Manual of Petroleum Measurement Standards
Chapter 6—Metering Assemblies

Section 4A —Lease Automatic Custody Transfer (LACT) Systems

First Edition, XXXX 2022

FOREWORD

Revision of API *MPMS* Chapter 6, *Metering Assemblies*, First Edition (202X) is ongoing. The revision supersedes all existing API MPMS Chapter 6 standards with the following four separate standards:

1. API *MPMS* Chapter 6.1A, *Metering Assemblies – General Considerations*, First Edition (2021)
2. API *MPMS* Chapter 6.2A, *Truck and Rail Loading and Unloading Measurement Systems*, First Edition (2021)
3. API *MPMS* Chapter 6.3A, *Pipeline and Marine Loading/Unloading Measurement Systems*, First Edition (2021)
4. API *MPMS* Chapter 6.4A, *LACT Systems*, First Edition (202X)

Three 6.XA series of Standards have been published and supersede the previous Standards as follows:

1. API *MPMS* Chapter 6.1A, *Metering Assemblies – General Considerations*, First Edition (2021), is a new standard which specifies the common requirements for all metering systems and does not supersede any other API *MPMS* Chapter 6 standards.
2. API *MPMS* Chapter 6.2A, *Truck and Rail Loading and Unloading Measurement Systems*, First Edition (2021), supersedes API *MPMS* Chapter 6.2, *Loading Rack Metering Systems*, Third Edition (2004), which is withdrawn.
3. API *MPMS* Chapter 6.3A, *Pipeline and Marine Loading/Unloading Measurement Systems*, First Edition (2021), supersedes API *MPMS* Chapter 6.5, *Metering Systems for Loading Marine Bulk Carriers*, Second Edition (1991), and API *MPMS* Chapter 6.6, *Pipeline Metering Systems*, Second Edition (1991), and Section 6.3.5 supersedes API *MPMS* Chapter 6.7, *Metering Viscous Hydrocarbons*, Second Edition (1991), all of which are withdrawn.

Upon publication of this document:

4. API *MPMS* Chapter 6.4A, *LACT Systems*, First Edition, supersedes API *MPMS* Chapter 6.1, *Lease Automatic Custody Transfer (LACT) Systems*, Second Edition (1991), including Addendum 1, August 2020, and Section 6.1.2 of Chapter 6.4A supersedes API *MPMS* Chapter 6.7, *Metering Viscous Hydrocarbons*, Second Edition (1991), all of which are withdrawn.

1 INTRODUCTION

This standard serves as a guide in the selection, installation, and operation of Lease Automatic Custody Transfer (LACT) metering systems. This standard does not endorse or advocate the preferential use of any specific type of metering system or metering system components.

In general, metering system installations have to meet certain fundamental requirements, including proper selection, sizing, and installation of metering system components, as well as inclusion of adequate protective and readout devices. Descriptions of metering system components are included either in this standard or other API *MPMS* Chapters.

Sections of Chapter 6 describe metering system design, selection, and operation. Section 6.1A describes the general considerations applicable to all metering systems and shall be consulted together with Section 6.4A (this section) when designing, selecting, and operating LACT measurement systems. When aspects are covered under the scope of other chapters of the API Manual of Petroleum Measurement Standards (MPMS), and to avoid replication and conflict, they are not covered by this standard. In these cases, this standard provides limited information and refers the user to those chapters.

For guidance on the design, selection, and operation of truck and rail loading and unloading systems, including truck mounted meters, refer to Section 6.2A. For guidance on the design, selection, and operation of pipeline and marine loading/unloading metering systems, refer to Section 6.3A.

2 Scope

This standard is part of a set of documents which detail the minimum requirements for Metering Systems in single phase liquid applications. This standard (Section 6.4A) details the specific requirements for the design, selection, and operation of Lease Automatic Custody Transfer (LACT) metering systems.

3 Normative References

The following referenced documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any addenda) applies.

API *MPMS* Chapter 4.2, *Proving Systems – Displacement Provers*
API *MPMS* Chapter 4.4, *Proving Systems – Tank Provers*
API *MPMS* Chapter 4.5, *Proving Systems – Master Meter Provers*
API *MPMS* Chapter 4.8, *Proving Systems – Operation of Proving Systems*
API *MPMS* Chapter 4 (all sections), *Proving Systems*
API *MPMS* Chapter 5 (all sections), *Metering*
API *MPMS* Chapter 6.1A, *Metering Assemblies – General Considerations*
API *MPMS* Chapter 7.4, *Temperature Determination – Dynamic Temperature Measurement*
API *MPMS* Chapter 8.1, *Standard Practice for Manual Sampling of Petroleum and Petroleum Products*
API *MPMS* Chapter 8.2, *Standard Practice for Automatic Sampling of Petroleum and Petroleum Products*
API *MPMS* Chapter 8 (all sections), *Sampling*
API *MPMS* Chapter 9.4, *Continuous Density Measurement Under Dynamic (Flowing) Conditions*
API *MPMS* Chapter 9 (all sections), *Density Determination*
API *MPMS* Chapter 10 (all sections), *Sediment and Water Determination*

API *MPMS* Chapter 21.2, *Electronic Liquid Volume Measurement Using Positive Displacement and Turbine Meters*

4 Terms, Definitions and Symbols

4.1 Terms and Definitions

For the purposes of this document, the following terms and definitions apply. Terms of more general use can be found in the API *MPMS* Chapter 1 Online Terms and Definitions Database.

