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FISCAL AND SALES ALLOCATION MODELS FOR UPSTREAM PRODUCTION SYSTEMS

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1. INTRODUCTION

1.1 SCOPE

This DEP specifies requirements and gives recommendations for fiscal and sales allocation models for upstream production systems. Allocation systems without either sales or fiscal aspects are excluded from this DEP. Hence, production allocation, i.e., the process of allocating fluids to well level, will be mentioned but is not the focus of this DEP, although such allocation might have a fiscal duty, e.g., the measurement of well fluids that immediately leave a concession area.

The DEP describes:

- a. the design and engineering requirements of the various allocation models, their associated metering and analytical hardware and their maintenance needs.
- b. the operational aspects of a metering and allocation system but not the tools needed to run an allocation process, e.g., Energy Components.

NOTES: 1. Custody transfer measurements do not fall within the scope of this DEP.
2. Selection of the allocation method, which furthermore depends on contractual, commercial, and legal requirements, does not fall within the scope of this DEP.

This is a revision of the DEP of the same number dated December 2008; see (1.5) regarding the changes.

1.2 DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS

Unless otherwise authorised by Shell GSI, the distribution of this DEP is confined to Shell companies and, where necessary, to Contractors and Manufacturers/Suppliers nominated by them. Any authorised access to DEPs does not for that reason constitute an authorisation to any documents, data or information to which the DEPs may refer.

This DEP is intended for use in facilities related to oil and gas production, particularly for instrument engineers, project engineers and hydrocarbon allocation engineers. This DEP may also be applied in other similar facilities.

When DEPs are applied, a Management of Change (MOC) process shall be implemented; this is of particular importance when existing facilities are to be modified.

If national and/or local regulations exist in which some of the requirements could be more stringent than in this DEP, the Contractor shall determine by careful scrutiny which of the requirements are the more stringent and which combination of requirements will be acceptable with regards to the safety, environmental, economic and legal aspects. In all cases, the Contractor shall inform the Principal of any deviation from the requirements of this DEP which is considered to be necessary in order to comply with national and/or local regulations. The Principal may then negotiate with the Authorities concerned, the objective being to obtain agreement to follow this DEP as closely as possible.

1.3 DEFINITIONS

1.3.1 General definitions

The **Contractor** is the party that carries out all or part of the design, engineering, procurement, construction, commissioning or management of a project, or operation of a facility. The Principal may undertake all or part of the duties of the Contractor.

The **Manufacturer/Supplier** is the party that manufactures or supplies equipment and services to perform the duties specified by the Contractor.

The **Principal** is the party that initiates the project and ultimately pays for it. The Principal may also include an agent or consultant authorised to act for, and on behalf of, the Principal.

The word **shall** indicates a requirement.

The word **should** indicates a recommendation.

1.3.2 Specific definitions

Term	Definition
allocation	Process by which a quantity of fluid measured at a sink is allocated to one or more contributing sources. (ISO/TR 26762)
allocation by difference	Allocation in which the system imbalance is assigned to a single unmeasured source
availability	Relative time that a system performs its assigned duty Unavailability is complementary to availability.
bias (error)	Systematic component of the error of a measuring instrument. (International Vocabulary of Metrology, VIM)
component-based allocation (CBA)	Allocation in which the quantity of fluid is redistributed according to its chemical components, each of them either as a measure of substance or mass
fiscal	Concerned with government finance
Froude numbers (Fr)	Ratio of inertial force and gravitational force for a particular phase NOTE: This is the ratio of kinetic to potential energy of the gas or the liquid.
gas volume fraction (GVF)	Gas volume flow rate, relative to the multiphase volume flow rate, at the pressure and temperature prevailing in that section The GVF is normally expressed as a fraction or percentage.
geo-chemical fingerprinting (GCF)	Allocation by which the quantity of fluid is redistributed according to the presence of trace components in the sink, which in a given range are unique for the sources
Lockhart Martinelli parameter (LM)	Ratio of the liquid Froude number and the gas Froude number
measurand	Quantity subjected to measurement (International Vocabulary of Metrology, VIM) NOTE: For estimations such as process simulation, the definition should be expanded to "A quantity subjected to measurement or estimation".
multi stage allocation	Allocation within a cascade of single stage allocation systems
node	Point in the system defined for the purpose of quantifying the quantity and quality of product passing through it. (ISO/TR 26762)
pay and check	Redundant measurement system whereby one system produces the fiscal data and the other checks the outcome of the previous
pro-rata quantity reconciliation (PRQ)	Method of reconciliation by which the system imbalance is redistributed over the sources pro rata of quantity measured.
quantity-based allocation (QBA)	Allocation according to the quantity of fluid
quantity mass-based allocation (QMA)	Allocation in which the quantity of fluid is expressed by mass
quantity volume-based allocation (QVA)	Allocation in which the quantity of fluid is expressed by volume
reconciliation	Process of dealing with any quantity imbalance between sources and sinks. (ISO/TR 26762)
redundancy	Duplication of functionality

