 PETROBRAS	TECHNICAL SPECIFICATION		Nº: I-ET-3010.2Q-1200-800-P4X-004
	CLIENT:	MARLIM LESTE E SUL	SHEET: 1 of 28
	JOB:	BASIC DESIGN – REVIT I	
	AREA:	MARLIM LESTE E SUL	
	TITLE:	MULTIPHASE FLOW METERING SYSTEM (MFMS)	ESUP
			INTERNAL
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INDEX OF REVISION

REV.	DESCRIPTION AND/OR REVISED SHEETS
0	ORIGINAL
A	REVISED WHERE INDICATED
B	REVISED WHERE INDICATED DUE TO CONSISTENCY ANALYSIS

	REV. 0	REV. A	REV. B	REV. C	REV. D	REV. E
DATE	APR/12/2024	JUN/14/2024	JUL/15/24			
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TITLE:

MULTIPHASE FLOW METERING SYSTEM (MFMS)

ESUP

INTERNAL

SUMMARY

1	INTRODUCTION.....	3
2	REFERENCE DOCUMENTS, CODES AND STANDARDS	5
3	ENVIRONMENTAL AND OPERATION CONDITIONS.....	10
4	MFMS SCOPE	11
5	SYSTEM DESCRIPTION	11
6	TOPSIDES MULTIPHASE FLOW METERS	16
7	MFMS PANEL	18
8	INTEGRATION SERVICES	22
9	ACCEPTANCE TESTS.....	23
10	DOCUMENTATION	25
11	TRAINING.....	27

1 INTRODUCTION

1.1 Objective

1.1.1 The Multiphase Flow Metering System (MFMS) is responsible for allocation of individual well production, as well as continuous monitoring of each well.

1.1.2 This Technical Specification describes the minimum requirements for supplying the UNIT's MFMS.

1.2 Definitions

1.2.1 Refer to I-ET-3010.00-1200-940-P4X-002 – GENERAL TECHNICAL TERMS for the definitions of general technical terms and find below the terms used in current specification that are not defined in aforementioned technical specification.

ALLOCATION METERING	Measurement to determine the volume of production to be allocated at each well.
BLACK OIL	Fluid properties model, based on empirical correlations, used to correct volumetric flow to reference conditions. This is a simplified model, based on the behavior of a standard non-volatile oil.
LOOKUP TABLE	Configuration mode in which external PVT software is used to create tables with fluid properties to be configured in the multiphase flow meter.
PVT	Data that describe the fluid and the behavior of its respective phases in relation to the variables pressure, volume and temperature, to correct the volumetric flow for the reference conditions.

1.3 Abbreviations, acronyms, and initialisms

1.3.1 The following abbreviations are used in this document:

BCSS	Subsea Electrical Submersible Pumping
CNEN	Comissão Nacional de Energia Nuclear (National Nuclear Energy Commission)
CSS	Control and Safety System
EoS	Equation of State
FAT	Factory Acceptance Test
FMS	Flow Metering System
GLR	Gas-Liquid Ratio
GOR	Gas-Oil Ratio
GVF	Gas Volume Fraction
HMI	Human-Machine Interface
MFMS	Multiphase Flow Metering System



PETROBRAS

TECHNICAL SPECIFICATION

I-ET-3010.2Q-1200-800-P4X-004

REV.: **B**

MARLIM LESTE E SUL

SHEET: 4 of 28

TITLE:

MULTIPHASE FLOW METERING SYSTEM (MFMS)

ESUP

INTERNAL

MSP	Subsea Production Manifold
P&ID	Piping and Instrumentation Diagram
PI	Plant Information (software)
RTM	ANP/Inmetro Technical Regulation of Measurement of Oil and Gas
SAT	Site Acceptance Test
SOS	Supervision and Operation System
SPCS	Subsea Production Control Systems
TMPFM	Topsides Multiphase Flow Meter
SMPFM	Subsea Multiphase Flow Meter
WLR	Water-Liquid Ratio

2 REFERENCE DOCUMENTS, CODES AND STANDARDS

2.1 External references

2.1.1 International codes, recommended practices, and standards

AGA – AMERICAN GAS ASSOCIATION

AGA REPORT Nº 8 THERMODYNAMIC PROPERTIES OF NATURAL GAS AND RELATED GASES - ALL PARTS

API – AMERICAN PETROLEUM INSTITUTE

API MPMS MEASUREMENT MULTIPHASE FLOW
Chapter 20.3

API MPMS MANUAL OF PETROLEUM MEASUREMENT STANDARDS – ALL PARTS

IEC – INTERNATIONAL ELECTROTECHNICAL COMMISSION

IEC 60079 EXPLOSIVE ATMOSPHERES – ALL PARTS

IEC 60529 DEGREES OF PROTECTION PROVIDED BY ENCLOSURES (IP CODE) – EDITION 2.2

IEC 61000 ELECTROMAGNETIC COMPATIBILITY (EMC) – ALL PARTS

IEC 61892 MOBILE AND FIXED OFFSHORE UNITS – ELECTRICAL INSTALLATIONS - ALL PARTS

IEC 62381 AUTOMATION SYSTEMS IN THE PROCESS INDUSTRY – FACTORY ACCEPTANCE TEST (FAT), SITE ACCEPTANCE TEST (SAT) AND SITE INTEGRATION TEST (SIT)

ISO – INTERNATIONAL ORGANIZATION FOR STANDARDIZATION

ISO/TS 21354 MEASUREMENT OF MULTIPHASE FLUID FLOW

ISO/TR 26762 NATURAL GAS — UPSTREAM AREA — ALLOCATION OF GAS AND CONDENSATE

ISO 5167 MEASUREMENT OF FLUID FLOW BY MEANS OF PRESSURE DIFFERENTIAL DEVICES INSERTED IN CIRCULAR-CROSS SECTION CONDUITS RUNNING FULL – ALL PARTS

ISO 5168 MEASUREMENT OF FLUID FLOW – PROCEDURES

FOR THE EVALUATION OF UNCERTAINTIES

ISO	6974	NATURAL GAS – DETERMINATION OF COMPOSITION AND ASSOCIATED UNCERTAINTY BY GAS CHROMATOGRAPHY – ALL PARTS
ISO	10012	MEASUREMENT MANAGEMENT SYSTEMS – REQUIREMENTS FOR MEASUREMENT PROCESSES AND MEASURING EQUIPMENT
ISO	GUM	GUIDE TO THE EXPRESSION OF UNCERTAINTY IN MEASUREMENTS


OIML – ORGANISATION INTERNATIONALE DE METROLOGIE LEGALE

OIML	R137	GAS METERS – ALL PARTS
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2.1.1 Brazilian Codes and Standards

