SOLV® flow measurement

Company Profile 2021

"Thank you for your interest in SOLV®"

SOLV® is an innovative engineering consultancy providing flow measurement services for custody transfer, fiscal, allocation and process metering. Includes technical audits of measurement systems, fluid properties calculation methods, hydrocarbon allocation system design, and uncertainty analysis.

Since formation in 2003 SOLV® has traded successfully with long term contracts in place for the future. Our expertise stems from the UK and Norwegian sectors of the North Sea, now with business in most areas of the world, including Gulf of Mexico, USA, North Africa, Middle East, Canada and SE Asia.

SOLV® pioneered the use of **MCS (Monte Carlo Simulation)** in flow measurement for uncertainty analysis of complex systems such as hydrocarbon allocation, fluid properties and multiphase flow meters. We use conventional **RSS (Root Sum Square)** uncertainty methods with **Partial Differentiation** or **Finite Difference** to find **Sensitivity**, if required.

SOLV® **analyzes uncertainty by RSS**, and **independently verifies results with MCS** for quality control, and to confirm validity of results to the client.

Some major projects are summarized below, with further project experience outlined in **Table 1** on the following pages:

Federal Wellpad Uncertainty, Bakken Basin 2019 allocation uncertainty of 4 to 7 BLM wells on 5 Wellpads to LACT Unit to Federal Regulations 43-CFR-3170 for oil;

North Africa, Production Allocation System 2006 to 2020 ongoing. FEED, detailed design and support for a 160,000 bpd oil plant hydrocarbon allocation system;

Alaska, North Slope, Measurement Technical Review 2014 to 2020 of Oil plant Fiscal, Multiphase and Process meters biennially for compliance with AOGCC;

Oman, Metering Support, Five Metering Systems 2016 to 2019 Audits, calibration witnessing, uncertainty, FAT, design and modifications;

PDO MAF, MOL, Allocation, Oman 2004 to 2006 MAF (Mina Al Falal) Material Balance Uncertainty, MOL (Main Oil Line) pipeline entry health check, and MOL Allocation Uncertainty in partnership with SGS (Shell Global Solutions); and,

SEPCo, Shell Exploration & Production Co., US 2006 to 2007 Audit and uncertainty of Shell's 90 percentile production for Sarbanes-Oxley compliance.

Please contact me at martin.basil@solv.net for more information.

Best regards, Martin Basil, BSc., FInstMC, MIET, MEI, Chartered Engineer, Director & Flow Measurement Consultant

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SOLV Limited - Project Experience 2003 to June 2021

SOLV® hydrocarbon flow measurement and allocation capabilities include:

1. Audits using criteria of Fiscal, Custody Transfer, and Process metering, and Hydrocarbon Allocation Systems;
2. Uncertainty Studies with RSS (Partial Derivative and Finite Difference sensitivity methods), MCS (Monte Carlo Simulation), and Hybrid RSS and MCS methods. SOLV® pioneered the use of MCS in flow measurement and allocation;
3. Specification of fiscal and allocation metering, and hydrocarbon allocation systems;
4. Design of fiscal and allocation metering, and hydrocarbon allocation systems;
5. Witnessing calibration, commissioning, FAT, SAT and related activities;
6. Preparation of documentation, technical manuals, and procedures;
7. Engineering studies;
8. Consultancy;
9. Supervision;
10. FLOWSOLV® PRO oil and gas flow calculation and fluid properties traceable, standards-based software; and,
11. FLOWSOLV® CUSTOM, flow measurement, fluid properties and allocation software development.