Term	Definition
sales	Income from sold products
single stage allocation	Allocation within a system with a single step between source and sink(s)
sinks	Product feed leaving a system node. (ISO/TR 26762)
source	Product feed entering a system node. (ISO/TR 26762)
system	Closed system supplied by more than one source and drained by one or more sinks
system imbalance	Difference between the quantity measured at the sink(s) and the sum of quantities measured at the sources
traded unit	Quantity measured at a sales point and expressed in the appropriate units of measurement
uncertainty	Estimate characterizing the range of values within which the true value of a measurand lies (International Vocabulary of Metrology, VIM) NOTE: In the context of this DEP, the uncertainty of a measurement shall be estimated on basis of two times the experimental standard deviation.
uncertainty-based reconciliation (UBR)	Method of reconciliation by which the system imbalance due to random variability is optimised by least mean square minimisation
yield-based allocation (YBA)	Allocation in which the fluid quantities are estimated from fluids produced at the sources
yield factor (YF)	Yield per source of quantity sales product relative to the total quantity of fluid produced by the same source

1.3.3 Abbreviations

Term	Definition
MDGC	multiple dimensional gas chromatography

1.4 CROSS-REFERENCES

Where cross-references to other parts of this DEP are made, the referenced section number is shown in brackets (). Other documents referenced in this DEP are listed in (6).

1.5 SUMMARY OF MAIN CHANGES

This DEP is a revision of the DEP of the same number dated December 2008. The following are the main, non-editorial changes.

Section	Change
1.1	Scope section revised.
3.6	Table modified.
4.8	Uncertainty estimate for less favourable conditions added.
5.2.2	References to new DEPs on custody transfer measurement.
5.2.3.1	1% by volume corrected to 1% by mass.
6	Replaced BS 5233 (withdrawn) with ISO/IEC Guide 99

1.6 COMMENTS ON THIS DEP

Comments on this DEP may be submitted to the Administrator using one of the following options:

Shell DEPs Online (Users with access to Shell DEPs Online)	Enter the Shell DEPs Online system at https://www.shelldeps.com Select a DEP and then go to the details screen for that DEP. Click on the "Give feedback" link, fill in the online form and submit.
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DEP Standard Form (Other users)	Use DEP Standard Form 00.00.05.80-Gen. to record feedback and email the form to the Administrator at standards@shell.com .

Feedback that has been registered in the DEP Feedback System by using one of the above options will be reviewed by the DEP Custodian for potential improvements to the DEP.

1.7 DUAL UNITS

This DEP contains both the International System (SI) units, as well as the corresponding US Customary (USC) units, which are given following the SI units in brackets. When agreed by the Principal, the indicated USC values/units may be used.

2. BACKGROUND, PHILOSOPHY AND CONTRACT CONDITIONS

2.1 BACKGROUND

The assignment of sales shares to the respective rightful owners and apportioning of associated tax revenues claimed by the government, if relevant, is a prerequisite for production chains where partners commingle their individual contribution into shared production systems. This assignment, which is referred to as the "sales and fiscal allocation process", is usually facilitated by:

- a. measurement hardware like field instrumentation, on-line analyser systems and laboratory equipment for off-line sample analyses;
- b. a computational allocation model and algorithms;
- c. software and hardware embodiment of the allocation model;
- d. procedures for the execution of the allocation process;
- e. hardware and software maintenance.