ANP – AGÊNCIA NACIONAL DO PETRÓLEO, GÁS NATURAL E BIOCOMBUSTÍVEIS

RESOLUÇÃO ANP Nº 44 (15/OUTUBRO/2015)	REGULAMENTO TÉCNICO DE MEDIÇÃO DE FLUIDO MULTIFÁSICO PARA APROPRIAÇÃO DE PETRÓLEO, GÁS NATURAL E ÁGUA, DE 15 DE OUTUBRO DE 2015
RESOLUÇÃO CONJUNTA ANP/INMETRO Nº 1 (10/JUNHO/2013)	REGULAMENTO TÉCNICO DE MEDIÇÃO DE PETRÓLEO E GÁS NATURAL, A QUE SE REFERE À RESOLUÇÃO CONJUNTA ANP/INMETRO Nº 1, DE 10 DE JUNHO DE 2013
OFÍCIO-CIRCULAR Nº1/2020/NFP/ANP (26/MAIO/2020)	ESCLARECIMENTOS DO REGULAMENTO TÉCNICO DE MEDIÇÃO (RTM)
RESOLUÇÃO ANP Nº 52 (26/DEZEMBRO/2013)	REGULAMENTO TÉCNICO DE IMPLEMENTAÇÃO DOS RESULTADOS DE ANÁLISES FÍSICO-QUÍMICAS NAS MEDIÇÕES SUBSEQUENTES DE PETRÓLEO E GÁS NATURAL, A QUE SE REFERE À RESOLUÇÃO ANP Nº 52, DE 26 DE DEZEMBRO DE 2013
RESOLUÇÃO ANP Nº 18 (27/MARÇO/2014)	REGULAMENTO TÉCNICO DE NOTIFICAÇÃO DE FALHAS DE SISTEMAS DE MEDIÇÃO DE PETRÓLEO E GÁS NATURAL E FALHAS DE ENQUADRAMENTO DO PETRÓLEO, A QUE SE REFERE À RESOLUÇÃO ANP Nº 18, DE 27 DE MARÇO DE 2014
RESOLUÇÃO ANP Nº 65 (10/ DEZEMBRO /2014)	REGULAMENTO TÉCNICO DE ENVIO DE DADOS DE PRODUÇÃO E MOVIMENTAÇÃO DE PETRÓLEO, GÁS

	TECHNICAL SPECIFICATION	I-ET-3010.2Q-1200-800-P4X-004	REV.: B
	MARLIM LESTE E SUL		SHEET: 7 of 28
	TITLE: MULTIPHASE FLOW METERING SYSTEM (MFMS)		ESUP
			INTERNAL

NATURAL E ÁGUA A QUE SE REFERE À RESOLUÇÃO ANP Nº 65, DE 10 DE DEZEMBRO DE 2014

RESOLUÇÃO Nº 737
(27/ JULHO /2018)

ALTERAÇÃO DA RESOLUÇÃO ANP Nº 65 DE 10 DE DEZEMBRO DE 2014

INMETRO – INSTITUTO NACIONAL DE METROLOGIA, NORMALIZAÇÃO E QUALIDADE INDUSTRIAL

PORTARIA Nº 291
(07/JULHO/2021)

REGULAMENTO TÉCNICO METROLÓGICO DOS SISTEMAS DE MEDIÇÃO DINÂMICA EQUIPADOS COM MEDIDORES PARA QUANTIDADE DE LÍQUIDOS

PORTARIA Nº 298
(08/JULHO/2021)

REGULAMENTO TÉCNICO METROLÓGICO CONSOLIDADO PARA OS COMPUTADORES DE VAZÃO E CONVERSORES DE VOLUME

PORTARIA Nº 115
(21/MARÇO/2022)

REGULAMENTO CONSOLIDADO PARA EQUIPAMENTOS ELÉTRICOS PARA ATMOSFERAS EXPLOSIVAS

OFÍCIO CIRCULAR Nº 032/DIMEL
(12/SETEMBRO/2017)

VERIFICAÇÕES METROLÓGICAS DE MEDIDORES, SISTEMAS DE MEDIÇÃO E COMPUTADORES DE VAZÃO

2.1.2 All MTE – Ministério do Trabalho regulations (NRs) shall be followed.

2.1.3 All applicable CNEN Regulatory Standards (Normas Regulatórias) in force, published in the Official Gazette of the Federal Government (Diário Oficial da União-DOU), shall be followed.

2.1.4 Classification Society

2.1.4.1 The detailed design shall be submitted to Classification Society for approval.

2.1.4.2 The Unified Requirements (URs) and Unified Interpretations (UIs) of IACS, applicable and in force in the detailing design, shall be observed and their requirements implemented.

2.1.4.3 The design and installation shall be updated following requirements, comments of Classification Society as well as URs and UIs mentioned in item 2.1.4.2.

2.2 Internal references

2.2.1 Typical Documents

I-ET-3010.00-1200-800-P4X-002

AUTOMATION, CONTROL AND INSTRUMENTATION ON PACKAGE UNITS



TITLE:

MULTIPHASE FLOW METERING SYSTEM (MFMS)

ESUP

INTERNAL

I-ET-3010.00-1200-800-P4X-013 GENERAL CRITERIA FOR INSTRUMENTATION PROJECTS

I-ET-3010.00-1200-813-P4X-001 GENERAL CRITERIA FOR FLOW METERING SYSTEMS

I-ET-3000.00-1400-196-P4X-001 ERGONOMICS REQUIREMENTS FOR TOPSIDES

2.2.1 Project Document List

I-DE-3010.2Q-5520-800-P4X-002 AUTOMATION AND CONTROL ARCHITECTURE

I-DE-3010.2Q-1200-813-P4X-001 FLOW METERING LOCATIONS (FMS)

I-DE-3010.2Q-1200-813-P4X-002 FLOW METERING SYSTEM (FMS) ARCHITECTURE

I-DE-3010.2Q-1210-944-P4X-001 SATELLITE PRODUCTION WELL A

I-DE-3010.2Q-1210-944-P4X-002 SATELLITE PRODUCTION WELL B

I-DE-3010.2Q-1210-944-P4X-003 SATELLITE PRODUCTION WELL C

I-DE-3010.2Q-1210-944-P4X-004 SATELLITE PRODUCTION WELL D

I-DE-3010.2Q-1210-944-P4X-005 SATELLITE PRODUCTION WELL E (WITH BCSS)

I-DE-3010.2Q-1210-944-P4X-006 SATELLITE PRODUCTION WELL F (SPARE)

I-DE-3010.2Q-1210-944-P4X-007 SATELLITE PRODUCTION WELL G (SPARE WITH BCSS)

I-DE-3010.2Q-1210-944-P4X-008 SUBSEA MANIFOLD PRODUCTION MSP-1

I-DE-3010.2Q-1210-944-P4X-009 SUBSEA MANIFOLD PRODUCTION MSP-2

I-DE-3010.2Q-1210-944-P4X-010 SUBSEA MANIFOLD PRODUCTION MSP-3

I-DE-3010.2Q-1210-944-P4X-011 SUBSEA MANIFOLD PRODUCTION MSP-4

I-DE-3010.2Q-1210-944-P4X-012 SUBSEA MANIFOLD PRODUCTION MSP-5

I-DE-3010.2Q-1210-944-P4X-013 SUBSEA MANIFOLD PRODUCTION MSP-6

I-DE-3010.2Q-1210-944-P4X-014 SUBSEA MANIFOLD PRODUCTION MSP-7

I-DE-3010.2Q-1210-944-P4X-015 SUBSEA MANIFOLD PRODUCTION MSP-8 (SPARE)



TITLE:

MULTIPHASE FLOW METERING SYSTEM (MFMS)