Table 1 Examples of SOLV® engineering and software projects

Project	Description
Uncertainty calculations for Refinery Product Custody Transfer Metering Skids (FEED) Abu Dhabi, 2021	Independent uncertainty calculations on two FEED custody transfer metering skids for ethane and heptane refinery products. Heptane liquid metering skid consisted of 2x100% z-configuration (duty/check) Coriolis meters. Ethane metering included 2x100% close-coupled series USMs with continuous check metering. Uncertainty was analyzed across multiple operating cases for each system in accordance with "The GUM" and ISO 5168, and was found to be within limits required by end-user.
Allocation Shrinkage Methodology 3rd Party Review Alaska, 2020	3rd party review of a methodology to calculate oil shrinkage for the purposes of allocation. The methodology was analyzed for evidence of bias and conformity to Energy Institute allocation standards (HM96), BLM (Bureau of Land Management) Oil and Gas regulation, and Code of Federal Regulations, 43-CFR-3170 Onshore Oil and Gas Production.
Allocation and Commingling Uncertainty Sensitivity Client input to BLM 2020	Sensitivity of the allocation uncertainty commingling sensitivity of well oil measurement to a LACT. Reviewed to Code of Federal Regulations; Title 43-CFR: Public Lands: Interior Part 3170-Onshore Oil and Gas production.; Subparts 3170 General, and 3173 Production Handling, 3174 Oil Measurement. Allocation and Commingling was examined for several model cases, to provide insight into the sensitivity of allocation and commingling

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	uncertainty to well meter uncertainty, flow rate, and different commingling interests. Bias due to non-linearity in the allocation equations was investigated with MCS (Monte Carlo Simulation). Bias in all cases was found to be less than ±0.0005% ov which is less than the flow computer calculation acceptance tolerance of ±0.001%; therefore is, **"...without statistically significant bias"** in accordance with 43-CFR-3174.4.
Federal Wellpad Uncertainty Study, Bakken Basin North Dakota, 2019	Uncertainty was estimated for 4 Wellpads comprising of 4 to 7 wells each with a dedicated 3-phase separator with Coriolis measurement on the oil leg and Senior orifice meter on the gas. Well oil meters are calibrated annually with a Coriolis Master Meter. Gas instrumentation and geometry of the flow element and line are calibrated and verified periodically. Wellpad processed oil is measured with high specification Coriolis LACT Unit for export and is calibrated monthly with SVP (Small Volume Prover for conformity to 43-CFR-3174.4 uncertainty standards. Wellpad processed gas is measured with a Junior Orifice Sales gas export and instrumentation and line geometry are calibrated and verified periodically for conformity to 43-CFR-3175 standards. Uncertainty was also estimated for a 5th Wellpad with 6 wells with dedicated 3 phase test separators, Buyback gas, Gas Lift, Sales gas, LACT for oil, and Road Tanker oil export. Root Sum Square (RSS) uncertainties were independently verified with Monte-Carlo Simulation (MCS).
Oil Plant (160,000 stbpd) Allocation System North Africa, 2006 to 2020	Multi-stage project with SOLV® involved from FEED stage, requirements, EPC, and support. Plant material balance of less than ±0.5% of throughput has been consistently achieved since start-up. **<u>1 - Allocation Uncertainty Study</u>** Estimate the allocation uncertainty for 5 developments, comprising 2 x Crude Oil, 2 x Gas Condensate, and a Rich Gas feed from an existing development. Allocation required for Crude Oil, Condensate, LPG, Flare, Gas Injection, and Gas Lift. Allocation by PSM (Process Simulation Model), MCA (Mass Component Allocation), and MSFS (Multi-stage Flash and Shrink) were considered. MCA was chosen as there was no recycle to the Reception Facilities separation and it required the same measurements as PSM. MSFS required less measurement however the sensitivity to Flash and Shrink constants between Crude and Gas Condensate meant that small errors could have a large impact on the allocation. MCA was considered simpler than PSM and does not require regular simulation runs. Measurement points were specified for 70 locations to account for all fluid movements and stock. Assigned a required measurement uncertainty according to type of measurement for input to MCA uncertainty model. MCS (Monte Carlo Simulation) MCA uncertainty model was built for a number of HMB (Heat & Mass Balance) scenarios to determine allocation uncertainty for each development, each owner and the