The results of the sales and fiscal allocation process shall be fair and equitable for partners who participate in the shared production, so as to ensure that none of them will either commercially gain or lose from participation in the scheme at the costs of others and that all partners will therefore have equal commercial exposure.

Shared production facilities cover a wide range of possible configurations. Traditionally the supporting technology is limited to surface equipment, i.e., all surface hardware that is installed downstream of the well choke and up to the sales and fiscal measurement systems at sales point. However, recent smart well developments enable hydrocarbon depletion from various subsurface compartments of a hydrocarbon reservoir to be controlled. In complex configurations, such subsurface compartments may be owned or even shared by different partners, thus necessitating the extension of the allocation procedures to subsurface level.

The results of the allocation scheme concern primarily sales and fiscal allocation, i.e., allocation of the commercial and fiscal value of the sales products delivered by the production chain. The assignment of fluids to their respective sources in a sales and fiscal allocation system is often intertwined with the production allocation process.

2.2 PHILOSOPHY

Any sales and fiscal allocation methodology shall be fair and equitable to all parties concerned.

The design of new installations or revision of existing installations shall be subject to agreement between contract parties and legal / metrology authorities concerned.

There should be a single party responsible for:

- a. the design of the allocation method;
- b. the advice on the design specification of the associated fiscal and allocation metering stations including advice on the methods of on-line and off-line analyses.

The relevant parties shall retain the right to witness commissioning and validation and to audit the contractual compliance of any system that facilitates the allocation process.

2.3 CONTRACT CONDITIONS

The contract should refer to the main commercial and fiscal issues.

Allocation and measurement details should be covered as an attachment to the contract thus avoiding undue revision of the contract if only technical details change. Any deviations or changes concerning the attachments should be justified and agreed at working level.

The overall uncertainty and availability data of the associated metering stations should initially be estimated from operational experience with other facilities of similar design and purpose, and quoted as target values in the contract.

Any proposal for a sales and fiscal allocation system shall be sent to the Principal for perusal and consent.

3 GENERAL REQUIREMENTS

3.1 UNITS OF MEASUREMENT

3.1.1 SI units

All calculated and measured values (temperature, pressure, mass, volume, density heating/calorific value, etc.) of oil and gas hydrocarbons shall be expressed in units according to the International System of units (SI). Values in other units where required (e.g., barrels, cubic feet) shall be derived from the SI units.

3.1.2 Standard reference conditions

Standard reference conditions for natural gas shall be in accordance with ISO 13443, as follows:

- a. 288.15K (15 °C, 59 °F)
- b. 101.325 kPa (14,6959 psia)

Standard reference conditions for petroleum liquids and liquefied petroleum gases shall be in accordance with ISO 5024, which are the same as the above with the exception of liquid hydrocarbons having a vapour pressure greater than atmospheric at 15 °C (59 °F), in which case the standard pressure shall be the equilibrium vapour pressure at 15 °C (59 °F).

3.2 QUANTITY

Gas quantities should be expressed as unit mass [kg] or volume [m³] under standard conditions or energy content [J].

NOTE: Volume under standard conditions is directly proportional to mass while energy is derived from mass.

Hydrocarbon liquid quantity should be expressed as either unit mass or volume at standard conditions.

NOTE: Mass should have preference over volume since the former complies with the law of conservation of mass whilst the latter, in order to be consistent, is subject to correction for pressure and temperature.

3.3 CALORIFIC VALUE

The calorific value of gas shall, depending on the application, be chosen as either mass-based [MJ/kg], volume-based [MJ/m³] or mole-based [MJ/mol] and shall refer to superior calorific value (SCV), all in accordance with ISO 6976.

NOTE: It is convenient to infer heating value directly from the mass, mass-based compositional analysis and mass-based calorific value of each component when prime mass flow transmitters are used such as Coriolis meters. The GLC apparatus used for that purpose can be calibrated directly to the relative mass contribution of each component.

The referenced condensation temperature of the freed water during combustion should, depending on contractual obligations, be chosen from the options left in ISO 6976. The referenced condensation temperature should be selected as 20 °C (293.15 K).