ESUP

INTERNAL

I-DE-3010.2Q-1210-944-P4X-016	SUBSEA MANIFOLD PRODUCTION MSP-9 (SPARE)
I-DE-3010.2Q-1244-944-P4X-001	WELL PIG LAUNCHERS (LP-1244001A/B)
I-DE-3010.2Q-1244-944-P4X-002	WELL PIG LAUNCHERS (LP-1244001C/D)
I-DE-3010.2Q-1244-944-P4X-003	WELL PIG LAUNCHERS (LP-1244001E/F)
I-DE-3010.2Q-1244-944-P4X-004	WELL PIG LAUNCHERS (LP-1244001G/H)
I-DE-3010.2Q-1244-944-P4X-005	WELL PIG LAUNCHERS (LP-1244001J/K)
I-DE-3010.2Q-1244-944-P4X-006	WELL PIG LAUNCHERS (LP-1244001L/M)
I-DE-3010.2Q-1244-944-P4X-007	WELL PIG LAUNCHERS (LP-1244001N/P)
I-DE-3010.2Q-1244-944-P4X-008	WELL PIG LAUNCHERS (LP-1244001Q/R)
I-DE-3010.2Q-1244-944-P4X-009	WELL PIG LAUNCHERS (LP-1244001S/T)
I-DE-3010.2Q-1244-944-P4X-010	WELL PIG LAUNCHERS (LP-1244001U/V)
I-DE-3010.2Q-1244-944-P4X-011	WELL PIG LAUNCHERS (LP-1244001W/X)
I-DE-3010.2Q-1244-944-P4X-012	WELL PIG LAUNCHERS (LP-1244001Y)
I-ET-3010.2Q-1200-800-P4X-003	FLOW METERING SYSTEM (FMS)
I-ET-3010.2Q-1200-800-P4X-001	INSTRUMENTATION ADDITIONAL TECHNICAL REQUIREMENTS
I-ET-3010.2Q-1200-800-P4X-003	FLOW METERING SYSTEM (FMS)
I-ET-3010.2Q-1200-800-P4X-005	FIELD INSTRUMENTATION
I-ET-3010.2Q-1200-800-P4X-014	AUTOMATION INTERFACE OF PACKAGED UNITS
I-ET-3010.2Q-1200-850-P4X-001	SPECIAL MONITORING SYSTEMS
I-ET-3010.2Q-1350-196-P4X-001	ERGONOMICS REQUIREMENTS FOR TOPSIDES
I-MD-3010.2Q-5520-800-P4X-003	AUTOMATION NETWORK DESCRIPTION



TITLE:

MULTIPHASE FLOW METERING SYSTEM (MFMS)

ESUP

INTERNAL

3 ENVIRONMENTAL AND OPERATION CONDITIONS


3.1 The equipment shall be suitable for offshore saliferous installation. For operating and environmental conditions, refer to I-ET-3010.2Q-1200-800-P4X-001 – INSTRUMENTATION ADDITIONAL TECHNICAL REQUIREMENTS.

3.2 The MFMS shall be fed according to I-ET-3010.00-1200-813-P4X-001 – GENERAL CRITERIA FOR FLOW METERING SYSTEMS.

3.3 The MFMS Panel shall convert, condition, and distribute the power supplies inside the panel, including voltage regulators where needed.

3.4 Data process to meter sizing will be provided during Detail Design. Each multiphase meter shall be designed and tested on the full range of pressure, temperature and flow rate.

3.5 All equipment proper to be used in hazardous areas shall have conformity certificates complying with “Portaria Inmetro N° 115” and its annexes.

 PETROBRAS	TECHNICAL SPECIFICATION	I-ET-3010.2Q-1200-800-P4X-004	REV.: B
	MARLIM LESTE E SUL		SHEET: 11 of 28
	TITLE:	MULTIPHASE FLOW METERING SYSTEM (MFMS)	ESUP
			INTERNAL

4 MFMS SCOPE

4.1 MFMS shall be comprised by:

4.1.1 Topsides Multiphase Flowmeter skids (Z-1210001A/V), to be provided by SELLER;

4.1.2 Subsea Multiphase Flow Meters (SMPFMs), to be provided by BUYER;

4.1.3 Topsides gas lift flow meters, to be provided by FMS VENDOR;

4.1.4 Subsea gas lift flow meters, to be provided by BUYER;

4.1.5 Flow meters from Test Separator, to be provided by FMS VENDOR;

4.1.6 MFMS Panel (PN-1223005), to be provided by SELLER;

4.1.7 Integration of MFMS with Subsea Master Control Stations (from PN-1210001A/B to PN-121009A/B) through Subsea Interface Panels (PN-5524001A/B), by SELLER;

4.1.8 Integration of MFMS with FMS Panel (PN-1223001), by SELLER;

4.1.9 Integration of MFMS with CSS through Topsides SOS Clusters Panel (PN-5523011), by SELLER;

4.1.10 Documentation, by SELLER;

4.1.11 FAT, calibrations (flow testing), SAT, SIT, training, and start-up services, by SELLER;

4.1.12 Metering system approval by national regulation Agencies, by SELLER.

4.1.13 Licensing related to radioactive materials and equipment in Brazil or in other countries, by SELLER.

4.2 Multiphase flow meters shall be field proven for offshore floating production units. Unproven devices or prototype equipment will not be accepted. Track record, including test and field data, shall be available for BUYER.

4.3 All TMPFM shall be supplied by the same MANUFACTURER.

4.4 TMPFM's MANUFACTURER shall offer technical support in Brazil.

4.5 Measurement units shall follow I-ET-3010.00-1200-813-P4X-001 - GENERAL CRITERIA FOR FLOW METERING SYSTEMS.

5 SYSTEM DESCRIPTION

5.1 The MFMS continuously allocates individual well production using multiphase flow meters. For production wells in subsea manifolds, production allocation is measured by Subsea Multiphase Flow Meters (SMFMs), subtracting the injected gas lift flow measured



by subsea single-phase gas lift flow meters. Satellite wells use Topsides Multiphase Flow Meters (TMPFMs) for allocation, subtracting the injected gas lift flow measured by topsides single-phase gas lift flow meters. The system also includes TMPFMs on production risers connected to subsea manifolds to verify SMPFM's performance. Additionally, single-phase water, oil, and gas flow meters installed at the Test Separator outlets are responsible to verify TMPFMs.

5.2 Every well connected to a Subsea Production Manifold (MSP) has a dedicated Subsea Multiphase Flow Meter (SMPFM) and subsea gas lift flow meters mounted on the manifold. These meters are connected to the Subsea Production Control System (SPCS) Panels and shall be linked to the MFMS Panel. These meters are BUYER's scope of supply and integration to MFMS is SELLER's scope of service.

5.3 Every satellite well connected to the UNIT has a dedicated Topsides Multiphase Flow Meter (TMPFM) installed at the topsides. These meters are connected to the MFMS Panel. Both MFMS Panel and TMPFMs are SELLER's scope of supply.

5.4 Every service/gas lift riser, including gas lift test, have a gas lift flow meter installed on topsides, including spare risers. These meters are FMS VENDOR's scope of supply. MFMS Panel shall be linked to the FMS Panel to receive the information of these meters. The complete list of data to be interchanged between FMS and MFMS is to be defined during Detail Design.

5.5 Flow meters installed in the Test Separator outlets is used to verify TMPFMs performance. These meters are FMS VENDOR's scope of supply. MFMS shall receive data from them through FMS Panel.

5.6 Typical schematics of the well production allocation are illustrated in Figure 5.1, for manifolded wells, and Figure 5.2, for satellite wells.

