



# Guideline for Petroleum Measurement and Quantity Determination

GUIDELINE

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## Target group

Industry and Government

## Definitions

- **Accuracy Verification Test (AVT):** also known as a verification test; can be electronic simulations that do not involve actual flow or process comparisons under flowing conditions.
- **Condensate:** liquid formed as a result of condensation caused by reduced pressure and temperature of hydrocarbons in a gaseous state in a natural underground reservoir.
- **Custody Transfer Meter:** a measuring device used in connection with purchase and sale and the calculation of taxes and royalties.
- **Density:** mass of a petroleum fluid sample divided by its volume at specified conditions of pressure and temperature.
- **Higher Heating Value (HHV):** the number of megajoules (MJ) liberated when one cubic metre (m<sup>3</sup>) of gas is completely burnt in air and all the water formed by the combustion reaction is condensed to the liquid state, under the test conditions set down in ISO 6974 – 1984(E) for the analysis of the natural gas, using ISO 6976 – 1995(E) for the calculations from that analysis. HHV for LNG loading uses GPA2261-2013 (via ISO 8943:2007).
- **Measuring device:** is used to work out, by direct measurement, the energy, mass or volume of petroleum transferred from one place to another.
- **Measurement uncertainty:** an expression of the result of an 'as measured' value which characterises the range within which 'true value' is expected to lie.
- **Repeatability:** the closeness of agreement between the results of successive measurements of the same measure and carried out under the same conditions of measurement.
- **Reproducibility:** the closeness of agreement between the results of measurement of the same measure and carried out under changed conditions of measurement.

- **Tank dipping:** also known as tank gauging; a process of measuring height of a liquid in a storage tank usually using a weighted graduated steel tape and bob.
- **Uplift:** loading of petroleum products into a ship's tanks.
- **Vessel Experience Factor:** the historical compilation of shore to vessel or vessel to shore cargo quantity difference and is used as a loss control tool to assess the validity of quantities derived from shore measurements.
- **Wet Gas:** Natural gas that contains less methane (typically less than 85% methane) and more ethane and other more complex hydrocarbons.
- **Wobbe index:** volume-basis calorific value, at specified reference conditions, divided by the square root of the relative density at the same specified metering reference conditions.

## Purpose of this document

The purpose of this guideline is to provide an overview of the measurement of petroleum fluids, quantity determination and accounting methodologies used by the Western Australian Department of Mines, Industry Regulations and Safety (DMIRS) in the determination of royalty payments. This guideline applies to measurement of petroleum production from Western Australia's onshore, State and territorial waters, Barrow Island and North West Shelf Project.

## Legislative context

There is a requirement for a petroleum or geothermal energy measuring device to be approved under the *Petroleum and Geothermal Energy Resources Act 1967* (PGERA67), the *Petroleum (Submerged Lands) Act 1982* (PSLA82), *Barrow Island Royalty Variation Agreement Act 1985* (BIRVAA85) and the *Offshore Petroleum (Royalty) Act 2006* (OPRA06).

Under section 147 of the PGERA67, section 148 of the PSLA82 and section 13 of the OPRA06, the quantity of recovered petroleum or geothermal energy by a permittee, holder of a drilling reservation, lessee or licensee during a period is taken to be the quantity measured by a measuring device approved by the Minister and installed at the wellhead or at such other place as the Minister approves. If there is no such measuring device or the Minister is not satisfied that such a device provides accurate or proper measurements, the quantity recovered is taken to be the quantity determined by the Minister.

## Introduction

Royalty payments are required to be paid to the State and Commonwealth on petroleum products that are recovered. An essential component in determining the royalty payable on a petroleum product is accurate measurement of the petroleum products that are sold. This measurement is conducted at the approved location, often at petroleum custody transfer point where sale takes place. There is an agreed 'royalty schedule' to back calculate the actual production.

Errors in measurements have consequences for royalty revenue, therefore it is important to ensure the accuracy of measuring equipment.

For liquids where tank dipping based measurement is used, every uplift is independently surveyed. Where possible, the government representative will also attend uplifts to audit the taking of measurements, sight and take copies of calibration certificates and use survey data to verify calculations of quantities.

Accuracy verification tests (AVTs) are conducted on nominated transfer flow meters (also known as a royalty meter or custody transfer meter (CTM)) and the government representative witnesses and audits these tests. These tests provide independent verification of the accuracy and reproducibility of measuring devices and of the calculation

methodology applied to the determination of the quantity of petroleum products subject to royalty payment. The AVTs are conducted over a defined extended period of time (e.g. monthly and/or quarterly).