NOTE: For units other than SI, and for other reference conditions, refer to ISO 13443.

Volumetric calorific value shall be referenced to standard reference conditions.

3.4 TREATMENT OF UNCERTAINTY AND ERRORS

3.4.1 Terms and expression of uncertainty

Expressions of uncertainty, repeatability and reproducibility shall comply with ISO/TS 21748 and ISO/TS 21749.

The uncertainty of flow measurements shall follow the methodology of ISO 5168.

The uncertainty of a specific analytical measurement shall be based on the referenced standard method and, if relevant, on the quality of reference calibration materials.

The allowable uncertainty shall, as a minimum, comply with the design specification.

Due attention shall be given to locally induced variability, which may add to the uncertainty that is inherited from the fabrication process and which may typically apply to complex instrumentation like multiphase flow meters and on-line analyser systems.

NOTE: On-line analyser systems do not always mimic in every detail the international standards but instead relate to them in other ways. For instance, the gas chromatographic design of on-line analysers for the measurement of calorific value according to ISO 6976 does not always follow ISO 6974 in every detail when implemented in an on-line process gas chromatograph. Hence, they may develop their own characteristic uncertainty footprint that may be enhanced by specific design details such as the sample handling systems common to analysers of this type.

For on-line analyser systems it is common practice in such a case for a calibration reference material to be used for checking the meter whilst the calibration reference material in turn is periodically checked with laboratory equipment that is in full compliance with the ISO concerned. The analytical performance of an on-line analyser is not necessarily less robust than that of a laboratory analyser. The high degree of specialisation and continuous state of readiness of on-line analysers are often underlying factors of their excellent performance.

3.4.2 Containment of uncertainty

The control of undue variance and errors shall be traceable by the use of statistical process control (SPC) methodology; i.e., through the use of control charts that are used for logging validation and calibration results. Control charts methodology and SPC ruling shall, as a minimum, comply with ASTM D 6299 and the deviations from it as described in Global Laboratory News No. 35 dated October 5th, 2006.

Regular validation shall prove the uncertainty performance of key equipment in general and of analytical performance of analyser systems (continuous on-line process analysers or laboratory-operated analysers) more specifically.

3.4.3 Computer simulations

The computer simulation of complex models, and more specifically of allocation models, shall utilise established and contractually agreed programmes, for which purpose either Crystal Ball or MATHCAD should be chosen. The models used for simulation shall be documented and traceable and shall be regularly updated with recent data that evolves from equipment testing.

Refer to (Appendix G) for a worked out Crystal Ball example.

3.5 TRACEABILITY OF RESULTS

Chemical and physical properties shall be traceable to calibration reference materials and/or to analytical methods in accordance with national or international standards.

3.6 CLASSIFICATION OF METERING SYSTEMS AND THEIR UNCERTAINTIES

The uncertainty of metering systems can be classified according to their application, as indicated in the table below.

Table 1 Uncertainty of metering systems

Class	Purpose	Uncertainty relative to traded units as per contractual or statutory requirements
1	Sales and fiscal measurement systems These apportion the quantity of hydrocarbon liquid and natural gas exiting a facility between the different fields that enter the facility. Purpose: sales and taxation. NOTE: This type of measurement is classified as a sink in an allocation system. Natural gas $\leq 1 \%$ Hydrocarbon liquids $\leq 0.25 \%$	
2	Allocation attribution systems These determine the quantity of hydrocarbon liquids (oil and condensate) and natural gas produced at an allocation node. Purpose: sales and taxation. NOTE: This type of measurement is classified as a source in an allocation system.	2.5 % to 10 %
3	Reservoir management/surveillance This determines the quantity of oil, water and gas produced from an individual well. Purpose: reservoir management.	$\leq 20 \%$
4	Environmental and emission trading	10% to 20% (flares) 5% to 10 % (other)

- NOTES:
1. The above quoted uncertainties are the compounded uncertainties that result from flow meters, from auxiliary instrumentation such as a water cut meter when net oil is to be reported, from algorithms and models, from fluid properties and from process simulation.
 2. The above quoted uncertainties are limit values which might need further optimisation to minimise the financial exposure of the partners; e.g., improved uncertainty as compared to the minimum standard might be justifiable for large volumes.