Typical Schematic – Production Allocation for Manifolded Wells:

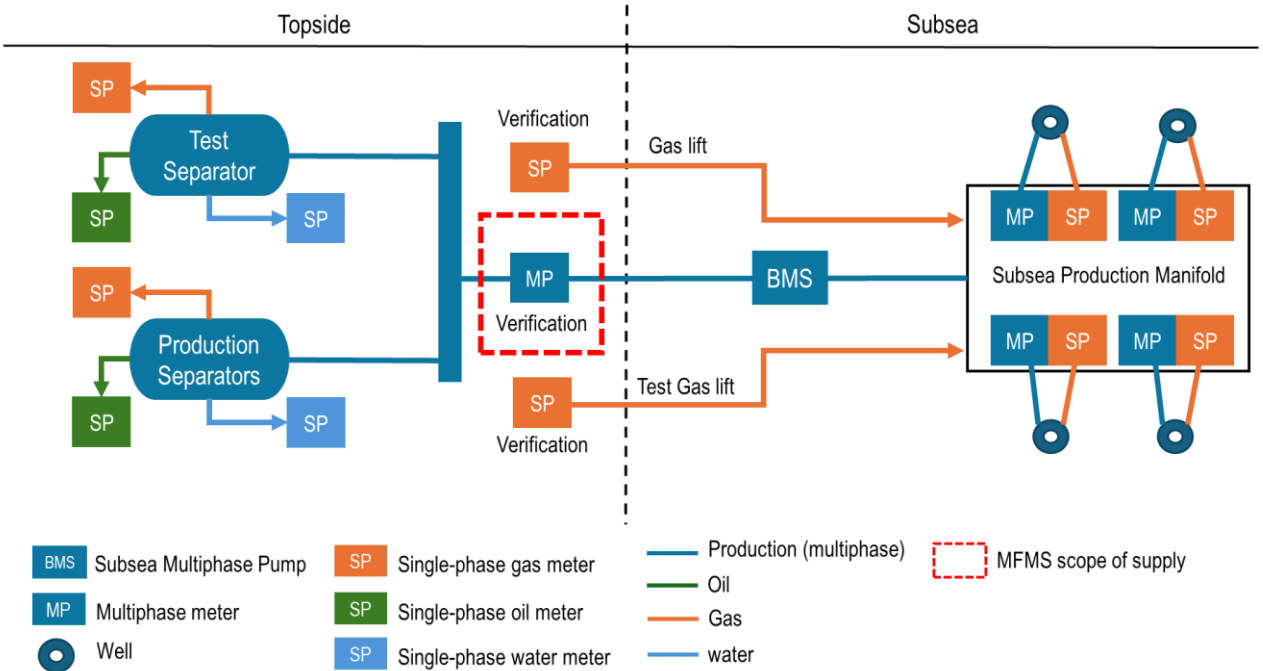


Figure 5.1 – Typical schematic of production allocation for manifolded wells.

Typical Schematic – Production Allocation for Satellite Wells:

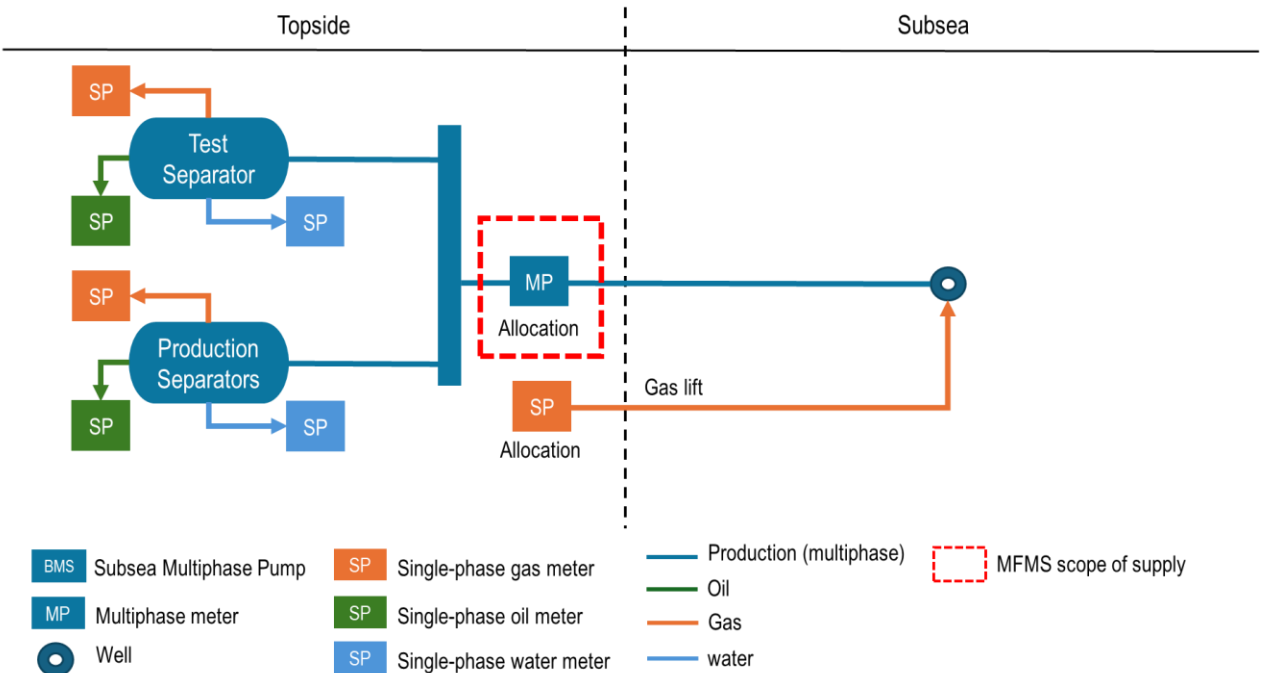


Figure 5.2 – Typical schematic of production allocation for satellite wells.

5.7 The MFMS shall integrate data from SMPFMs, TMPFMs and single-phase gas lift meters, as well as single-phase oil, gas, and water meters from Test Separator. The data to be retrieved include instantaneous flow rates, total volume, pressure, temperature, and meter diagnostics. A schematic diagram of MFMS integration with other automation systems is illustrated in Figure 5.3.

Schematic Diagram of MFMS Integration with Other Unit Automation Systems:

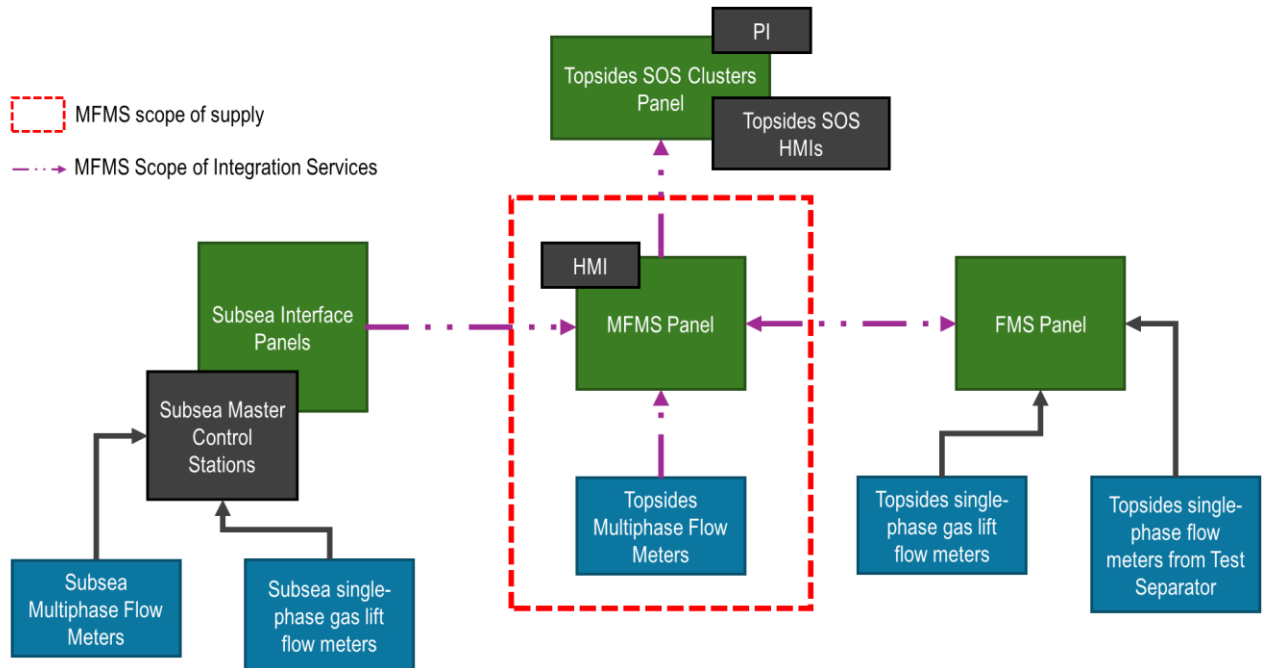



Figure 5.3 – Schematic diagram of MFMS integration with other automation systems.

