for many years. A number of meters for measurement in multiphase flow have been developed during the last few years by research organisations, meter manufacturers, oil & gas production companies and others.

These developments employ different technologies, and the prototypes have been quite dissimilar in design and function. Some lines of development have been abandoned.

Only during the past year or two have meters been developed and tested to the stage at which multiphase flow measurement is a realistic option in an industrial environment. The number of uses and users is now expected to increase.

Multiphase flow measurement has yet to be established as a separate discipline. Meters from different manufacturers will always differ in their design, function and capabilities. In order to promote mutual understanding of multiphase flow meters and their use among users, manufacturers and others, some form of guidelines or user manual would seem appropriate. The 'Handbook of Multiphase Metering' has been written to serve that purpose and to help provide a common basis for the field of in-line multiphase measurement systems.

It is not the intention that the document should be regarded as a final document. Rather, it is hoped that it will initiate more international work in which the issues and topics raised here can be further developed.

THE SCOPE OF THE HANDBOOK

The 'Handbook of Multiphase Metering' is intended to serve as a guide for users and manufacturers of multiphase flow meters. Its purpose is to provide a common basis for, and assistance in, the classification of applications and meters, as well as guidance and recommendations for the use of such meters.

The document may also serve as an introduction to newcomers in the field of multiphase flow measurement, with definition of terms and description of multiphase flow in closed conduits being included.

The primary focus is on in-line meters for direct measurement of true multiphase flow of oil, gas and water. Even if the individual flow rates of each constituent are of primary interest, fractions of oil, gas and water are sometimes useful as operational parameters.

Other meters, e.g. separation meters and model/calculation type "meters", do not fall within the scope of this document, and are only briefly discussed. Other constituents than oil, gas and water are not dealt with.

The performance of a multiphase meter in terms of accuracy, repeatability, range, etc. is of great importance, as is the user's ability to compare different meters in these respects. One section covers this issue, and proposes standard ways of how performance can be described.

Related to performance are the testing and qualification of the meters, which are also covered. Guidance is provided to help optimise the outcome of such activities.

Since meters are in-line, flow rates are measured at process operating conditions. Conversion of flow rates to standard conditions, which involves multiphase sampling, knowledge of composition and mass transfer between phases at fluctuating pressures and temperatures, is only briefly dealt with here.

EXTRACTS FROM THE HANDBOOK

Terminology and definitions

Much of the terminology used to characterise multiphase flow and multiphase flow measurement have so far not been clearly defined. Consequently, commonly used terms are in many cases not used correctly, or may have different meanings in different contexts. The 'Handbook of Multiphase Metering' has made an attempt to put definitions to the most commonly used terminology within this dicipline. A list of the most important terms that have been defined is given below;

Flow regime
Gas-liquid-ratio (GLR)
Gas-oil-ratio (GOR)
Gas volume fraction (GVF)
Hold-up
Homogeneous multiphase flow
Multiphase flow
Multiphase flow rate
Multiphase flow velocity
Multiphase flow rate meter
Multiphase fraction meter
Multiphase meter
Oil-continuous multiphase flow
Phase
Phase area fraction
Phase flow rate
Phase mass fraction
Phase velocity
Phase volume fraction
Slip
Slip ratio
Slip velocity
Superficial phase velocity
Velocity profile
Void fraction
Volume flow rate
Water-continuous multiphase flow
Water cut (WC)
Water-in-liquid ratio (WLR)

In addition to these definitions of terminology, the handbook also gives an introduction to multiphase flow in vertical and horisontal flowlines, and gives descriptions of the different flow regimes that may be experienced. The terminology used to describe multiphase flow regimes is presented.