4.1.1 lease automatic custody transfer (LACT) system

An arrangement of equipment designed for the unattended custody transfer of liquid hydrocarbons from producing leases to the transporting carrier. Arrangement of equipment designed for the unattended custody transfer of liquid hydrocarbons from producing leases to the transporting carrier. Provides the means for determining quantity and quality and the means for fail-safe and tamperproof operation.

NOTE Sometimes referred to as a "LACT Unit"

4.1.2 merchantable oil

Crude oil or condensate which meets a defined specification or criteria within a contractual agreement or regulatory requirement.

4.1.3 non-merchantable oil

Crude oil or condensate that does not meet a specification (e.g., water content, quality, physical property, etc.) that is identified in a contractual agreement or regulatory requirement.

4.1.4 viscous hydrocarbon

Any liquid hydrocarbon that resists flow because of high shear or tensile stress and therefore may require special treatment or equipment in its handling or storage.

4.1.5 transporting carrier

Entity or company responsible for receiving and transporting hydrocarbon, typically by means of pipeline, marine vessel, rail car, or truck.

4.1.6 slip stream sample loop

Low-volume stream diverted from the main pipeline, intended to be representative of the total flowing stream.

4.2 Acronyms, Abbreviations, and Symbols

ACT – Automatic Custody Transfer
ASME – American Society of Mechanical Engineers
GPA – Gas Processors Association
LACT – Lease Automatic Custody Transfer
NPSH – Net Positive Suction Head
PLC – Programmable Logic Controller
S&W – Sediment and Water
WCA – Water Cut Analyzer

5 LACT System Overview

A LACT system is an integrated system of primary, secondary, tertiary measurement components, along with piping and valving, that provides the means to determine the custody transfer quantity, quality, and associated data documented on the measurement ticket. LACT systems typically include additional equipment not always found in a pipeline liquid metering system, such as pumps and motors, pump controls, air eliminators, diverter valves, and water cut analyzers.

The calculation method of the quantity on a measurement ticket (also called quantity transaction record or QTR, batch ticket, or just 'ticket') is dependent upon the type of meter used (volumetric or mass) and the units of measure.

5.1 General LACT Configuration

Figure 1 is a schematic flow diagram showing the principal components of a meter-equipped LACT unit. All items shown may be used in an installation, but if certain components are not required for the measurement of quantity or quality measurement or control, they may be omitted. It is recognized also that other component arrangements are possible.

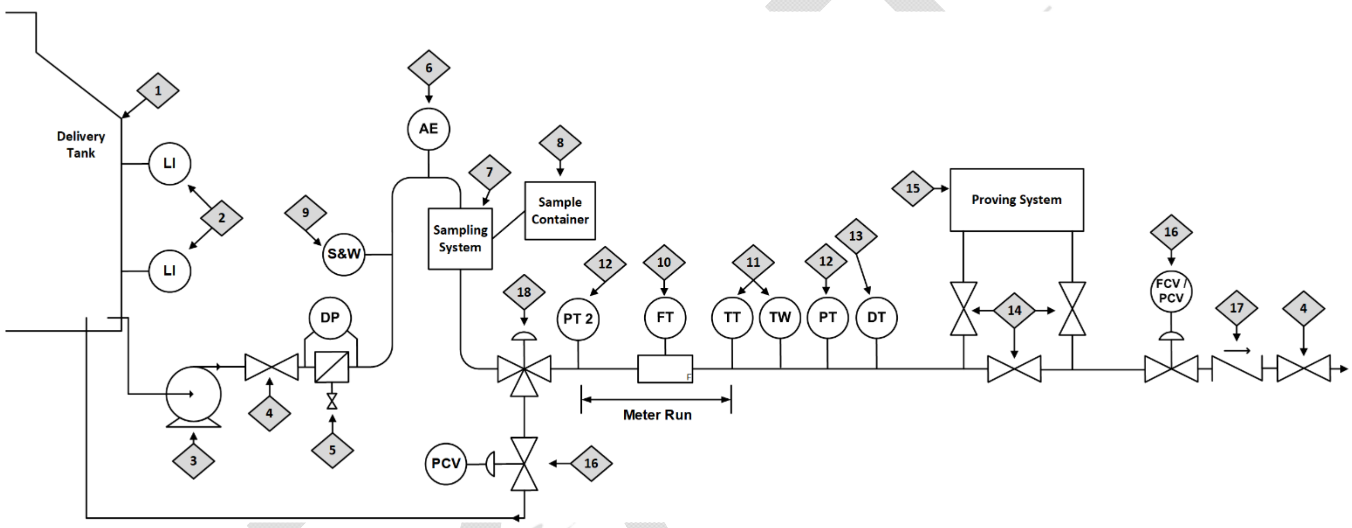

Figure 1 – Typical LACT Metering System

1. Delivery Tank
2. Delivery Tank Level Device
3. Charge Pump and Motor
4. Inlet / Outlet Isolation Valves
5. Strainer
6. Air Eliminator
7. Sampling System
8. Sample Container and Circulation Pump
9. Water Cut Analyzer
10. Custody Transfer Meter
11. Temperature Measurement Device
12. Pressure Measurement Device
13. Density Meter
14. Prover Valve Manifold
15. Proving System
16. Back Pressure Valve
17. Check Valve
18. Diverter Valve