Audits on AVTs are performed on risk basis, or as deemed necessary by DMIRS. Audits are conducted by DMIRS's Petroleum Division, in some cases with the assistance of a consultant, to meet the requirements of the Western Australian Auditor General. This information will contribute to the determination of government revenues.

The audits cover the measurement of:

- liquid hydrocarbons
- gaseous hydrocarbons

Liquid hydrocarbon fluids include crude oil, condensate, liquefied natural gas (LNG) and liquefied petroleum gas (LPG). 'Gaseous hydrocarbons' refers to natural gas, including inert gas components. Measurements are also taken on gas that is flared, used for operational purposes and used for domestic supply.

Measurement of wet gas refers to the measurement of a two phase fluid (gas and liquid) measured simultaneously in a single meter. Gas is the dominant fluid (gas volume fraction greater than 90% of the total fluid volume).

Multiphase hydrocarbon measurement meters or processes cover the measurement of gaseous and liquid hydrocarbons and water and are associated with wellhead production allocation requirements.

Wet gas and multiphase hydrocarbon measurements cannot be used for royalty purposes, as by industry standards they are not considered to be accurate enough. However, such measurements may be used to validate primary royalty metering outcomes.

## Guideline principles

The ascertainment of the quantity of petroleum recovered (under section 147 of the PGERA67, section 148 of the PSLA82, the BIRVAA85 and section 13 of the OPRA2006) is by the use of a measuring device that is approved by the Minister. In order to obtain the Minister's approval of that measuring device, a permittee, holder of a drilling reservation, lessee or licensee, must provide details of the measuring equipment and procedure used to the DMIRS, Petroleum Division. There is not currently an application form for approval. The details should therefore accompany a letter asking for the Minister's approval of the measuring device.

To ensure consistency and a full understanding of the proposed measuring device and petroleum quantity, the details of the measuring equipment and procedure should provide, as a minimum, the following:

For flowmeters:

1. A piping and instrumentation diagram (P&ID) of the metering skid for CTM.
2. Specifications of the CTM and Gas Chromatograph (GC), including accuracy and repeatability/reproducibility information.
3. The procedure for hydrocarbon allocation from multiple wells.
4. The AVT schedule for all CTMs and GCs.
5. Calibration certificates for installed CTMs.
6. A list of applicable standards for the metering equipment and AVT.
7. Procedure for operation, maintenance, calibrations and verifications of the CTM.

For tank strapping based measuring:

1. Details of the tanks including calibration certificate (usually valid for 10 years).
2. Details of the procedure and equipment to be used when measuring uplifts.

The success of a technical metering audit is dependent on a sound understanding of the hydrocarbon fluid measurement process and having clearly defined goals as to what needs to be inspected and verified during the audit.

This guideline only applies to the measurement of hydrocarbon fluids at defined custody transfer points (e.g. at the wellhead or such other place that the Minister approves) where sales take place and for the following petroleum fluids:

- crude oil
- condensate
- LNG (Liquid Natural Gas)
- natural gas
- LPG (Liquid Petroleum gas)

Measurements are also taken on gas used in the operation, for example, as fuel, flared or vented gas. The audit requirements vary in accordance with the petroleum product being measured. Listed below in Table 1 are the parameters that may be measured during an audit.

**Table 1. Typical measurement parameters applied to fluid types**

Fluid type	Volume	Mass	Energy
Crude oil	•	•	
Condensate	•	•	
LNG	•	•	•
LPG	•	•	
Natural Gas	•	•	•

## Measurement parameters and procedures

All measurement parameters and procedures are subject to review.

A revised frequency of testing for royalty measurement systems may apply under start-up or abnormal operating conditions, as notified by the registered title holder.

Calibration equipment is to be certified by an accredited laboratory at defined periods. Royalty meters are to be traceable to National and/or International Standards and certified at a flow calibration facility that can demonstrate laboratory accreditation to the International Laboratory Accreditation Co-operation (ILAC).

## Crude oil and condensate

### Measurement methods

The key measurement parameters are volume, flow rate and fluid density at reference base conditions. Actual measurements are recalculated to apply the reference base conditions.

Volume determination for custody transfer purposes is based on either shore- or ship-based tanks strapping with a comparison made between the two sets of final figures. For tank transfer operations, the following would be audited: product sampling procedures, tank strapping, product density, product quality (e.g. basic sediment and water), receiving ship Vessel Experience Factor (VEF), and application of tables and general calculation/recording processes.

Validation of equipment is carried out in accordance with the National Association of Testing Authorities (NATA) or similar acceptable accredited laboratory/organisation recommendations.

### Measurement uncertainty

The uncertainty requirement is generally contract specific. However, an uncertainty of +/- 0.25% is aimed for.