A format for initial evaluation of multiphase meter implementation

Two fill-in forms suitable for an initial evaluation of installation of a multiphase meter are proposed. These fill-in forms could be used by users, or by manufacturers, to compare meter performance specifications with actual process data at an intended installation point. The forms are intended as a first evaluation only, and more comprehensive investigations will have to follow before any certain decitions of suitability can be made. When using the fill-in forms, the following should be included:

- A sketch showing imortant details of the installation point:
  - upstream / downstream piping and process equipment
  - available space
  - other relevant information
- Process conditions:
  - the list in the form is not exhaustive, and other process parameters may be required
  - an attempt should be made to identify which flow regimes that are to be expected at the actual installation
- Expected multiphase production profile:
  - data to enter the graph must be given at process condition
  - superficial velocity axes should be linear, from zero to any required upper velocity range

- secondary flowrate axes should be filled in according to the actual line size, or used to select a more suitable metering line size
- the production profile, or multi-well production rates, should be marked on the graph, using WLR and year / well no. as legend

- Multiphase uncertainty calculations:
  - data to enter the table must be given at process condition
  - a representative number of expected production points should be filled in
  - average multiphase velocitiy, WLR and GVF may easily be calculated for each of the selected production points
  - absolute and relative deviations in measured phase flow rates may be calculated for each of the selected production points, using manufacturers performance specification