6 Design and Installation

6.1 General System Design and Installation Considerations

LACT systems encompass a broad range of measurement systems – from a simple, single-meter system which measures a few hundred barrels per day, to a complex, multiple-meter system which measures several hundred thousand barrels per day. LACT systems can have various configurations, depending on flow rate, type of transporting carrier, intermittent or continuous operation, maintenance requirements, contractual and regulatory requirements, method for interruption of non-merchantable oil, redundancy requirements, proving requirements, and prover design.

System components shall be designed to accommodate the full range of expected operating conditions, including flow rate, pressure, temperature, density, viscosity, sediment, and water content ranges. The system shall be designed to operate at a pressure that exceeds the expected equilibrium vapor pressure by an amount sufficient to avoid formation of any vapor.

System components shall be selected or designed to accommodate the full range of expected ambient conditions (e.g., temperature, offshore salt-laden atmosphere, adverse environmental conditions, etc.). Consideration should be given to the effects of these ambient conditions on measurement accuracy and/or access for maintenance. For some applications, it is appropriate to install the LACT system under a shelter or inside a building.

The system shall be designed to accommodate the expected physical properties of the fluid and any potential for wax/paraffin appearance. The system should operate above the fluid's wax appearance temperature and the design can require the use of heat tracing and/or insulation to ensure this temperature is maintained.

The system should be able to detect failed components to minimize mismeasurement or hazardous operating conditions. Additionally, it can be necessary to provide a means to control flow rates, periods of flow, and quantities of oil delivered into the transporting carrier's system.

The design of the system shall provide a means for detecting leakage throughout the system, for example, double-block and bleed valves or valve assemblies, sight glasses, flow or level indication, and/or pressure instruments. The system design shall include means to prevent or detect unintended addition or removal of fluid that could adversely impact the measured quantity or quality delivered to the transporting carrier's system. The system shall also be designed or equipped to prevent unintended reverse flow of liquid through the measuring devices.

All components of the system that require periodic inspection, verification, or calibration should be safely accessible.

An example LACT system data sheet is provided in Annex A to aid in system design or assessment.

6.1.1 Handling of Non-Merchantable Oil

LACT systems shall include a means of determining whether the flowing product entering a transporting carrier's system is merchantable oil. The system shall be designed such that when non-merchantable oil is detected the agreed upon action for handling of the non-merchantable oil is taken.

Depending on the installation, handling of non-merchantable oil can be accomplished by:

A) use of a divert valve(s) that recycles non-merchantable oil back to storage or a wet oil system
B) system generated command to stop the charge pump motor
C) system generated command to close the LACT delivery valve or other valve to isolate the transporting carrier's system
D) continue delivery of non-merchantable oil to transporting carrier's system with notification to the transporting carrier

E) a combination of the above

6.1.2 High Viscosity Applications

Viscous hydrocarbons present a higher resistance to flow and can require special treatment or equipment to promote accurate measurement. It is more difficult to separate entrained air or vapor from viscous liquids. As viscosity increases, the retention time required for separating entrained gas from the liquid increases. Special meter modifications can be required and the meter manufacturer should be consulted.

It is important that the temperature / viscosity of the liquid be maintained within a range which does not influence meter accuracy beyond performance requirements. Variations can necessitate viscosity indexing, Reynolds Number indexing, and/or more frequent proving. Many viscous liquids can be heated to lower the viscosity and facilitate handling. Special consideration should be taken for meters, auxiliary equipment, and fittings to accommodate or mitigate the effects of high temperatures during handling of heated liquids; for example, the following should be considered:

A) System equipment can be subject to temperature limitations.
B) System insulation maintains temperature control and contributes to personnel safety; however, insulation can limit access to equipment.
C) Care should be taken to ensure the product remains in the liquid phase.

For services in which the product requires heating and the line to the LACT is required to be liquid full between movements, it may be advisable to circulate the liquid through the LACT system and a return line back to storage. Heating and/or insulating of any liquid full piping (e.g., return line) may also be advisable. The return line should tee off as close to the meter inlet as possible. In some applications, it can be necessary to circulate the liquid through the entire system, including the meter; however, appropriate steps shall be taken to ensure the measurement ticket accurately reflects the quantity delivered to the transporting carrier's system. An automatic method of controlling circulation and meter registration is recommended in this type of installation. Valves should be located in the return line to permit control of flow.

6.1.3 Redundancy

Redundant meters, meter runs, and other system components should be considered when shut down for maintenance or repair is not practical.

Redundancy should be considered for the following metering system components:

A) Flow Meters (and flow conditioning, where required)
B) Strainers
C) Valves
D) Instrumentation
E) Water Cut Analyzers
F) Density Meters
G) Sampling System Components (e.g., Sample Probes, Receivers, Actuators)
H) Flow Computers and Control Panel Components

Redundant metering systems typically include n+1 parallel meters, where n is the required number of meters to accommodate the maximum metering system instantaneous flow rate. Common n+1 design configurations include 3 X 50% metering (i.e., two flowing meters + one spare meter) and 2 X 100% metering (i.e., one flowing meter + one spare meter).