## LNG

### Measurement methods

The key measurement parameters are volume, density, composition and quality. Volume determination for custody transfer purposes is based on ship tank volumes determined by radar measurements. LNG density is calculated using an agreed formula based on temperature and composition, with quality and composition provided by a shore-based accredited laboratory. The composition is determined by gas chromatographic analysis of vaporised LNG samples. Quality refers to the calculated parameters of higher heating value (HHV), compressibility, density at reference base conditions and molar mass of composition.

Validation of the measurement equipment and the frequency of validation is conducted in accordance with NATA or similar acceptable accredited laboratory/organisation recommendations.

### Measurement uncertainty

The uncertainty requirement is to be (within +/- 0.25%) in accordance with accredited ship tank tables, chemical laboratory procedures and associated tables applied to the LNG measurement process.

## LPG

### Measurement methods

The key measurement parameters are volume, density, composition. Volume determination for custody transfer purposes is based on ship tank volumes determined by radar measurements or float type level gauge. LPG density is calculated using an agreed formula based on temperature and composition provided by a shore-based accredited laboratory. The composition is determined by gas chromatographic analysis of vaporised LPG samples. Quality refers to the calculated parameter of density at reference base conditions and molar mass of composition.

Validation of the measurement equipment and the frequency of validation is conducted in accordance with NATA or similar acceptable accredited laboratory/organisation recommendations.

### Measurement uncertainty

The uncertainty requirement is to be (within +/- 0.25%) in accordance with accredited ship tank tables, chemical laboratory procedures and associated tables applied to the LPG measurement process.

## Natural gas

### Measurement methods

Measurement is obtained from flowmeters and associated gas chromatographs (GC). The key measurement parameters are actual volume or mass flow measurement, flowing pressure and temperature measurement, direct or calculated density measurement, gas composition and quality parameters determination. Quality refers to HHV, compressibility, molar mass and Wobbe Index.

### Measurement uncertainty

1. For metering systems with a design and operating capability of an average daily flow rate of 5 TJ/d or greater, the uncertainty requirement is +/- 1.0% of the actual mass flow rate of the measurement system at a 95% confidence level.
2. For metering systems with design and operating capability of daily average flow rates of less than 5 TJ/d, the uncertainty requirement is +/- 2.0% of actual mass flow rate of the measurement system at a 95% confidence level.

3. For gas chromatograph systems, the uncertainty requirement is +/- 0.25% at a 95% confidence level for higher heating value.

Uncertainty criteria for corrected volume flow rate and energy flow rate are to be appropriately determined.

## Requirements for measurement equipment validation and recertification frequency

1. Full AVTs are to be conducted quarterly for metering systems with a design and operating capability with daily average flow rates of 5 TJ/d or greater –
  - a. Includes verification of the primary meters (by series proving or software diagnostics), secondary transducers, gas chromatograph and loop checks.
  - b. Ancillary instruments such as H<sub>2</sub>O and H<sub>2</sub>S analysers are to be verified quarterly against an appropriate standard.
  - c. In addition, gas chromatograph system operations are to be verified against a representative primary reference gas mixture at least once per month.
2. Full AVTs are to be conducted half yearly for metering systems with a design and operating capability with daily average flow rates of less than 5 TJ/d –
  - a. Includes verification of the primary meters (by series proving or software diagnostics or metrology checks), secondary transducers, gas chromatograph and loop checks.
  - b. In addition, gas chromatograph system operations are to be verified against a representative primary reference gas mixture at least once every two months.
3. The suggested recertification frequency of primary meters could be extended out as per a and b below. The upper limit would be based on the check meter being independent and tested at a greater frequency.
  - a. 7 – 10 years if check meter of lesser accuracy exists
  - b. 10 – 20 years if check meter of equal accuracy exists.

## Supporting information

This guideline has associated supporting information, as shown in the following links:

- North West Shelf Project Royalty Verification Manual – Hydrocarbon Fluid Measurement. Appendix F. Rev. 2 February 2010.

## Reference links

This guideline is aligned with the following legislation, standards, or other reference sources:

- *Petroleum and Geothermal Energy Resources Act 1967* (Section 147)
- *Petroleum (Submerged Lands) Act 1982* (Section 148)
- *Barrow Island Royalty Variation Agreement Act 1985*
- *Offshore Petroleum (Royalty) Act 2006* (Section 13).
- Petroleum and Geothermal Energy Resources (Resource Management and Administration) Regulations 2015 (Schedule 3 – Item 12)
- Petroleum (Submerged Lands) (Resource Management and Administration) Regulations 2015 (Schedule 3 – Item 12)