Multiphase meter implementation evaluation

Application: ____________________

Installation location: ____________________

Date: ____________________

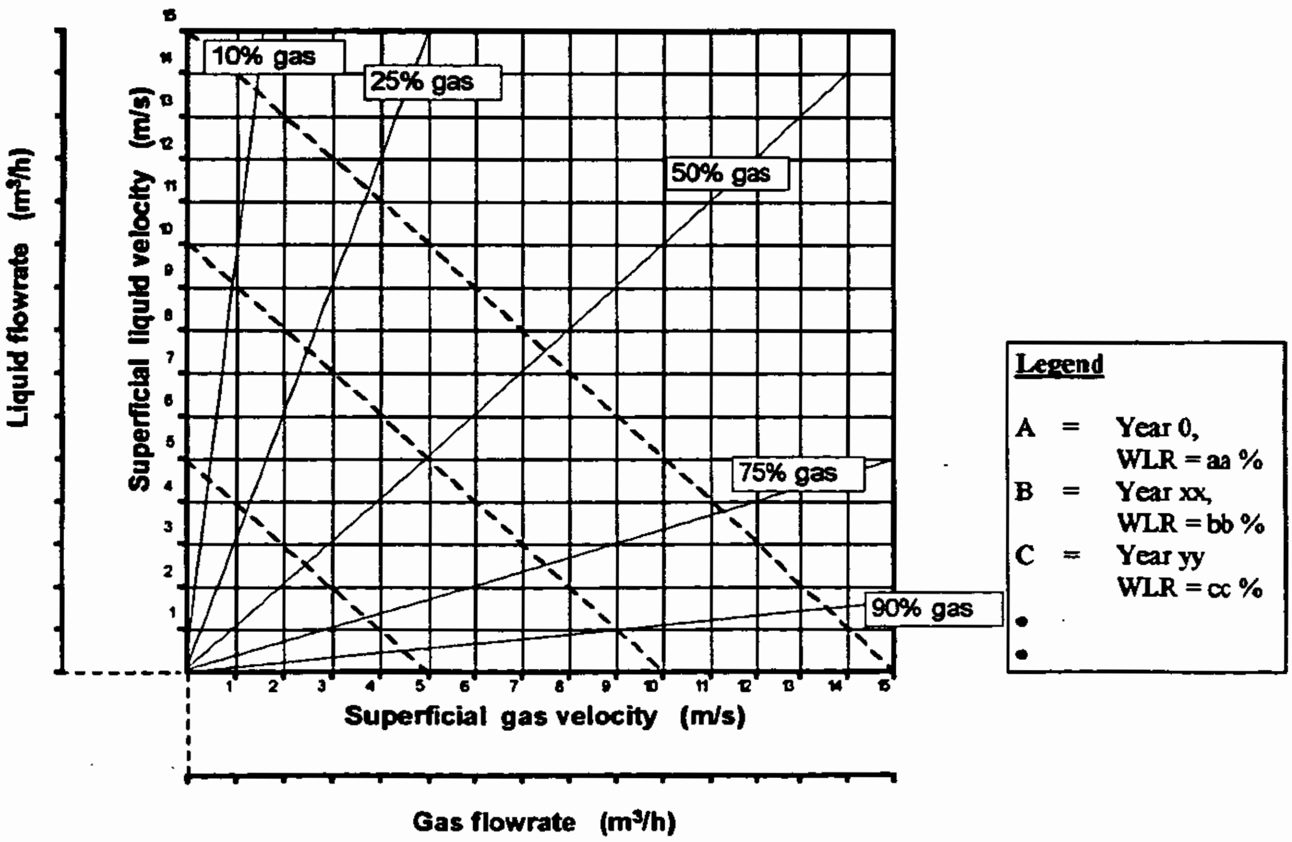
Reference: ____________________

Installation point piping configuration:

Process conditions:

Pressure:		**Temperature:**	
Oil density:		**Oil viscosity:**	
Gas density:		**Gas viscosity:**	
Water density:		**Water salinity:**	
Expected flow regimes:			

Expected multiphase production profile (at process conditions):



MULTIPHASE METER - UNCERTAINTY CALCULATIONS

APPLICATION:
Field:
Platform:
Installation:
Case:

PROCESS CONDITIONS:
Pressure:
Temperature:

METER DATA:
Meter type:
Model:
No of Meters:
Meter Size:
Inner Diam:

FLOW RATES - At Process Conditions

YEAR	WATER FLOW m3/h	GAS FLOW m3/h	OIL FLOW m3/h

FLOW CHARACTERIZATION

MULTIPHASE FLOW VEL. m/s	WLR %	GVF %

ESTIMATED UNCERTAINTY IN EACH PHASE (1)

WATER		GAS		OIL	
relative %	absolute m3/h	relative %	absolute m3/hr	relative %	absolute m3/hr

Note: (1) Assuming calibration parameters given within uncertainty limits specified by supplier, e.g.;
- Oil density
- Gas density
- Water density
- Water conductivity

Performance specification

The preferred performance specification of a multiphase flow rate meter is given in terms of the percentage uncertainty of actual oil, gas and water volume flow rates. However, in many cases this specification will be impractical, and not suited for a best possible description of the actual meter's performance. Other frequently used specifications are therefore,

- as a percentage of the actual total multiphase flow rate, or
- as uncertainties in actual liquid and gas flow rates, and with an absolute uncertainty specification of water-in-liquid ratio.

Tables 1 to 3 provides an overview of these three different methods commonly used to describe the uncertainty of multiphase meters, applied to typical flow conditions. The resulting uncertainty numbers are presented in terms of relative (% of phase volume flow rate) and absolute (m^3/hr) uncertainty.

As is seen in these tables, even though the different uncertainty specifications at a first may look seem similar, they differ significantly.

Other methods for specifying multiphase meters exists, and the purpose of Tables 1 to 3 is to give some guidance to how different specifications can be compared, rather than providing a complete overview of the methods. Due to the significant difference in performance between these methods of expression, the manufacturer should clearly state his method of specification.

These three methods of performance specification will in the following be explained through examples:

Method 1: Uncertainties relative to actual phase flow rates.

By this method the uncertainty of the meter is described as a fixed per cent (relative) of the actual volumetric flow rate of each phase.

In the examples shown in Table 8.1, each phase volume flow rate has a ±10% relative uncertainty. The resulting absolute uncertainties in terms of m^3/h are calculated as ±10% of the actual phase volume flow rate.