6.1.4 Bidirectional Metering

In some cases, LACT measurement applications require bidirectional metering capability, such as an offshore “buyback” metering configuration during which liquid hydrocarbon is temporarily transferred from a transportation system to a production facility. When bidirectional measurement is required, it is recommended to use a separate meter run for each direction (e.g., from a production facility or to a production facility). Alternatively, piping with appropriate valving can be used to reverse facility flow direction through a unidirectional meter run. The use of bidirectional meter runs on LACT systems is discouraged.

6.2 Flow Meter

The purpose of the custody transfer meter is to accurately measure the quantity of liquid hydrocarbons being transferred between parties. LACT meters shall be designed in accordance with API *MPMS* Chapter 5.

LACT meter types should be selected based on compatibility with fluid properties and design ranges for the application, including ranges of instantaneous flow rate, density, viscosity, temperature, pressure, and water content. It is essential to size LACT meters for the instantaneous flow rate range of an application rather than production volume of a system that has intermittent rather than continuous flow. Meter linearity over the operating range of the specific application should be considered during meter selection. See API *MPMS* Ch. 5.1[3] for additional information related to meter linearity.

The four technologies listed below are considered acceptable for use in LACT metering systems. Additional meter types can be suitable for LACT custody transfer applications if there is a published API *MPMS* Chapter 5 standard specific to the meter type.

- Displacement meter
- Turbine meter
- Coriolis meter
- Ultrasonic meter - multipath wetted transducer type

Displacement meters measure flow directly by separating the flowing liquid stream into discrete segments and counting the segments or meter revolutions. Displacement meters do not require conditioned flow. Various displacement meter accessories are available, such as flow transmitters, local volume totalizers, mechanical output drives used for portable meter proving, and meter output adjustors to correct for meter error or liquid properties. The number of mechanical accessory devices should be limited as much as practical to minimize additional mechanical load and meter wear. Some displacement meters can be mounted horizontally or vertically. The meter manufacturer should be consulted for proper orientation to prevent issues related to bearing load and wear. When electronic flow registration is used, displacement meter output signals are typically amplified and transmitted to a flow computation device. See API *MPMS* Ch. 5.2[4] for additional information related to displacement meters.

Turbine meters infer flow by sensing the rotation of blades or a blade assembly in the flowing liquid stream. Turbine meters may be mounted either vertically or horizontally; however, downward flow through a vertically mounted meter is not recommended because the rotor will ride continuously on the downstream bearing resulting in hydraulic imbalance and associated meter wear or error. The meter manufacturer should be consulted for proper orientation to prevent issues related to bearing load and wear. Turbine meters require conditioned flow and turbine meter runs are typically fitted with mechanical flow conditioners. Turbine meter output signals are typically amplified and transmitted to a flow computation device. See API *MPMS* Ch. 5.3[5] for additional information related to turbine meters.

Coriolis meters process flow by measuring the Coriolis force caused by liquid stream flow through one or more meter flow tubes. Coriolis meters have primary mass flow and liquid density measurements, from which volumetric flow rate can also be derived. Coriolis meter outputs can be configured as volumetric or mass outputs. Unless specifically required by the manufacturer, Coriolis meters do not require conditioned flow. The meter manufacturer should be consulted for preferred orientation. Coriolis meters have available meter and process diagnostics that can be accessed with a digital communication connection. See API *MPMS* Ch. 5.6[6] for additional information related to Coriolis meters.

Multipath ultrasonic meters process flow by measuring ultrasonic signals transmitted through the liquid flowing stream. Ultrasonic meters require conditioned flow and ultrasonic meter runs are typically fitted with mechanical flow conditioners. Ultrasonic meters have available meter and process diagnostics that can be accessed with a digital communication connection. See API *MPMS* Ch. 5.8[7] for additional information related to ultrasonic meters.

All meter types have varying sensitivities to fluid properties such as density, viscosity, and solids content. Meter manufacturers should be consulted to ensure compatibility with fluid properties and operating conditions.

LACT meter output resolution varies by meter type and design. In some cases, the raw meter output resolution provides fewer pulses than required by meter proving requirements as specified in API *MPMS* Ch. 4.8 and flow computation devices with pulse interpolation functionality are used to meet resolution requirements for meter proving. See API *MPMS* Ch. 4.6[2] for additional information on pulse interpolation.

LACT meter output units typically correspond to the units specified in applicable contracts or regulation (i.e., volume-based meter outputs for volume-based transactions and mass-based meter outputs for mass-based transactions).

For meter types that require periodic meter zero verifications or adjustments, LACT metering systems should include the appropriate double-block-and-bleed valves or valve manifolds to facilitate isolation of a liquid-filled flow meter and verification of a no-flow condition.

Flow meters capable of digital communications often have additional information or diagnostics available via the digital interface that can provide valuable information. These meters should be installed such that meter information and diagnostics are readily accessible.