Project	Description
	owner's overall uncertainty exposure. Sensitivity of the allocation due to erroneous measurement and hydrocarbon composition was examined. **2 - Allocation Measurement Specification** A requirements specification was prepared for detailed design of the instrumentation and software for Production Allocation System for detailed design and implementation by the EPC (Engineering, Procurement, and Construction) contractor. **3 - Production Allocation System EPC** EPC contract was awarded for construction of the Oil Plant. SOLV® was contracted by the EPC contractor to perform detailed design of the hydrocarbon allocation system. Allocation equations were defined and implemented in a 3-day test model for use in testing, commissioning, and acceptance. The work was divided into two stages for the Oil Train start up and the NGL Train completion. Using the test model, a Factory Acceptance Test (FAT) with the software developer was successfully completed for each stage. Oil Plant and NGL Plant allocation Site Acceptance Tests (SATs) respectively were successfully completed. The SAT included commissioning of the allocation measurement instrumentation, and laboratory facilities. **4 - Production Allocation Support 2014 to 2021** Ongoing support and troubleshooting of instrumentation and software. Regular Technical Audits of instrumentation, software, laboratory, maintenance and reporting.
Routine Measurement Technical Review North Slope, Alaska, 2014 to 2020	Periodic performance review of all fiscal and allocation measurement for oil plant export to nearby facility for processing and commingling with other fields prior to pipeline export. Original development set a precedent in the region for the implementation of MPFM (Multi-Phase Flow Meter) in Fiscal measurement. In addition to the Fiscal 3-phase MPFM measurement of oil, gas and water, the review includes imports for gas lift, gas injection, fuel gas, and water injection. Well Test MPFM's are also reviewed. Several recommendations have been made to improve aspects of the measurement including utilization of a DWT (Dead Weight Tester) which has eliminated unnecessary replacement of the MPFM DP transmitters. Specified, implemented and support with MCS (Monte Carlo Simulation) to find Fiscal Measurement Uncertainty to determine pipeline tariff with a functional mathematical model of the MPFM.
Support for six Metering Systems Oman, 2016 to 2019	Measurement validation for Duty/Standby (2) High GVF Wet Gas MPFM, inspection, calibration checks and validation procedure. Review of Well Test High GVF Wet Gas MPFM. Audit of Gas Export 2 stream USM and Uncertainty, including calibration on gas at high RN (Reynolds Number), as original calibration on Air at low RN, to correct MF.

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	Witness calibration of 2 ultrasonic meters at typical line conditions to flow rate and Reynolds Number. Condensate LACT Unit Duty/Standby SVP and sample skid FAT witness. Preparation of Stream, SVP and Sample equations. Preparation of Gravimetric Coriolis SVP mass calibration to API MPMS standards 4.9.4. Design of Wet Gas Venturi metering system and flow computer configuration, including calibration of Venturi on water.
Independent Witness of Pipeline Metering Prover Waterdraw Calibration Wyoming, Colorado, Oklahoma 2018	Volumetric Waterdraw of five Coriolis LACT Unit Bidirectional Prover volume recertification on a Pipeline from Wyoming, to Oklahoma Witnessed preparation and calibration of volume in accordance with API MPMS Chpt. 4, 11, and 12. Calibration vendors were validated with SOLV® developed Volumetric Waterdraw calculation method with digit agreement in all cases confirming the validity of the calibration
FLOWSOLV® V5.3 PRO Software oil and gas flow measurement and fluid properties software **FLOWSOLV® UNITS™** **FLOWSOLV® CUSTOM™** SOLV Limited, Scotland, 2011 to 2020	Upgrade of FLOWSOLV® V4 to V5.0 to enhance and expand to 50 hydrocarbon calculation methods, with modularization for use in custom software applications. V5.1 addition of API MPMS Chpt. 11.1:2004 Amd. 2007/08 Oil thermal and compressibility correction to standard conditions with Imperial tables 5/6, 23/24, metric 15°C tables 53/54 and 20°C Tables 59/60 with Alternate Observed or User Defined Standard conditions. V5.2 addition of light hydrocarbon methods, API MPMS Chpt. 11.2.2/2M Compressibility, 11.2.4 Thermal Expansion, and 11.2.5 Equilibrium Pressure. V5.3 and V5.3 PRO update to basic version with 17 calculations for process plant, and PRO version with 50 hydrocarbon flow measurement and fluid property calculation methods for Fiscal, Custody Transfer, and Allocation applications. FLOWSOLV® is a flexible standard's-based flow computation software product with rigorous traceability to standards, and compliance checks. FLOWSOLV® UNITS™ is a free unit conversion application, included with FLOWSOLV®. FLOWSOLV® CUSTOM™ software development service is offered using existing modules from FLOWSOLV® and other software for specialized applications. To find out more visit www.flowsolv.com
AGA8:2017 Part 1 and Part 2 SOLV Limited, Scotland, 2018	Detail and Gross gas compressibility and density complying to Part 1 replacing existing AGA8:1994 and AGA10 2004 standards. Gas compressibility and density complying to Part 2, GERG2008. Both developed independently and verified with NIST REFPROP V10.
AGA10 DLL USA, 2016	Supply of AGA10 DLL for integration with an existing software package for use with Ultrasonic flow meters. Developed using the FLOWSOLV® AGA10 module.