Table 1

Specification: +/- 10 % of phase volume flow rate (WLR = 20 %)			
Fluid	**Flow rate [m³/h]**	**Uncertainty [m³/h]**	**Uncertainty [%]**
Multiphase	125	+/- 12.5	+/- 10 %
Gas	100	+/- 10.0	+/- 10 %
Oil	20	+/- 2.00	+/- 10 %
Water	5	+/- 0.50	+/- 10 %
Specification: +/- 10 % of phase volume flow rate (WLR = 4.76 %)			
Multiphase	125	+/- 12.5	+/- 10 %
Gas	20	+/- 2.0	+/- 10 %
Oil	100	+/- 10.0	+/- 10 %
Water	5	+/- 0.50	+/- 10 %

Method 2: Percentage of total multiphase flow rate.

By this method assumes the uncertainty of the multiphase meter is described as a fixed per cent of the total multiphase volume flow. The absolute uncertainty in terms of m^3/hr is thus equal for all three components for a given total flow.

In the examples of Table 2, an uncertainty level of ±5% is used. Of a total flow of 125 m^3/hr, this equals ±6.3 m^3/hr, which is then the absolute uncertainty for all three phases, independent of the composition (since the total flow is the same for all four cases).

The relative uncertainty numbers can be derived simply by calculating the ratio between the absolute uncertainty and the actual flow rate for that component:

$$\delta Q_P = (Q_M * \delta X) / Q_P$$

where
- δQ_P = the relative uncertainty in phase flow rate
- δX = the specified uncertainty
- Q_M = the multiphase flow rate
- Q_P = the phase flow rate at Q_M

Table 2

Specification: +/- 5 % of total multiphase flow rate (WLR = 20 %)			
Fluid	**Flow rate [m³/h]**	**Uncertainty [m³/h]**	**Uncertainty [%]**
Multiphase	125	+/- 6.25	+/- 5.00
Gas	100	+/- 6.25	+/- 6.25
Oil	20	+/- 6.25	+/- 31.25
Water	5	+/- 6.25	+/- 125.00
Specification: +/- 5 % of total multiph. flow rate (WLR = 4.76 %)			
Total flow	125	+/- 6.25	+/- 5.00
Gas	20	+/- 6.25	+/- 31.25
Oil	100	+/- 6.25	+/- 6.25
Water	5	+/- 6.25	+/- 125.00

Method 3: Percentage of gas and liquid flow rates, combined with absolute uncertainty in WLR.

The relative uncertainty in gas flow rate is given specificly, whereas the uncertainties of oil and water rates results out of uncertainty in two levels. First, there is a relative uncertainty in the liquid flow rate, and this one must be combined with a second absolute uncertainty regarding the determination of the WLR of the fluid. It is assumed that these two uncertainties can be regarded as independant of each other.

The examples of Table 8.3 displays results for a case where the uncertainty of the gas volume flow rate is $\pm 10\%$. The liquid volume flow rate uncertainty is $\pm 10\%$, which is combined with an uncertainty of determining the WLR of ± 3 % absolute.

The absolute uncertainty in the water volume flow rate, ΔV_W, is then given by

$$\Delta V_W = SQRT\ \{(\Delta WLR * V_L)^2 + (\delta V_L * V_L * WLR)^2\}$$

where
- WLR = the actual water-in-liquid ratio
- ΔWLR = the absolute uncertainty in WLR
- V_L = the actual liquid volume flowrate
- δV_L = the relative uncertainty in the liquid volume flowrate

Table 3

Fluid	Flow rate [m³/h]	Uncertainty [m³/h]	Uncertainty [%]
Specification:	+/- 10 % of gas flow rate +/- 10 % of liquid flow rate (WLR = 20 %) +/- 3 % absolute uncertainty in WLR		
Multiphase	125	+/- 12.5	+/- 10.0
Liquid	25	+/- 2.5	+/- 10.0
Gas	100	+/- 10	+/- 10.0
Oil	20	+/- 2.14	+/- 10.7
Water	5	+/- 0.90	+/- 18.0
Specification:	+/- 10 % of gas flow rate +/- 10 % of liquid flow rate (WC = 4.76 %) +/- 3 % absolute uncertainty in WC		
Multiphase	125	+/- 12.5	+/- 10
Liquid	105	+/- 10.5	+/- 10
Gas	20	+/- 2	+/- 10
Oil	100	+/- 10.5	+/- 10.5
Water	5	+/- 3.19	+/- 63.8

The relative uncertainty in water volume flow rate is then simply given by the relation between the absolute uncertainty in water volume flow rate, ΔV_W, and the actual water volume flowrate.