6.3 Proving System

The purpose of the proving system is to provide a known quantity for comparison with a meter's indicated quantity in order to establish a meter factor. The proving system may be either portable or stationary and shall be designed in accordance with API *MPMS* Chapter 4.

The type of prover to be chosen depends on company measurement policies, expected frequency of use, meter type, economics, regulatory requirements, and contractual agreements between parties.

6.3.1 Prover Valve Manifold

The purpose of the prover valve manifold is to direct flow to either the downstream pipeline or to the prover. The prover valve manifold shall be designed in accordance with API *MPMS* Chapter 4.

6.4 Quality Determination

6.4.1 Sampling System

The purpose of a sampler is to extract a representative sample for quality determination. The system shall have a means to perform automatic sampling in accordance with API *MPMS* Chapter 8.2. When a manual sample point is to be used for custody transfer it shall be in accordance with API *MPMS* Chapter 8.1. Both the manual and automatic sample locations shall have a means to condition the flow prior to extracting the sample per API *MPMS* Chapter 8.2. In addition to API *MPMS* Chapter 8 design requirements, the following sections address individual Sampling System components design recommendations to meet equipment design requirements for unattended custody transfer of liquid hydrocarbons.

6.4.1.1 Stream Conditioning

A static mixer is recommended to ensure the flowing product is adequately and evenly dispersed to ensure a homogenous sample at the sample extraction point. Alternatively, there are multiple types of stream conditioning methods that may be considered depending on each specific site's flowing conditions.

To facilitate sample system performance testing, installation of a water injection test connection upstream of the sampling system and stream conditioning should be considered. Water injection test connections should be located downstream of devices that would accumulate injected water. Water injection test connections should be sized to match the injection meter size required for the maximum expected water flow through the sampling system (i.e., product of max water content and maximum flow rate). Refer to API *MPMS* Chapter 8.2 for additional details.

6.4.1.2 Sample Extractor & Controller

The purpose of the extractor or sample probe and controller is to grab samples that are proportional to flow. The sample extractor should be an isokinetic type, which helps to ensure the extracted sample is more representative of the flowing stream. Sample extractors should be paced based on the volume measured by the flow meter(s).

Manual sample probes are used to take spot samples in operation and during sampling system performance testing. A manual sample probe should be installed within the same homogenous piping zone as the automatic sample extractor. See API *MPMS* Chapter 8.1 for additional manual sample probe details.

Sample extractors and manual sample probes should be externally marked to indicate flow direction for verification of installation orientation.

6.4.1.3 Sample Line

The purpose of the sample delivery line or tubing from the sample extractor to the sample container is to consistently deliver the sample into the container while maintaining the sample integrity and composition as extracted by the sample probe.

The sample line diameter should be large enough to prevent paraffin and other waxing materials from obstructing the sample line. A minimum nominal diameter of 3/8" is recommended. Sample delivery lines should continually slope down to the container entry point without any dead legs. A sample delivery line slope of at least 1" per foot is recommended; therefore, sample container systems should be located as close as practical to sample extractors. Sample delivery lines should contain only the necessary valves and fittings to minimize liquid traps. Valves and fittings should be sized as close as practical to internal diameter of the sample delivery line. Heat trace and insulation can be required in some applications to ensure adequate flow. Reference API *MPMS* Chapter 8.2 for more information about minimizing contamination when using multiple sample containers.

6.4.1.4 Sample Container System

The purpose of the sample container system is to collect the extracted samples from the sampler and maintain sample integrity without altering the collected sample composition. The sample container and associated equipment shall be designed and installed in accordance with API *MPMS* Chapter 8.2 and to be compatible with liquid hydrocarbons. In locations with extreme weather conditions, the sample container system should be protected from adverse ambient conditions that can affect the physical properties and chemical composition of the sample.

The sample container should be equipped with a pressure safety device, high level detection, level indicator, combination positive pressure / vacuum gauge, and mixing device. Consider a mechanical device to prevent over filling the container as a backup to the primary overfill protection. Container and over pressure protection shall be chosen to maintain the integrity of the sampled product (e.g., loss of light ends). Sample container design should facilitate proper mixing of the sample to ensure a homogenous sample and should be tested according to API *MPMS* Chapter 8.3[8].

Multiple sample containers should be considered if sample segregation is needed or if operationally necessary.

6.4.1.5 Circulation Pump

The purpose of the circulation pump is to mix the full content of the container for quality determination. For locations with stationary sample containers, it is recommended that each sample container have its own pump.

6.4.2 Water Cut Analyzer

The purpose of the water cut analyzer (WCA) is to monitor the water content of the liquid hydrocarbon. It may also be used to ensure the water content is within contractual limits. Refer to API TR 2570[14] for guidance on design and installation of water cut analyzer.

Where a divert mechanism is used for returning non-merchantable oil, the WCA shall be installed upstream of the divert mechanism.

Selection of the WCA should consider if there is a potential for wax in the product. When wax can be present, the manufacturer should be consulted to determine if construction or internal coatings can be adopted to inhibit wax buildup.

6.4.3 Density Meter

The purpose of the density meter is to provide an accurate flowing density. A method for verification of the density meter should be included in the LACT design. This typically involves the use of a hydrometer or a master density meter. A pycnometer can also be used, but it can be difficult to clean the pycnometer due to the nature of the product. The installation, use, and verification of online density meters shall be done in accordance with API *MPMS* Ch. 9.4.