Metering systems in Classes 1 and 2 meters fall within the scope of this DEP.

Metering systems in Class 3 do not fall within the scope of this DEP unless they combine their duty as a reservoir management/surveillance device with the duty as a Class 2 sales allocation device, which is rarely the case.

Class 4 metering systems are not considered in this DEP. However, a single meter might combine two classes; e.g., in allocation system a flare meter may be classified as Class 2 for fiscal purposes while it might be classified as Class 4 for the purpose of emission trading, in which case the meter shall comply with the most stringent requirement of both classes.

3.7 AVAILABILITY, REDUNDANCY AND TURN DOWN CONSIDERATIONS

3.7.1 General

The design shall fulfil the contractually agreed availability requirements, which shall consider any period of outage and flow reduction as a result of maintenance or equipment failure.

The projected availability shall be demonstrable to all parties concerned by an agreed failure analysis methodology.

As a general rule, equipment failure affecting agreed availability shall be restored as early as practicable. Hardware design, maintenance strategy and spare parts policy, which may also include complete assemblies, shall facilitate this requirement.

3.7.2 Class 1 measurements

Payment and taxation are a direct result of the quantities measured by the respective Class 1 measurement systems. Hence, measurement uncertainty or, worse, errors will propagate proportionally into the pay regime.

Class 1 measurements shall be robust against the failure of a single component without affecting the uncertainty of the measurement.

In multi-meter run stations the redundancy requirements for each meter run are subject to failure analysis and should be agreed upon on the basis of the availability requirements.

Redundancy at meter run level, if required, should be a system of Pay and Check, each capable of producing independently the contractually required data.

Redundancy shall be designed to minimise common mode failure. For this purpose, due attention shall be paid to the diversity of measurement principles and to the design of supporting systems, e.g., uninterruptible power supply systems.

3.7.3 Class 2 measurements

The effects of uncertainty or errors in Class 2 metering systems on the pay regime depend usually on the allocation model and algorithms used.

Full redundancy is not often a requirement for Class 1.

A single failure of a Class 2 measurement shall not impede the allocation process but is allowed to affect uncertainty within the constraints of the allocation model; e.g., by sacrificing not more than one degree of freedom, which usually degrades the reconciliation model to one of inference by difference and which therefore affects uncertainty (4.7).

3.8 GENERAL ENGINEERING AND DESIGN REQUIREMENTS FOR INSTRUMENTATION

General engineering and design requirements for instrumentation systems shall comply with DEP 32.31.00.32-Gen.

Systems shall be designed and selected to meet the specified uncertainty and availability performance.

Design and engineering shall be optimised to the total cost of ownership, which shall account for the complete life cycle of the project. The design aim is for the method of measurement and the operating and maintenance procedures to be suitable for the process conditions occurring during the lifetime of the system. Due consideration shall be given to possible changes in flow rate and fluid properties over the lifetime of the production system.

System design, maintenance strategy and spare part policy shall facilitate system validation in order to prove system uncertainty as appropriate. Hence, the relevant calibration/validation facilities shall be considered as part of the design phase, which should also include the necessary maintenance management systems.

NOTE: The use of a mobile prover unit should be considered in cases where a permanent prover for the purpose of calibration or the use of a master-meter for the purpose of validation cannot be justified. Meter validation might furthermore be achieved by comparing meters that are installed in one piping manifold, which would require a multiple of smaller meters that are normally running in parallel but which, for the purpose of validation, can be switched in series. This also might improve redundancy and overall uncertainty as compared to a single meter.

Instrument locations shall be safely accessible for the purposes of operation and maintenance. However, there may be physical limitations such as those that obviously apply to sub-sea measurements.

Equipment construction shall comply with the safety and area classification of the area concerned and shall suit prevailing environmental conditions. Mitigation should be sought in providing protective shelter if conditions are incompatible but only if other alternatives are not available.