5.8 Data from SMPFMs and single-phase gas lift flow meters are retrieved from the SPCSs through Subsea Interface Panels. In addition, MFMS shall be able to write in defined registers of SPCS Panels. Data communication between the systems shall be confirmed during Detailed Design phase. SELLER shall consult with CSS VENDOR to ensure seamless integration.

5.9 Data from topsides single-phase flow meters, including gas lift meters and oil, gas, and water flow meters from Test Separator, are sourced from the FMS Panel. Additionally, MFMS shall provide data from subsea meters and TMPFMs to FMS Panel. Topsides single-phase meters and FMS Panel are FMS VENDOR’s scope of supply. SELLER shall interact with the FMS VENDOR to ensure proper integration. For further details about the FMS flow meters, see I-ET-3010.2Q-1200-800-P4X-003 – FLOW METERING SYSTEM (FMS).

5.10 The flow rate data from SMPFMs and TMPFMs, as well as from subsea gas lift flow meters, shall be transmitted to the Topsides SOS HMIs (PN-5523002A/E) and to Plant Information (PI) Server in the Central Control Room (CCR) though Topsides SOS Clusters Panel (PN-5523011). SELLER shall interact with CSS VENDOR to ensure seamless

	TECHNICAL SPECIFICATION	I-ET-3010.2Q-1200-800-P4X-004	REV.: B
	MARLIM LESTE E SUL		SHEET: 15 of 28
	TITLE:	MULTIPHASE FLOW METERING SYSTEM (MFMS)	ESUP
			INTERNAL

integration. PI data list to be available in onshore servers shall be confirmed during Detailed Design.

5.11 The MFMS shall utilize data reconciliation methods to compare the flow rates measured by the subsea meters installed on the production manifolds with those measured by their corresponding topsides meters, including multiphase and single-phase flowmeters. This is to monitor and verify the performance of the subsea flow meters.

5.12 The MFMS shall utilize data reconciliation methods to compare the oil, gas, and water flow rates measured by the TMPFMs with those measured by single-phase flow meters installed at the Test Separator outlets. This is to monitor and verify the performance of TMPFMs.

5.13 The MFMS shall include software to calculate each well's oil, gas, and water production, and generate well production test reports.

5.14 The MFMS shall be able to allocate well production by measuring the difference between SMPFMs and their respective TMPFM in case of contingencies. This requirement also extends to the subsea gas lift meters.

5.15 The MFMS shall comply with "Resolução ANP No 44/2015" (or other updated document which substitutes or complements it) and with manufacturer's recommendation.

5.16 This Technical Specification shall be read in conjunction with I-ET-3010.00-1200-813-P4X-001 – GENERAL CRITERIA FOR FLOW METERING SYSTEMS and the documents listed in item 2.2.

5.17 The MFMS automation shall also comply with its respective Automation Package requirements according to I-ET-3010.00-1200-800-P4X-002 – AUTOMATION, CONTROL AND INSTRUMENTATION ON PACKAGE UNITS and I-ET-3010.2Q-1200-800-P4X-014 – AUTOMATION INTERFACE OF PACKAGED UNITS.

5.18 The requirements for specification of flow instruments shall be in accordance with I-ET-3010.00-1200-813-P4X-001 – GENERAL CRITERIA FOR FLOW METERING SYSTEMS, I-ET-3010.00-1200-800-P4X-013 – GENERAL CRITERIA FOR INSTRUMENTATION PROJECTS and to I-ET-3010.2Q-1200-800-P4X-005 – FIELD INSTRUMENTATION.

5.19 Ergonomics requirements for operation and maintenance listed in I-ET-3000.00-1400-196-P4X-001 – ERGONOMICS REQUIREMENTS FOR TOPSIDES shall be followed. Complete access to all flow meters and components shall be provided.

5.20 Care shall be taken for the meter's installation, as the signal attenuation due to cable length shall not affect the quality of the signal reception at the meters electronic and MFMS Panel.

6 TOPSIDES MULTIPHASE FLOW METERS

6.1 Every production riser connected to the UNIT shall have a TMPFM installed on topsides, including slots for spare production risers. The TMPFMs shall be linked to the MFMS Panel. These meters and the MFMS Panel shall be supplied by SELLER.

6.2 TMPFM connected to a satellite production well is responsible for its production allocation.

6.3 SMPFM installed on Subsea Production Manifolds (MSPs) are responsible for production allocation of the manifolded wells.

6.4 TMPFM connected to manifolded production riser is responsible for continuous performance verification of the respective SMPFMs by applying reconciliation factor.

6.5 The operating envelope of the multiphase meters shall encompass the entire expected flow range over the lifetime of the wells. TMPFM connected to manifolded production riser shall include the minimum flow rate of one single producing well and the maximum flow rate of four wells producing simultaneously. If it is not possible to meet the required uncertainty with the same multiphase meters over operational lifetime, additional streams in parallel shall be foreseen. Detailed process data for multiphase meters sizing will be provided during detailed design.

6.6 The TMPFMs shall support black-oil, lookup table, and custom PVT models for the Equation of State (EoS) compatible with the fluids on the reservoir, which shall be available in the MFMS Panel.

6.7 The meters shall be able to update fluid properties and convert them to process operation conditions based on data collected samples taken at the Test Separator outlets.

6.8 The TMPFMs shall have diagnostic capabilities, which must be available in the MFMS Panel. They shall include operational status indication for every component of multiphase meter.

6.9 Maximum acceptable pressure loss due to TMPFM is 400 kPa in each production line.

6.10 TMPFMs shall meet the following uncertainty criteria over the entire operating range:

6.10.1 Expanded uncertainty in volumetric liquid flow, at actual process conditions, less than or equal to $\pm 6\%$ with 95% coverage probability;

6.10.2 Expanded uncertainty in volumetric gas flow, at actual process conditions, less than or equal to $\pm 10\%$ with 95% coverage probability;

6.10.3 Expanded uncertainty in measured Water-Liquid Ratio (WLR), at actual process conditions, less than or equal to $\pm 4\%$ with 95% coverage probability.

6.11 Primary flow element venturi tube shall be in accordance with ISO 5167 part 4, following pipe material specification.

6.12 TMPFMs shall have dedicated pressure, differential pressure and temperature transmitters.

6.13 TMPFMs shall have salinity probe for monitoring of the water phase to correct the WLR.

6.14 Flow computer shall be part of meter electronics, suitable for hazardous area and required enclosure rating. Flow computer shall interface with TMPFM sensors and instruments for flow calculations and communicate with MFMS Panel.

6.15 The TMPFMs shall be supplied on a skid with maximum dimensions according to project equipment list.

6.16 The TMPFMs shall be installed in a vertically ascending flow, upstream of the choke valve and shall be designed to accommodate pipe vibration due to high linear momentum, turbulence, and high pressure of the fluid. A blind-t mixer shall be installed upstream of the flow meter. SELLER shall ensure that the meter installation arrangement will guarantee phase homogeneity.