Accordingly, the absolute uncertainty in oil volume flow rate, ΔV_o, is given by

$$\Delta V_o = SQRT\ \{(\Delta WLR * V_L)^2 + (\delta V_L * V_L * (1\text{-}WLR))^2\}$$

Establishing the reproducibility of a given meter

The reproducibility of a meter is a quantitative expression of the agreement between the results of measurements of the same value of the same quantity, where the individual measurements are made under different defined conditions.

One significant difference between multiphase meters and single-phase meters is that most of the uncertainty of a multiphase meter is caused by variations in process conditions and fluid properties, rather than the uncertainty of the primary measurement elements. Therefore, the meter's ability to reproduce its performance under different process conditions, installation set-ups and flow regimes becomes a very important parameter.

A format for the presentation of a multiphase meter performance specification

A fill-in form for summarizing the performance specification of a multiphase meter is proposed. The fill-in form could be used by users, or by manufacturers, to assemble essensial information from different manufacturers product information packages, to a common format. When using the fill-in form, the following should be included:

- A sketch showing imortant details of installation requirements:
  - horizontal / vertical upwards / vertical downwards flow
  - mixer / not mixer
  - straight upstream / downstream lengthts
- Rated conditions of use:
  - the list in the form is not exhaustive, and other parameters important for the particular meter should be included
  - flow regimes that the meter is designed to handle should be listed
  - the interval in which the influence parameters are allowed to vary, still maintaining the uncertainty specifications, should be specified
- Influence quantities:
  - the list may, or may not, include the same parameters as listed "Rated conditions of use"; all influence parameters important for the particular meter should be included
- Operating range:
  - superficial velocity axes should be linear, from zero to any required upper velocity range
  - secondary flowrate axes may be used to denote or select a suitable meter size
  - operating range should be marked on the graph, and may be divided into as many sub-areas as required
- Uncertainty specification:
  - uncertainties should be given for each sub-range of the operating range
  - uncertainties in phase flowrates should preferably be given relative to actual phase flowrates
  - absolute deviations in WLR and GVF may be given as indicated
  - the uncertaity specification may be quoted for as many WLR-ranges as required
- Additional information:
  - method of meter calibration / special calibration requirements must be identified
  - reference to more comprehensive product information should be indicated

Multiphase meter performance specification

Manufacturer: ____________________
Meter type: ____________________
Date : ____________________
Reference: ____________________

Required Installation Configuration Schematic:

Rated conditions of use:

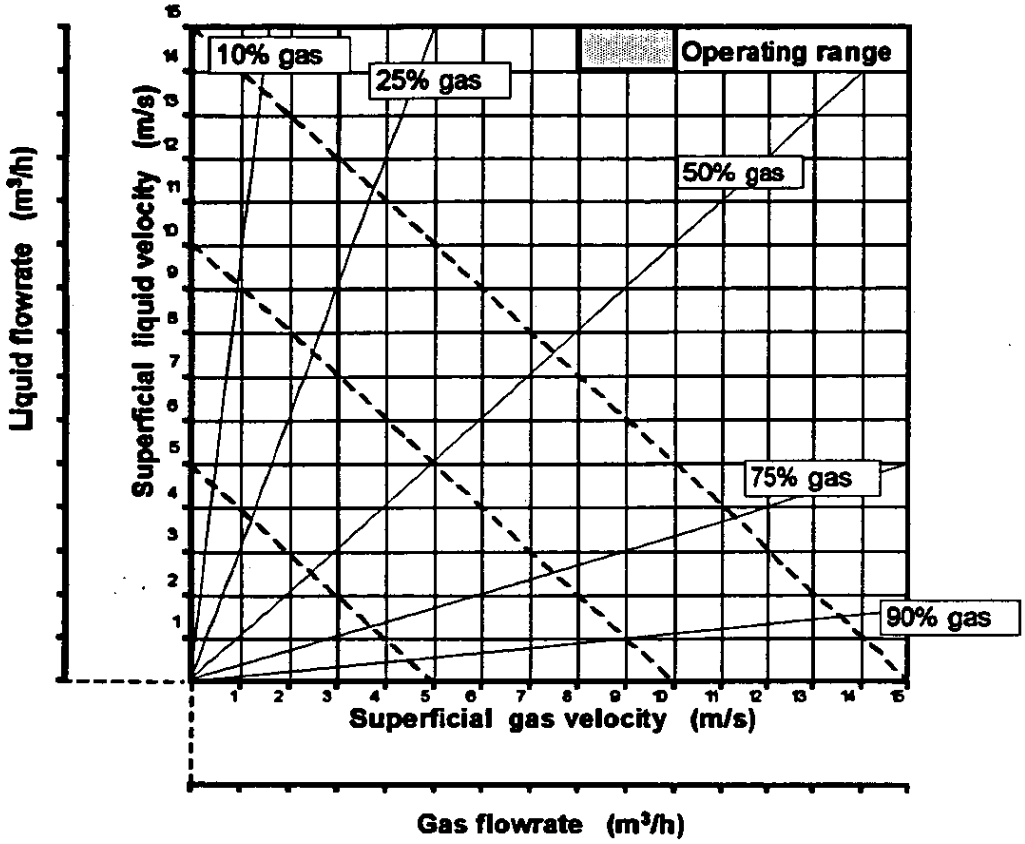
Pressure:		Temperature:	
Oil density:		Oil viscosity:	
Gas density:		Gas viscosity:	
Water density:		Water salinity:	
Flow regimes:			

Influence quantities:

Quantity	Influencing	Effect
Oil density:		
Gas density:		
Water density:		

Flow regime:		

Operating range:



Uncertainty specification:

Sub - Range	WLR Range (%)	Uncertainties; according to Method 1, 2 or 3				
		Oil	Water	Gas	Liquid	WLR
A	0 - x					
B	0 - x					
C	0 - x					
D	0 - x					
E	0 - x					
A	x-100					
B	x-100					
C	x-100					
D	x-100					
E	x-100					

Calibration requirements:

Reference:

A format for presentation of summary test results.

A fill-in form for summarizing test results of a multiphase meter is proposed. The fill-in form could be used by users, or by manufacturers, to present summaries from different tests, and of different meters, using a common format. When using the fill-in form, the following should be included:

- A sketch showing imortant details of the test installation:
  - horizontal / vertical upwards / vertical downwards flow
  - mixer / not mixer
  - straight upstream / downstream lengthts
  - phase commingling point / distance to meter under test
  - position of reference measurements
- Process conditions:
  - the list in the form is not exhaustive, and other parameters important for the particular test should be included
  - flow regimes that the meter under test has been subjected to, and how these regimes were controlled or observed
- Reference measurements:
  - type and quality of reference measurements shold be provided
  - reference to installation point on installation sketch should be given
- Multiphase meter calibration prior to test:
  - a qualitative description of the calibration performed by meter manufacturer, or by test institution, prior to the test
  - reference to a complete calibration report should be provided
- Test matrix:
  - superficial velocity axes should be linear, from zero to any required upper velocity range
  - secondary flowrate axes should be filled in according to the actual meter size
  - test-points should be marked on the graph, using WLR as legend
- Test results summary:
  - a representative number of test points should be filled in
  - deviations in phase flowrates should preferably be given relative to actual phase flowrates
  - absolute deviations in WLR and GVF may be given as indicated
  - the uncertaity specification may be quoted for as many WLR-ranges as required
  - any particular observations during test should be identified in the comments field
  - reference to a more comprehensive test report should be indicated