NOTE: For example, a delicate on-line analyser system may, depending on its type, require an environment that is temperature and humidity controlled, which might result in a purposely-built analyser house complete with air conditioning. If, additionally, the installed analyser equipment is not designed to meet area classification requirements, e.g., as specified by IEC 60079-10, controlled over-pressurisation might be required to prevent the ingress of ambient atmosphere surrounding the premise. This is typically the case when the surroundings of such a system are classified as zone II and the electrical equipment does not comply with the requirements of area classification zone I. The latter is the consequence of regulation because the unventilated system will be rated as gaining one degree in severity as compared to the surrounding area in which the system is installed (i.e., it will go from zone II to zone I).

Design and engineering and especially equipment selection shall only be finalised when the details of the sales agreement for the fiscal and allocation measurements (if applicable), the fluid parameters and meter location are known, e.g.:

- a. Type of fluid
- b. Type of flow regime
- c. Fluid contamination
- d. Erosion and corrosion aspects
- e. Expected production and flow profile over the full life cycle of facilities concerned
- f. Performance specification in terms of:
 - turn down
 - redundancy
 - reliability
 - analytical capability
 - uncertainty
- g. Operating and maintenance strategy
- h. Allocation methodology

In this way, unnecessary changes during the lifetime of the metering installation, which are expensive and may cause production deferment, can be minimised.

4. ALLOCATION

4.1 GENERAL

Allocation is the assignment of a quantity measured at a sink to one or more contributing sources. Allocation can be single or multi stage.

A single stage allocation is defined as a reconciliation process with one or more sources and one or more sinks.

Examples of systems with multiple sinks are:

- a. a sales gas system where fuel gas is tapped for own use, which quantity may be deducted from the measured sales gas if the costs are shared by the partners proportionally to the quantity that each of them supplied respectively.
- b. a system with a multiple sales basket.

A multi stage allocation is a cascading single-stage reconciliation process where a sink may serve as a source in the next stage.

Reconciliation is the mathematical process of removing any quantity imbalance between sources and sinks, which typically accounts for the measurement imbalance and various effects such as (1) phase changes between the gas and liquid, (2) temperature and pressure effects on fluids that might result in fluid shrinkage or expansion, (3) system losses and (4) non-measured exits. The latter two could be typically flared gas and sometimes gas for own use.

For optimum results meters should be free of bias, whilst in the same stage of allocation, source meters should yield similar uncertainties if allocation is not uncertainty based (4.3). Sink meters should yield better uncertainty than source meters in the same system. Similarity in performance for the same stage of allocation should be achieved by identical design specification and identical equipment selection for all producers.

The uncertainty performance of the measurement at the sink, i.e., the reconciliation meter, should be a significant factor better than the uncertainty performance at the respective sources, i.e., the sources meters, and shall yield minimal zero-random error.

NOTE: Errors developing during the course of normal operation should either be corrected through scheduled maintenance, i.e., meter validation, or by ad hoc intervention in the event of instant errors. However, not all metering systems are easily accessible for maintenance, which applies in particular to meters far upstream in the production process such as subsea systems. In the latter case, systematic errors developing after deployment should be characterised by analyzing and trending the system balance performance and reconciled afterwards.

Similar accuracy performance is best guaranteed if metering assemblies and their associated equipment are built according to identical base specifications and preferably by one Contractor.

Allocation methodology should comply with ISO/TR 26762. For symbols and nomenclature used in the formulas refer to (Appendix A).

Allocation is normally utilised in complex production and delivery chains, which could typically be a configuration of reconciliation stages. Each reconciliation stage has a defined number of inputs or sources that combine into a single output or sink. Such a system is called a Single Stage Allocation Model.

A node tag can be attached to every input and output whilst each output can be assigned in turn as an input node or to the next reconciliation stage. The system is called a Multi Stage Allocation Model if built up this way; i.e., by a multiple of Single Stage Allocation Models.

If all streams feeding into and leaving a production station or terminal are measured, there will be an imbalance between the (total) outgoing bulk stream(s) or sink(s) and the sum of the incoming streams or sources, which is inevitably due to:

- a. measurement and model inaccuracies;
- b. process variability;
- c. unmeasured streams;
- d. inaccurate (well production) estimates;
- e. other inaccuracies in the system.