6.17 SELLER shall provide removable spool to replace the multiphase flow meter, allowing its removal for maintenance and keeping the production without the meter. One removable spool shall be supplied for each skid.

6.18 TMPFM shall be equipped with radioactive sources, for better accuracy. The half-life of radioactive sources shall be at least 20 years.

6.19 For all radioactive materials and equipment, SELLER shall comply with CNEN resolutions for all stages of the process, logistics, handling, storage, manufacturing, and assembly carried out in Brazil until UNIT handover. For activities in other countries, SELLER shall follow the national rules of the respective country for importing, transporting, storage and exporting the radioactive source. A comprehensive safety plan covering all these aspects shall be submitted to BUYER for proper risk assessment management.

6.20 TMPFMs equipped with radioactive sources shall be manufactured so that, during the operation, maintenance and storage, workers are not exposed to radiation above that stipulated in CNEN NN 3.01.

6.21 SELLER is responsible for ownership transference of radioactive sources to BUYER and all legal requirements associated to it.

6.22 Radioactive sources to be installed and calibrated when UNIT is at final location or within shipyard activities in Brazil near to the beginning of operation.

6.23 SELLER shall supply 20 (twenty) TMPFMs (Z-1210001A/V), as indicated on the Table 5.1.

Table 5.1 – List of TMPFMs to be supplied by SELLER.

Tag	Service
Z-1210001A	Satellite production well A
Z-1210001B	Satellite production well B

Z-1210001C	Satellite production well C
Z-1210001D	Satellite production well D
Z-1210001E	Satellite production well E (with BCSS)
Z-1210001F	Satellite production well F (spare)
Z-1210001G	Satellite production well G (spare with BCSS)
Z-1210001H	Subsea manifold production MSP-1
Z-1210001J	Subsea manifold production MSP-2 – production riser 1
Z-1210001K	Subsea manifold production MSP-2 – production riser 2
Z-1210001L	Subsea manifold production MSP-3
Z-1210001M	Subsea manifold production MSP-4
Z-1210001N	Subsea manifold production MSP-5 – production riser 1
Z-1210001P	Subsea manifold production MSP-5 – production riser 2
Z-1210001Q	Subsea manifold production MSP-6
Z-1210001R	Subsea manifold production MSP-7
Z-1210001S	Subsea manifold production MSP-8 (spare) – production riser 1
Z-1210001T	Subsea manifold production MSP-8 (spare) – production riser 2
Z-1210001U	Subsea manifold production MSP-9 (spare) – production riser 1
Z-1210001V	Subsea manifold production MSP-9 (spare) – production riser 2

7 MFMS PANEL

7.1 A MFMS Panel (PN-1223005) shall be supplied to perform well production allocation calculations. For this purpose, the panel shall be integrated to all necessary subsea and topsides meters for computing these volumes, as illustrated in Figure 5.3.

7.2 MFMS Panel shall be installed indoors, in an air-conditioned area, at the AUTOMATION & ELECTRICAL PANELS ROOM (AEPR).

7.3 The MFMS Panel comprises of MFMS Server, MFMS HMI and MFMS LAN Ethernet Switches. For further details, see I-DE-3010.2Q-1200-813-P4X-0002 – FLOW METERING SYSTEM (FMS) ARCHITECTURE.

7.4 The MFMS Panel shall include all required hardware, software, and accessories to totalize and save metering data, implement standard algorithms for flow calculation, provide HMI to operators and metering technical responsible, guarantee data inviolability and comply with all legal requirements.

7.5 The MFMS Panel shall be able to do the following tests:

7.5.1 Continuously compare the flow rate of the commingled SMPFMs with their respective TMPFM using data reconciliation factor, including gas lift flow rates;

7.5.2 Individually compare each SMPFM with its respective TMPFM, including gas lift flow rates;

7.5.3 Individually compare TMPFM with single-phase flow meters from the Test Separator outlets;

7.5.4 Continuously compare the flow rates of the subsea gas lift flow meters with their respective topsides gas lift flow meters using data reconciliation factors;

7.5.5 Individually compare subsea gas lift flow meter with their respective topsides gas lift meters installed in the gas lift test line.

7.5.6 For all above mentioned tests, the MFMS shall be able to generate a report with the test results for the given period of time.

7.6 Communication between MFMS Panel and TMPFM may be defined by SELLER.


7.7 The MFMS Panel shall communicate with SPCS Panels to receive subsea meters data. In addition, MFMS shall be able to write in defined registers of SPCS Panels. MFMS Panel shall foresee supervisory screens for this subsea multiphase and gas lift meters interface. Communication protocol shall be defined during detail design.

7.8 The MFMS Panel shall receive and store the process data, parameters, and diagnostics available from SMPFMs and TMPFMs. These data shall also be available to FMS Virtual Server and FMS HMIs and PI System through OPC UA, including the following variables as a minimum:

- Volumetric oil flow at reference conditions (m³/h);
- Volumetric water flow at reference conditions (m³/h);
- Volumetric gas flow at reference conditions (m³/h);
- Volumetric oil flow at actual conditions (Am³/h);
- Volumetric water flow at actual conditions (Am³/h);
- Volumetric gas flow at actual conditions (Am³/h);
- Mass flow of oil (kg/h);
- Mass flow of water (kg/h);
- Mass flow of gas (kg/h);
- Mass flow of liquid (kg/h);
- HC mass flow (kg/h);
- Total mass flow (kg/h);
- Oil hold-up at actual conditions (%);
- Gas hold-up at actual conditions (%);
- Water hold-up at actual conditions (%);
- Gas-Liquid Ratio (GLR) at reference conditions (%);
- Gas-Oil Ratio (GOR) at reference conditions (%);
- WLR at reference conditions (%);
- GLR at actual conditions (%);

- GOR at actual conditions (%);
- WLR at actual conditions (%);
- Static pressure (kPa);
- Differential pressure (kPa);
- Temperature (°C);
- Water salinity;
- Oil specific mass at reference conditions (kg/m³);
- Gas specific mass at reference conditions (kg/m³);
- Water specific mass at reference conditions (kg/m³);
- Oil specific mass at actual conditions (kg/m³);
- Gas specific mass at actual conditions (kg/m³);
- Water specific mass at actual conditions (kg/m³);
- Oil dynamic viscosity at reference conditions (cP);
- Gas dynamic viscosity at reference conditions (cP);
- Water dynamic viscosity at reference conditions (cP);
- Oil dynamic viscosity at actual conditions (cP);
- Gas dynamic viscosity at actual conditions (cP);
- Water dynamic viscosity at actual conditions (cP);
- Hourly volumetric oil flow at reference conditions (m³);
- Hourly volumetric water flow at reference conditions (m³);
- Hourly volumetric gas flow at reference conditions (m³);
- Hourly volumetric oil flow at actual conditions (Am³);
- Hourly volumetric water flow at actual conditions (Am³);
- Hourly volumetric gas flow at actual conditions (Am³);
- Daily volumetric oil flow at reference conditions (m³);
- Daily volumetric water flow at reference conditions (m³);
- Daily volumetric gas flow at reference conditions (m³);
- Daily volumetric oil flow at actual conditions (Am³);
- Daily volumetric water flow at actual conditions (Am³);
- Daily volumetric gas flow at actual conditions (Am³);

7.9 The MFMS shall support the following functionalities:

	TECHNICAL SPECIFICATION	I-ET-3010.2Q-1200-800-P4X-004	REV.: B
	MARLIM LESTE E SUL		SHEET: 21 of 28
	TITLE:	MULTIPHASE FLOW METERING SYSTEM (MFMS)	ESUP
			INTERNAL

7.9.1 Support for black-oil, lookup table, and custom PVT models for the EoS compatible with the fluids on the reservoir. SELLER shall include in its scope of supply a development of a custom PVT model as per provided well characterization operational conditions.