6.4.4 Online Quality Monitor / Analyzer

Other quality monitoring instruments such as organic chlorides, H_2S, vapor pressure monitors and others may be installed to measure specific quality requirements of a system. Such instruments should be designed and installed such that they do not interfere with the meter or other measurement devices. These types of quality monitoring equipment are not within the scope of this document.

6.4.5 Slip Stream Sample Loop Installations

If a slip stream sample loop (fast loop) is being used for devices described in sections 6.4.1 through 6.4.4 the design shall ensure that the product is returned without bypassing the metering section, divert mechanism, sampling system, or proving connections. If the slip stream sample loop is used for multiple devices, the design shall ensure devices do not interfere with each other. The manual sampling point may be included in the fast loop/slip stream.

6.5 Secondary Measurement Devices

6.5.1 Pressure Measurement Devices

The purpose of pressure measurement devices is to accurately determine the pressure of the fluid passing through the meter and prover. Pressure measurement devices shall be installed in accordance with API *MPMS* Ch. 4, Ch. 5, and Ch. 6.1A. The pressure measurement device for the meter should be located as close as practical downstream of the meter. For meters that are affected by variations in flow profile, pressure measurement devices should be outside of any stream conditioning meter run piping-length requirements. Pressure measurement device installation shall allow for verification and calibration of the pressure measurement device in accordance with API *MPMS* Ch. 21.2.

6.5.2 Temperature Measurement Devices & Test Thermowells

The purpose of temperature measurement devices is to accurately determine the temperature of the fluid passing through the meter and prover. Temperature measurement devices shall be installed in accordance with API *MPMS* Ch. 4, Ch. 5, Ch. 6.1A, and Ch. 7.4. A test thermowell should be installed to allow for verification and calibration of the temperature measurement device. The temperature measurement device and the test thermowell for the meter should be located as close as practical downstream of the meter. For meters that are affected by variations in flow profile, temperature measurement devices should be outside of any stream conditioning meter run piping-length requirements.

6.6 Additional LACT System Components

6.6.1 Delivery Tank

The purpose of the delivery tank is to provide merchantable oil that is stabilized with sufficient static head pressure to provide sufficient flow or enough NPSH to feed the LACT charge pump(s). The delivery tank shall be adequately sized to provide sufficient volume during the meter proving. The suction line shall be designed to prevent vortex generation and shall not introduce material (e.g., sediment, water, etc.) into the flow stream that can settle into the bottom of the tank. Level indicator devices on the delivery tank may be used to provide the start and stop commands to the charge pump.

6.6.2 Pumps and Motors

API 610[10], 674[11], and 676[12] should be consulted for additional guidance regarding pump design and characteristics. These same API standards also provide guidance on drivers, couplings, seals, baseplates, and other auxiliaries. API RP 686[13] provides industry best practice on receiving, storage/preservation, foundations/grouting, equipment installation, and commissioning for almost any equipment on the LACT unit, but most particularly for the rotating equipment. Pressure and hydraulic analysis should be performed to ensure sufficient pressure and flow are provided for pumps.

6.6.2.1 Charge Pump and Motor

LACT systems shall be designed to operate at flow rates within the meter manufacturer's recommended range. If NPSH could be insufficient to achieve this flow rate, a charge pump shall be included in the LACT system design.

Charge pumps that do not induce pressure pulsations or flow rate surges shall be selected. Centrifugal pumps are preferred, but non-reciprocating, positive displacement pumps may be considered. Reciprocating positive displacement pumps and progressing cavity pumps are not recommended for use as the charge pump. Configuration should be self-purging to avoid gas lock. When a positive displacement pump is specified, a relief valve shall be provided on the pump discharge to either return oil to storage or to the pump suction. Charge pump sizing should be carefully reviewed when integrating the pump on the LACT skid. To prevent charge pump cavitation, system piping and valving should be designed to maintain adequate NPSH. In addition to monitoring meter flow rates, a dedicated flow switch could be installed to protect LACT system pumps from adverse operating conditions.

6.6.2.2 Injection Pump and Motor

A pipeline injection pump could be necessary for delivery of product from the LACT system to the transporting carrier. The pipeline injection pump may be mounted on the LACT system skid (depending on the size of the pump and motor).

Pipeline injection pump takeaway capacity should not exceed the LACT measurement system charge pump supply and enough piping volume should be provided in between the two pumps to prevent unstable sales meter back pressure from occurring due to pump interaction.

When the pipeline injection pump maintains sufficient back pressure on the system, the use of a back pressure control valve can be omitted.

6.6.3 Strainer

Strainers are recommended upstream of the charge pump and/or meter to remove contaminants from the flow stream that can cause fouling or damage to downstream system components. The strainer should be designed taking into consideration the pressure drop at maximum flow rate and maximum viscosity. A pressure drop between 15 kPa and 35 kPa (2 psi to 5 psi) is commonly used for design considerations. To help minimize pressure drop, the strainer body should be at least one nominal line size larger than the flow meter and/or associated piping.