Allocation is accomplished either (1) pro-rata of the measured quantities or (2) on basis of the minimum allocation error due to random variability. The following allocation methods could be a subset of any of those 2:

- a. Component based allocation
- b. mass based allocation
- c. Volumetric based allocation
- d. Standard volume-based allocation
- e. Calorific-value or energy-based allocation
- f. Yield base allocation

In addition, the following allocation methods could be used:

- a. Allocation by difference
- b. Allocation by geo-chemical fingerprinting

In some allocation methods each operators share can be adjusted to reflect differences in the value of the contribution. This is also called value adjusted allocation.

The most commonly used allocation methods and their typical domains of application are tabulated below and explained in the following sections.

Method			Unstable crude	Unstable gas / condensate	Stabilised crude	Dew pointed gas
Pro-rata quantity allocation	Uncertainty-based allocation	Component-based allocation	N	Y	N	N
		Quantity mass-based allocation	Y	Y	Y	Y
		Quantity volume-based allocation	N	N	Y	Y
		Quantity volume-based allocation with correction for shrinkage and/or expansion	Y	Y	-	-
		Standard volume-based allocation	N	N	N	Y
		Calorific value-based allocation	N	N	N	Y
		Yield-based allocation	N	Y	N	N
Other methods		Allocation by difference	N	N	N	N
		Allocation by geo-chemical fingerprinting	Y	N	Y	N

N: not recommended

Y: can be used

Allocation by difference is in general not recommended because the total system imbalance is absorbed by the unmeasured stream.

4.2 PRO-RATA QUANTITY ALLOCATION

In systems where inputs and outputs are measured, adjustments and calculations are made to balance the inputs with the outputs and / or to calculate outputs from inputs mainly to satisfy material conservation. Such systems ignore the variability of the imbalance due to measurement uncertainties.

Pro-rata quantity reconciliation is achieved by apportioning outputs between inputs on a pro-rata quantity basis, which assumes:

- a. the output measurement(s) or sink(s) to be more accurate than the inputs;
- b. the measurement uncertainty of all inputs or sources to be of similar nature.

Reconciliation by pro rata balancing is only acceptable if the meters at the same allocation stage have similar measurement uncertainties. This approach shall be modified to accommodate systems where there may be wide variation in measurement uncertainty of individual input meters (4.3).

The method can handle non zero-random errors provided that they are of similar magnitude per source meter.

NOTE: Similar accuracy performance is best guaranteed if metering assemblies and their associated equipment are built according to identical base specifications and preferably by one Contractor.

4.3 UNCERTAINTY-BASED ALLOCATION

In uncertainty-based reconciliation the error in allocation due solely to random variability is optimised by means of least-mean-square minimisation.

In this way any imbalance will be assigned according to the random variability induced by the various meters and therefore imbalance will be progressively assigned to elements with high uncertainty relative to other elements in the system. This allocation requires good knowledge of current meter performance in terms of accuracy and assumes that systematic errors, if any, are effectively eliminated during the course of maintenance, thus yielding only zero-mean random error. The latter, however, might be progressively difficult to achieve in far-upstream locations of the production system; e.g., sub-sea measurements. Hence, uncertainty-based allocation should be applied only to systems that can cope with the following requirements. Of each element contributing to the allocation performance:

- a. bias shall have been removed;
- b. the measurement uncertainty shall be known.

Meter design and maintenance should be compatible with the above.

The method is suitable for gas and condensate systems and for oil systems. The approach should not be used in metering systems that are prone to develop systematic errors; e.g., mass flow metering systems with fixed density input. It should furthermore be based on single fluid measurements and not be applied to a multiphase flow environment unless the phases are separated in order to obtain results that comply with the above-mentioned requirements.

Systems shall be accessible for maintenance. Statistical process control (SPC) facilities should be used in maintenance to control bias and curb undue variability (3.4.2).

The above considerations also apply to inferred measurements, e.g., as derived from simulation like ST-Flash, which at this stage should be checked for variability by applying sensitivity analyses.

The methodology of uncertainty-based allocation should comply with API RP 85. An example of uncertainty-based reconciliation is given in (Appendix D).