Project	Description
AGA10 MatLab Addin Norway, 2011	MatLab Addin for DNV research project developed using the FLOWSOLV® AGA10 module.
MPFM Allocation Uncertainty North Slope, Alaska, 2012	Defined uncertainty matrix for allocation tariff adjustment for field life for a heavy oil multiphase measurement. A 4-dimensional table for oil flow rate, viscosity, GVF, and WLR was populated for use with 4-way linear interpolation to find a daily FWA (Flow Weighted Average) flow rate. Tables were generated for the Schlumberger Vx29 and Vx52 MPFM (Multi-Phase Flow-Meter). Multi-Phase flow rate, DP etc. was found with a functional mathematical model of the Schlumberger Vx meter. A hybrid RSS (Root Sum Square) and MCS (Monte Carlo Simulation) was used with the Vx model to find each uncertainty data point for population of the 4-mensional matrix.
Pipeline Meter Uncertainty Canada/USA, 2013	Uncertainty Model of Storage facilities and a 2,500-mile pipeline with 6 LACT Units. Models are run regularly to obtain the uncertainty at actual operating conditions and product for pipeline operations. Developed as RSS (Root Sum Square) conforming to the GUM (Guide to the Expression of Uncertainty in Measurement) method.
Condensate Gathering System Uncertainty Wyoming, 2007, 2008, 2012	Assess the uncertainty of a Coriolis measurement for allocation of gas condensate to lease holders and the BLM for a gas gathering system.
Condensate, Custody Transfer Metering Requirements and Uncertainty Muscat, Oman, 2009	Statement of Requirements for a Crude Oil Coriolis Metering System with BS&W and Master Meter for RFQ. Uncertainty Analysis for typical system using modified ISO/IEEE/OIML/BSI GUM (International Guide the Uncertainty of Measurement) RSS (Root Sum Square) method, verified by MCS (Monte Carlo Simulation)
MFPM FAT Norway, 2009	FAT (Factory Acceptance Test) of four of MPFM (Multi-Phase Flow Meters) at the MPM, Norway.
Platform Hub MPFM Specification and Allocation Uncertainty Gulf of Mexico, USA, 2005 to 2008	Specification and uncertainty for MPM multi-phase flowmeters for allocation of oil and gas production of the 3rd party field and platform hub production. Analysis with Monte Carlo Simulation of the MPM.
Crude Oil Tanker Loading Brunei, 2007	Investigation of discrepancy between export loading tanks and liquid ultrasonic Custody Transfer meter to identify the cause
MPFM Heavy Oil Uncertainty North Slope, Alaska 2007	Uncertainty analysis of a Dual Gamma Venturi MPFM (Multi Phase Flow Meter) for a heavy oil application with very low Reynolds Number which required a correction to the Venturi Cd (Coefficient of Discharge). Monte Carlo was used to simulate the Dual Gamma phase detector measurement on a physical model from first principles.
Sarbanes-Oxley Compliance SEPCo, USA, 2006 to 2007	Custody Transfer uncertainty analysis and validation of measurement for SEPCo (Shell Exploration and Production Company) 90 percentile