7.9.2 Continuous calculations of PVT input to all multiphase meters (both subsea and topside), as well as test separator single-phase meters.

7.9.3 MFMS shall be able to convert all measured flow rates in actual conditions to ANP reference conditions. Intermediate conditions may be implemented for TMPFM verification, such as Test Separator actual conditions.

7.10 The MFMS Server shall retain all historical registers and reports for at least 10 years, using hard disks or solid-state disks and on an incremental daily basis.

7.11 Metering reports (well allocation; performance verification; batch for metering testing; alarm and events; audit trail) shall be readily available for ANP and/or BUYER representatives on board, as well as recorded for further internal or authority audit.

7.12 The MFMS shall generate, as minimum, the following log files:

7.12.1 Daily configuration data log (for gas lift meters and multiphase meters);

7.12.2 Daily input and output data log (for gas lift meters and multiphase meters);

7.12.3 Daily audit trail log (for each gas lift meter and multiphase meters);

7.12.4 Daily alarm log (for each gas lift meter and multiphase meters);

7.12.5 Test verification report.

7.13 All log files generated shall be created based at the actual data calculated by MFMS and HMI simply by uploading. The files shall be kept at the MFMS Server non-volatile memory / dedicated directory.

7.14 All log files shall be generated according to the formats defined in (last editions): API/MPMS 21.1, Electronic Gas Measurement; API/MPMS 21.2, Flow Measurement-Electronic Liquid Measurement.

7.15 MFMS Panel shall have control access to avoid non-authorized modifications.

7.16 Means for synchronizing the MFMS Server shall be provided using the CSS clock as a reference.

7.17 MFMS Panel shall have a 20% spare of the total amount of I/O channels counted for all types of I/O cards. Additionally, it shall be foreseen empty slots related to 10% of the I/O count, for future use.

7.18 All empty I/O slots shall be provided with blank plates.



7.19 All channels, including spare or additional channels, shall be wired to terminals, ready for field interconnection.

7.20 All terminal blocks shall be provided with 20% of wired extra terminal connectors and 10% of extra terminal connectors, for future use.

7.21 Application program shall be capable to process at least the total amount of I/O channels counted, including installed and uninstalled spares.

7.22 For more panel characteristics, see I-ET-3010.00-5520-888-P4X-001 – AUTOMATION PANELS.

8 INTEGRATION SERVICES

8.1 The MFMS is responsible for the production allocation measurement of the wells connected to the UNIT. To perform this function, the system shall integrate data from system that are outside SELLER's scope of supply. To ensure this integration, SELLER shall interact with vendors of the other systems (FMS VENDOR, BUYER, and CSS VENDOR) to align communication details.

8.2 MFMS shall be integrated to SPCS Panels to read and write data from/to SMPFMs and from subsea single-phase gas lift flow meters (to be supplied by BUYER). The communication with SPCS shall be done through Subsea Interface Panels (to be supplied by CSS VENDOR).

8.3 SELLER shall align communication details with SPCS Panel vendor (BUYER) and Subsea Interface Panels (CSS VENDOR) to ensure the properly operation of the integrated system. SELLER shall also foresee commissioning of subsea meters together with meter MANUFACTURER.

8.4 MFMS shall be integrated to FMS Panel to read data from topsides single-phase flow meters, including gas lift meters and oil, gas, and water flow meters from Test Separator, and to write data from multiphases and subsea gas-lift flow meters. FMS Panel is supplied by FMS VENDOR. SELLER shall align communication details with FMS VENDOR to ensure the properly operation of the integrated system.

8.5 MFMS shall be integrated to Topsides SOS HMIs (PN-5523002A/E) and to Plant Information (PI) Server though Topsides SOS Clusters Panel (PN-5523011) to send data from multiphase and subsea single-phase gas lift flow meters. Topsides SOS Clusters Panel is CSS VENDOR's scope of supply. SELLER shall align communication details with CSS VENDOR to ensure the properly operation of the integrated system.

8.6 SELLER shall include in its scope of work the deployment of onboard embark of technical professionals to commission and assist in the operation of the TMPFMs during the start-up of the wells.

8.7 For further details about interfaces with other systems, see I-DE-3010.2Q-1200-813-P4X-002 – FLOW METERING SYSTEM (FMS) ARCHITECTURE.

9 ACCEPTANCE TESTS

9.1 For FAT, SAT and SIT refer to IEC-62381 – AUTOMATION SYSTEMS IN THE PROCESS INDUSTRY – FACTORY ACCEPTANCE TEST (FAT), SITE ACCEPTANCE TEST (SAT) AND SITE INTEGRATION TEST (SIT).

9.2 For approval of the multiphase metering project, the multiphase meters model shall be subject to performance testing in an independent laboratory to ensure that performance meets the required uncertainty criteria as per paragraph 3.1 of “Resolução ANP No 44/2015”.

9.2.1 Performance tests shall be executed with fluids as close as possible to actual process conditions, covering the operational envelope and flow rates multiphase meters will be subjected to during the actual application.

9.2.2 Complete documentation of performance tests shall be consolidated in Portuguese language and sent to BUYER, for ANP submission.

9.3 Additional to ANP performance test, it is required a calibration (dynamic flow loop test) for each multiphase flow meter.

9.3.1 The venturi's discharge coefficient shall be determined on this individual calibration.

9.3.2 Performance of the meter shall be verified during flow loop test.

9.3.3 Flow loop test required oil (crude oil or mineral oil), water and gas (air or nitrogen) as calibration fluids.

9.3.4 Salinity probes shall be checked for different salt concentrations, as per project required process conditions. Calibration may be executed as a static test.

9.4 BUYER is expected to witness the performance approval test of the multiphase meters and the individual flow loop tests. Notification shall be sent at least 45 days in advance.

9.5 SELLER shall submit to BUYER, for approval, detailed FAT, SAT and SIT programs at least 60 (sixty) days in advance of programmed test date.

9.6 Backup of MFMS Server configuration and MFMS Server software shall be supplied to BUYER after completion of each test (FAT, SAT and SIT).

9.7 FAT minimum requirements

9.7.1 The following tests and inspections shall be performed at SELLER installations (FAT) prior to delivery, as a minimum:

9.7.1.1 Physical assembly (visual and dimensional);

9.7.1.2 Calibration of flow meters and field instruments;

9.7.1.3 Equipment functionality;

9.7.1.4 Skid functionality, integrated to MFMS Panel;

9.7.1.5 Loop test of each instrument;

9.7.1.6 MFMS functionality, including calculation verification for each measurement;

9.7.1.7 MFMS HMI functionality;

9.7.1.8 Reports generation;

9.7.1.9 Panel tests, as required at I-ET-3010.00-5520-888-P4X-001 – AUTOMATION PANELS;

9.7.2 The metering skids shall be properly and completely assembled and shall be assessed integrated to the MFMS Panel.

9.7.3 Factory Acceptance Test (FAT) shall be done for each TMPFM supplied covering at least functional tests according to technical specification and individual performance proven through calibration. All equipment, panel, devices, and instruments shall be energized for testing.

9.7.4 All functionality and equipment of the metering skids shall be assessed, such as electronic panel, secondary transmitters, salinity probe, flow totalization, meter verification, and so on.

9.7.5 The programming and parametrization of the MFMS Server and other programmable equipment/device shall be done prior to FAT, so that it is available for verification during the tests.