Ensure the design of the strainer is suitable for the type of metering technology selected (consult meter manufacturer). The strainer basket perforations and/or mesh size should be sized in accordance with the meter and prover manufacturer's recommendations. A means should be provided to ensure the strainer basket is held in position for meters that are influenced by flow profile disturbances, refer to API *MPMS* Chapter 5 and API TR 2578[15] for additional details.

Strainer baskets should be designed to handle expected worst case differential pressure considering maximum flowrate with dirty or partially obstructed basket.

A means of monitoring the differential pressure across the strainer is recommended. Increased differential pressure could indicate that the strainer requires cleaning and could cause a flow profile distortion. Possible methods of meeting this recommendation are two independent pressure devices, one located on each side of the strainer, or a single differential pressure device installed across the strainer.

6.6.4 Air Eliminator

The purpose of an air eliminator is to remove gases (e.g., air, gas, vapor) from the flowing liquid before entering the sampling, metering, and proving systems. If the production site design or mode of operation is such that air will not enter the LACT system, an air eliminator is not required.

The type and size of air eliminator equipment is dependent on the expected amount of air to be encountered. These can range from a liquid / vapor separator vessel to simple air release head(s) installed on a strainer lid or high point. When required, air eliminators shall be installed downstream of the charge pump and upstream of the meter, proving system, and sampling. Refer to API *MPMS* Ch. 6.1A for additional information on air eliminators.

Conventional air elimination devices are intended to vent to atmospheric pressure. Integrating this with a closed drain system can inadvertently apply back pressure to the device such that it does not function as originally intended. Soft seated check valves are commonly installed on the air eliminator discharge before integrating with a closed drain system to help prevent backflow past the air eliminator. The manufacturer of the device should be consulted to understand additional measures (e.g., pressure alarm, liquid sensing element, sight glass) to be taken into account during the design of the system.

Running the outlet of the air eliminator to the sump can cause issues if the valve becomes stuck open. Means to monitor and drain the sump before spills occur should be considered. Running the outlet of the air eliminator directly to a slop tank could also accomplish this, but care should be taken to ensure additional back pressure is not added to the air eliminator.

6.6.5 Valves

6.6.5.1 Back Pressure Valve

The purpose of the back pressure valve is to maintain the minimum required positive liquid head pressure or back pressure on the system. The back pressure valve shall be located downstream of the meter, prover, and sampling system. Meter and equipment manufacturers should be consulted to determine the required minimum back pressure.

Depending on the type of valve used for maintaining back pressure, this valve could also be capable of providing additional functionality for controlling flow. When a single valve is expected to provide back pressure control and flow control, the valve should be controlled based on flow with a back pressure override, such that the required minimum back pressure is maintained.

Other means of maintaining back pressure are commonly used, such as orifice plates or other restriction devices. Such devices, when installed in place of back pressure valves, shall meet the same functional requirements.

6.6.5.2 Product Divert Valve(s)

Product divert valve(s) are often required by contract or regulation to prevent the flow of non-merchantable oil into the transporting carrier's system. Divert valve(s) typically route non-merchantable oil to treatment facilities, an alternate location, or back to source. Product divert control can be implemented using a single 2-positon 3-way valve, or two 2-position 2-way valves.

When divert systems are required, the divert system:

a) shall move to the divert position when the system detects non-merchantable oil. Note that any timing delays (e.g., prior to transitioning from metering mode to divert mode after detection of non-merchantable oil, prior to transitioning from divert mode to metering mode upon pump startup or detection of merchantable product) should be agreed upon by the relevant parties.
b) shall move to the divert position upon loss of pneumatic supply or electrical power, or upon loss of control signal
c) should move to the divert position when the pumps are shut down

Product divert valve(s) should be installed upstream of the meter. Where the product divert valve(s) are installed downstream of the meter, steps shall be taken to ensure that the measurement ticket accurately reflects the quantity delivered to the transporting carrier's system.

A recirculation pump could be required to provide sufficient pressure for delivery to the divert destination (e.g., wet oil storage). Installation is dependent on the hydraulic requirements of the system.

The use of a back pressure valve, orifice, or other means could be required to ensure back pressure on the divert line is relatively equal to the sales line back pressure to minimize hydraulic shock when operating the divert valve.

6.6.5.3 Check Valve

The purpose of check valve(s) in a LACT system is to prevent metered fluid from flowing backward through the system. Check valve(s) should be installed on the LACT system unless backward flow is prevented by other means in all operating scenarios. The use of a check valve on the divert line could also be required.

6.6.5.4 Inlet / Outlet Isolation Valves

For maintenance purposes, isolation valves should be installed upstream and downstream of the LACT system or meter runs.

Consideration should be given to the method by which non-merchantable oil will be isolated. If planning to isolate the delivery to the transporting carrier using these valves, then the valve type, actuation, and time of closure should be considered.

6.6.6 Electrical Panels

6.6.6.1 Power Panel

The purpose of the power panel is to provide power to the major equipment on the LACT system. This includes all pipeline motor-operated valves, charge pump, injection pump, recirculation pump, diverter valve, etc. The power panel should not power the measuring equipment such as the meter, instrumentation, sampler, etc.

Devices associated with reducing current and controlling pump speed, such as soft starts and variable frequency drives, should be located in this panel.