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	production for Sarbanes-Oxley compliance in the USA. Included offshore and onshore oil and gas production at five facilities.
Indonesia, Audit and Uncertainty Indonesia, 2006	Audit and uncertainty analysis of fiscal ultrasonic gas custody transfer meters at three onshore facilities in Sumatra and two offshore facilities in the South China sea.
COSTALD Flow Computer Constants Alderley, 2004, to 2005	Thermal Compressibility correction constants found using COSTALD (Corresponding States Liquid Density) for 17 refinery products to correct volumes to standard conditions.
Well Test Allocation Uncertainty North Slope, Alaska, USA, 2005	Well test allocation uncertainty at two drill sites using Monte Carlo Simulation.
LNG Meter Type Approval Trials Kenai, Alaska, USA, 2005	Trials of Coriolis and multipath Ultrasonic Meters at an LNG plant in Alaska to assess suitability for flow measurement of LNG in Qatar. Meters were compared to storage tanks calibrated by ship loading. Developed data acquisition spreadsheets with AGA8 gas density and COSTALD LNG liquid density and statistical analysis of result. Ultrasonic meter selected for client type approval for measurement.
PDO Oman, MOL Allocation SGS (Shell Global Solutions), Hague, Netherlands, 2006	Investigation of Crude Oil allocation uncertainty using data from an earlier site inspection of 48 measurement entry points to PDO MOL in Oman in partnership with SGS. Allocation methods were examined to determine the most equitable method.
PDO MOL Entry Health Check PDO, Oman, 2005	Site inspection to document each of 48 measurement nodes entering the MOL. Estimate uncertainty, bias, and asses meter condition. Meters comprised full Custody Transfer meters with prover's, PD, Coriolis, Ultrasonic, Orifice and V cone meters.
PDO Course and MOL Meter Calibration PDO, Oman, 2005	Delivery of storage tank electronic tape dip measurement and tank calibration course. Calibration of the MAF (Mina Al Falal) terminal MOL reception meter with storage tank measurement.
PDO MAF Oil Export Terminal Uncertainty PDO, Oman 2004	Uncertainty study and model of the PDO (Petroleum Directorate Oman) MAF (Mina Al Falal) oil export terminal measurement and material balance uncertainty. Included export ship loading meters, refinery feed and returns, export to Shell marketing, tank farm, and MOL (Main Oil Line) import.
Gas Platform Audit Gulf of Mexico, USA 2004	High level audit of all flow measurements, including subsea Venturi meters.
Platform MPFM Uncertainty, Gulf of Mexico Gulf of Mexico, USA, 2004	Study to determine the uncertainty of allocation of oil and gas exports to fields, and wells including material balance where well production is found by monthly well testing with Schlumberger Vx MPFM.
Condensate Master Meter Replacement North Sea, 2004	Replacement of Crude Oil Export metering system prover loop due to lining failure. Replaced by Krohne Altosonic V Ultrasonic Master Meter. Development of flow computer equations with Reynolds Number correction, flow computer configuration and uncertainty analysis.

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Power Station Teesside, UK, 2004	Review of gas turbine cooling air, fuel gas, steam and water flow measurement.
API UATG RP85 API, 2003	Uncertainty input to API (American Petroleum Institute) RP85 (Recommended Practice) UBA (Uncertainty Based Allocation) for well-rate determination and uncertainty for multiphase flow meters.

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