9.7.6 All I/O (100%) of the MFMS Panel, including spare ones and network connections, shall be assessed during FAT.

9.7.7 MFMS supervisory screens shall be sent to BUYER for comments, so that all modifications are already implemented by SELLER for verification during FAT.

9.7.8 All functionality of the MFMS HMI shall be checked and tested during FAT, such as:

- Screens validation, object animation, page and menu navigation;
- User control access protection;
- Alarm generation;
- Report generation;
- Historian;
- Server configuration and parametrization;
- Performance verification routines;
- Meter diagnostics;

- Communication with CSS, with memory map validation;
- Communication with FMS, with memory map validation;
- Communication with SPCS, with memory map validation.

9.7.9 BUYER is expected to witness the FAT of the multiphase meters. Notification shall be sent at least 45 days in advance.

9.8 SAT and SIT minimum requirements

9.8.1 After the installation of the equipment on the UNIT, all the tests shall be repeated by MANUFACTURER, considering the integration of all field equipment, MFMS Panel, FMS Panel, SPCS Panels and CSS (SAT and SIT).

9.8.2 All instruments and equipment (100%) shall have its communication tested with MFMS Panel, MFMS HMI, SPCS Panel and CSS.

9.8.3 All memory map address from MFMS Server shall be validated with the FMS Panel.

9.8.4 All memory map address from MFMS Server shall be validated with the SPCS Panel.

9.8.5 All memory map address from MFMS Server shall be validated with CSS (Package Unit Server and SOS HMI).

9.8.6 Calibration of radioactive sources aboard the UNIT by MANUFACTURER, considering real field oil (if available).

9.8.7 SELLER shall supply all necessary typical consumables for commissioning.

10 DOCUMENTATION

10.1 In the beginning of the UNIT design, within 6 months' time from MFMS Kick-Off-Meeting, SELLER shall provide to BUYER the following documents (in Brazilian-Portuguese language) to be submitted to ANP for preliminary approval, according to "Resolução ANP nº 44":

10.1.1 Schematic Diagram of Flow Metering for Allocation;

10.1.2 Technical Description of the Allocation Flow Metering System;

10.1.3 Preliminary performance verification plan for the multiphases and subsea gas lift flow meters, according to "Resolução ANP nº 44" requirements;

10.1.4 Multiphase fluid sample collection plan, "Resolução ANP nº 44" requirements;

10.1.5 PVT data update plan, "Resolução ANP nº 44" requirements;

10.1.6 MFMS Commissioning plan;

10.1.7 TMPFMs performance test report.

10.2 Within 2 months after the FAT, the SELLER shall provide to BUYER the TMPFMs performance test report. The report shall contain at least the following information:

10.2.1 Report identification;

10.2.2 Date of report issuance;

10.2.3 Identification of the model and serial number of the tested multiphase meter;

10.2.4 Test period;

10.2.5 Test boundary conditions: GVF, salinity, BSW, mass and volumetric flow rates of each fluid, minimum and maximum pressure, minimum and maximum temperature, specific gravity and dynamic viscosity limits of the measured fluids, and tested operational limits;

10.2.6 Deviations from the standard for each fluid and for gases and liquids;

10.2.7 Software version used in the multiphase fluid meter or measurement system;

10.2.8 Characterization of the PVT of the fluids used in the test;

10.2.9 Descriptive memorial of the measurement systems used as standards for the tests;

10.2.10 Test results and conclusions;

10.2.11 Observations and additional information;

10.2.12 Identification of the person(s) responsible for the report.

10.3 Six (6) months before UNIT sail away (or 4 months prior to ANP inspection on shipyard, whichever comes sooner), SELLER shall provide to BUYER the complementary documentation of the MFMS to be submitted to ANP for approval. BUYER will send the complete list of required documents, which shall include as a minimum the following list:

10.3.1 Instruments manuals;

10.3.2 Flow meter operation, configuration and maintenance manual;


10.3.3 Flow meter installation manual;

10.3.4 Instruments datasheets;

10.3.5 General arrangement of the skid;

10.3.6 Complete list of meter spare parts with respective part numbers and reference price;

10.3.7 A list of recommended spare parts for 2 years of operation;

	TECHNICAL SPECIFICATION	I-ET-3010.2Q-1200-800-P4X-004	REV.: B
	MARLIM LESTE E SUL		SHEET: 27 of 28
	TITLE: MULTIPHASE FLOW METERING SYSTEM (MFMS)		ESUP
			INTERNAL

10.3.8 Documentation sent to CNEN related to the radioactive source;

10.3.9 Modbus map with address, type of data and description of variables provided by the Flow Meter;

10.3.10 Procedure for monitoring parameters and diagnosing the flow meter and ensuring that it is fully operational and meeting uncertainty specifications. This procedure shall also indicate measures that must be taken when problems are identified, such as the need to calibrate system instruments.

10.3.11 Meter sizing memorial, which demonstrates the analyzes conducted to choose the model offered and prove compliance with the process conditions and operating envelope;

10.3.12 Meter uncertainty calculation memorial. The uncertainty calculation must provide the uncertainty of mass flow rates and volumetric flow rates of oil, gas and water for the local condition, typical operating condition of the test separator and reference condition;

10.3.13 Calibration certificates for static pressure, temperature and differential pressure transmitters and salinity probe and others that may be part of the system;

10.3.14 Report containing the base values of key variables for future monitoring;

10.3.15 Equipment test report that satisfies item 3 of Resolução ANP 44/2015;

10.3.16 Flow computer configuration reports;

10.3.17 Radioactive source performance tests on field.

10.4 SELLER is responsible to provide any additional information or document, as requested by ANP.


10.5 SELLER is responsible for designing and implementing the entire system, including documentation and inspection, securing approval from both ANP and BUYER.

11 TRAINING

11.1 SELLER shall provide training to qualify BUYER technicians to operate and maintain (erect, dismantle, replace parts, adjust, etc.) each equipment. The training shall encompass all items to its understanding.

11.2 The training shall be performed at UNIT construction yard and/or aboard the UNIT after completion of the Performance Acceptance Tests and prior to BUYER approval of the system acceptance term.

11.3 SELLER shall provide all documentation and materials required for the training program (including the latest revision of the as built documentation, brochures, booklets, material for presentations, transparencies, etc.).

	TECHNICAL SPECIFICATION	I-ET-3010.2Q-1200-800-P4X-004	REV.: B
	MARLIM LESTE E SUL		SHEET: 28 of 28
	TITLE:	MULTIPHASE FLOW METERING SYSTEM (MFMS)	ESUP
			INTERNAL

11.4 Each individual equipment training program shall encompass all operation and maintenance aspects. All trainees shall be operational and maintenance professionals. The participants shall be awarded certificates after the completion of the training course.

11.5 Three Operation and Maintenance training courses shall be delivered for 10 (ten) technicians (a total of 30 technicians), in Brazilian Portuguese and shall be performed using identical equipment as supplied.

11.6 SELLER shall take full responsibility for the professionals teaching the training course, including for their transportation and lodging.

11.7 SELLER shall submit for approval the detailed training program.

11.8 SELLER shall supply 2 (two) digital media copies (USB flash drive) of the training course.

11.9 The training program shall cover, at least, the following items:

- 11.9.1 System overview;
- 11.9.2 Functional operation of each component;
- 11.9.3 Operation/navigation through the HMI screens;
- 11.9.4 Operation routines and procedures;
- 11.9.5 Reports generation;
- 11.9.6 Configuration;
- 11.9.7 Troubleshooting;
- 11.9.8 Maintenance.