4.4 COMPONENT-BASED ALLOCATION

4.4.1 General

In a component-based allocation system, assignment is on the basis of the measured (chemical) components in the fluid, which are expressed either as mole or mass. Hence, component-based allocation requires a material balance that covers all input and output streams. The method ideally suits systems where phase changes take place, also in systems with a multiple sales basket; e.g., gas / condensate systems.

NOTE: Assume the case of a gas / oil system, whereby each of the sources consist of a multiple oil / gas phase. At each entry point, the phases of the sources are separately measured, both in mass and composition. Hence, the molar flow for a defined range of components can be established for each source. At the delivery point, the phases are separated, resulting in unsterilized condensate and rich gas. Both products are treated, resulting in dry sales gas and stabilised sales condensate. Both sales streams are measured, both in mass and composition, thereby resulting in a molar outflow at the sales point for the same defined range of components as the sources.

Component-based allocation is most suitable for gas condensate systems but should not be used for oil systems.

Substance or mass component-based allocation systems require a molar or mass balance per component and therefore a system of quantity flow measurements and flow compositional measurements sources and sink(s). Hence, sampling and analyses in such a

system, whether on-line or off-line, might be difficult to achieve. Substance or mass component-based allocation systems are transparent and readily intelligible systems. Relevant trading units can be conveniently derived from this method; e.g., allocation by mass, calorific value, volume, etc.

Component-based allocation assumes that each source delivers the same proportion of components as is found in each of the bulk phases.

NOTE: A complex system like a liquefied natural gas delivery chain could typically yield the following sales basket:

- Liquefied natural gas (LNG)
- Natural gas liquids (NGL)
- Liquefied petroleum gas (LPG)
- Domestic gas (DOMGAS)

As each of the sales products is distinctively priced, the same amount of gas/liquid in different sales product categories could be sold at various prices. CBA is capable of relating directly the physical properties and, therefore often sales value, to the amount of gas/liquid delivered by each of the sources. The method, however, ignores thermodynamic effects.

NOTE: In a gas / oil system, for example, the production and quality of sales gas and sales condensate might change relatively in the event of shutdown of one of the sources. Even if no other source changes its flow, the income for each might still change due to changing equilibrium under the influence of changing composition, which might result from the one stream being shutdown and thereby giving rise to a changing composition of sales gas and sales condensate, consequently yielding different values as compared to the situation before. The effects, however, are usually considered negligible.

Component cut-off shall be based on a sensitivity study, which shall test performance against a predefined error in allocation.

An example of component based allocation is given in (Appendix C).

4.4.2 Component cut off

Component-based allocation depends a great deal on a reliable system of sampling and analyses, whether on-line or off-line. The correctness of allocation depends not only on the quality of data, but also on the extent of compositional analysis, which is subject to practical limits. It may be sufficient in gas condensate systems to e.g., wrap and sum all the components C5 and heavier, i.e., C5⁺, which might simplify the allocation method as compared to a more detailed analytical essay. It should be investigated during the engineering phase what the effects of such a component cut-off would be.

NOTE: Natural gas is usually analysed to C6⁺ e.g., in accordance with ISO 6974, which can be done either on-line or off-line. Condensate analysis, which can only be carried out off-line in a laboratory, goes far beyond this capability.

4.5 QUANTITY-BASED ALLOCATION

In a quantity-based allocation system, assignment is based on one of the following measured units. After the quantity allocation, a further value adjustment may be included to reflect differences in the value of the contributing oil.

4.5.1 Quantity mass-based allocation

Mass-based allocation employs the principle of conservation of mass. Added uncertainties and bias that might otherwise result from ignoring the impact of pressure and temperature on fluid conditions are avoided, thereby yielding an intrinsically more accurate system than e.g., volumetric-based allocation. This makes it one of the preferred methods.

NOTE: The Coriolis type of mass flow meter offers an attractive alternative to more traditional volumetric flow or flow impulse meters. The latter two categories require density correction for compressible fluids like gas, which complicates measurement. Coriolis meters can also be used in gas applications and have been approved for that purpose by weights and measures authorities; refer also to AGA report no. 11. Quantity mass-based allocation is suitable for single-phase gas and single-phase liquid systems.

4.5.2 Quantity volume-based allocation

In a quantity volume-based allocation system, assignment is on the basis of measured volume.