Multiphase meter test summary

Meter identification: ______________________
Test location: ______________________
Test period: ______________________
Test responsible: ______________________

Test Installation Configuration Schematic:

Process conditions:

Pressure:		Temperature:	
Oil density:		Oil viscosity:	
Gas density:		Gas viscosity:	
Water density:		Water salinity:	
Flow regimes (how observed):			

Reference measurements:

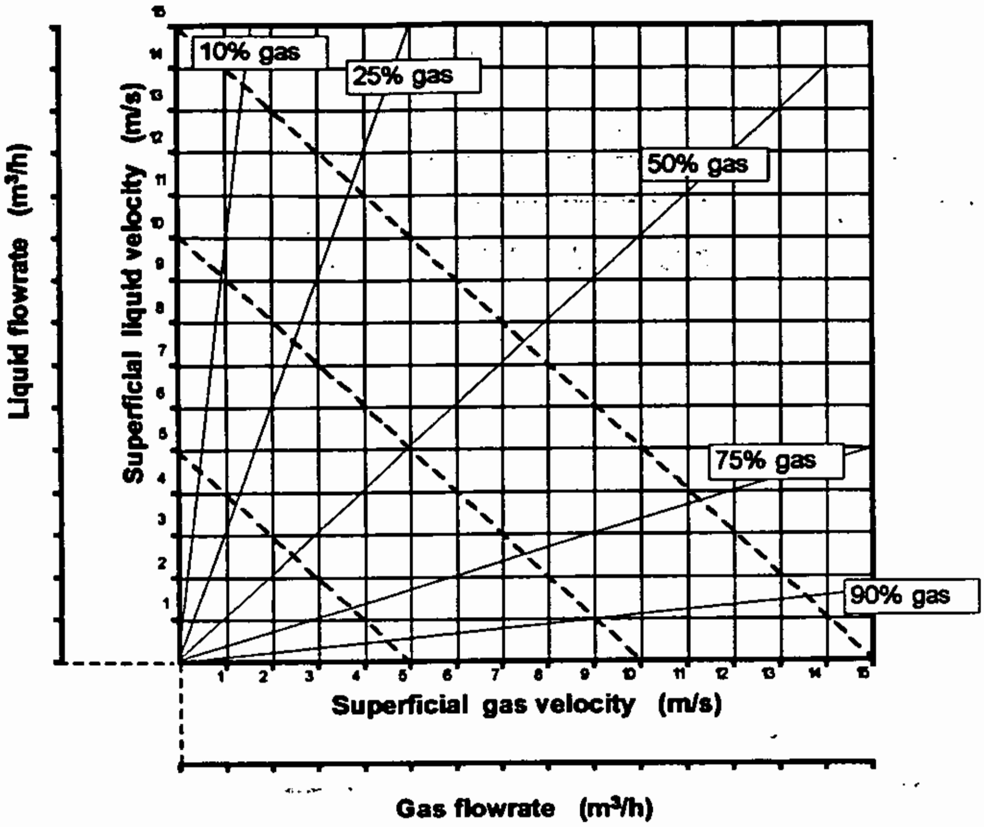
Phase	Reference meter type	Position (ref. to Piping Config. Schematic)	Uncertainty	Comments
Oil				
Water				
Gas				

Multiphase meter calibration prior to test:

Description:

Calibrated by:	
Date of calibration:	
Reference to calibration	

Test Matrix:



Legend

A = 0 % WLR
B = 10 % WLR
C = 20 % WLR
D = 30 % WLR
•
•

Test results summary:

Reference measurements (m³/h)			Test results (m³/h)					Deviations;				
Oil	Water	Gas	Oil	Wat.	Gas	Liq.	WLR	Oil	Wat.	Gas	Liq.	WLR

Comments:

Test report reference:

References

[1] Paper presented at the North Sea Flow Measurement Workshop, a workshop arranged by NFOGM & TUV-NEL

Note that this reference was not part of the original paper, but has been added subsequently to make the paper searchable in Google Scholar.