6.6.6.2 Measurement and Control Panel(s)

The automation equipment that controls and monitors the LACT system are contained in the measurement and control panel(s). All wiring from devices that can affect the net quantity determination of the flowing stream should be run to the measurement and control panel(s). This should include, but not be limited to, wiring from the flow meters, meter and prover temperature devices, meter and prover pressure devices, densitometers, water cut analyzer, samplers, prover detector switches, flow computer, flow control or back pressure control valves, relief or vent detection devices and alarms.

In some locations, wiring for communications with remote supervisory and control systems are incorporated into the measurement and control panel(s), allowing for offsite monitoring, data logging, and control.

Instrumentation and communication wiring shall include shielding where required by electrical code or recommended by device manufacturers. Pulse, frequency, and analog signal types are far more susceptible to noise that could potentially create measurement errors. Therefore, wiring for these signals requires proper shielding.

The measurement and control panel(s) often contain the local user interface to the process. Panel(s) may also include devices to meet requirements for alarming, on-site data logging, etc.

7 Flow Computation and Records

Calculations used to produce a measurement ticket are selected based on the measured liquid fluid properties and whether volumetric or mass measurement techniques are being applied. Calculation requirements are outlined in API *MPMS* Ch. 21.2 (volume), API *MPMS* Ch. 21.2, Addendum 1, Section 2 (mass), and GPA 8182[23].

Provisions should be included to capture and retain an audit trail, which consists of the documents and records necessary to allow the measurement ticket to be audited (refer to API *MPMS* Ch. 21.2). Elements of the audit trail can include:

— Configuration logs

— Event and alarm logs
— Pressure, temperature, and density verification records
— Prover calibration certificate
— Calibration records (where applicable)
— Calibration standard certificates

8 Operations and Maintenance Considerations

8.1 Quantity Calculation

Users should consider regular verification of measurement ticket calculations in accordance with API *MPMS* Chapter 12[9] and GPA 8182[23]. These verifications are typically performed annually and after changes to the configuration.

8.2 Quality Determination

Hydrocarbon quality should be tested to ensure properties, such as density, S&W, H_2S, sulfur, and vapor pressure, are within limits as defined by contractual or regulatory requirements. Representative samples should be tested in accordance with API and ASTM[16-19] standards to determine hydrocarbon properties.

When sample results are used in quantity transaction calculations, representative samples shall be tested in accordance with an API *MPMS* Chapter 9, API *MPMS* Chapter 10, or applicable ASTM[16-19] standard.

8.3 Custody Transfer Meters

LACT meters should be periodically proved in accordance with API *MPMS* Ch. 4.5 and API *MPMS* Ch. 4.8. Meter provers used for establishing LACT meter factors can be displacement provers, tank provers, or master meter provers that are designed in accordance with API *MPMS* Ch. 4.2, API *MPMS* Ch. 4.4, and API *MPMS* Ch. 4.5, respectively. LACT meter proving should be performed in accordance with a written meter proving procedure. If metering systems do not operate at a relatively constant flow rate (e.g., ±10 percent) and meters are not re-proved on rate change, a periodic linearity check (e.g., annual) should be performed to determine if a meter factor linearization method (refer to API *MPMS* Ch. 21.2) needs to be adopted in order to meet contractual or regulatory requirements. During this linearity check, flow rate control should be used at the time of meter proving to ensure proving can be performed over the flow rate range.

NOTE See Annex B for determining normal operating conditions.

Meter factor control charts should be maintained for LACT meters. Control charts should indicate meter factors and associated meter control limits.

For LACT systems without redundant or online spare metering, availability of spare meters at or near the site should be considered to minimize metering system down time in the event of a meter failure or performance outside of tolerance.

Refer to the appropriate API *MPMS* Chapter 5 standard for additional guidance related to the operation and maintenance of a specific meter type.

8.4 Strainers

A maintenance program should be followed for inspection and cleaning of strainer baskets.

If a means of monitoring differential pressure is provided, the pressure across the strainer during flowing periods should be monitored regularly. High differential pressure is an indication that the basket contains debris and should be cleaned. Zero or abnormally low differential pressure can be an indication that the basket is ruptured, and the strainer is not providing adequate protection for downstream equipment.

8.5 Valves

All valves that can impact measured quantities shall maintain a leak tight seal when closed. Seal integrity should be verified periodically.

8.6 Provers

Refer to API *MPMS* Chapter 4.8 for operation and maintenance requirements for provers.

8.7 Sampling Systems

Refer to API *MPMS* Chapter 8.2 for operation and maintenance requirements for sampling systems.

8.8 Density Meters

Refer to API *MPMS* Chapter 9.4 for operation and maintenance requirements; including the determination of density meter factors (DMF), for density meters.

8.9 Temperature and Pressure Devices

The verification or calibration of temperature and pressure measuring devices is necessary to ensure they comply with company, regulatory, and contractual requirements. See API *MPMS* Ch. 6.1A for further information.

8.10 Flow Computation Devices

Flow computation device (e.g., flow computer) maintenance programs should include:

- Verification of flow computation device configuration
- Review of audit trail
- Review of event and alarm logs
- Verification and calibration of device analog inputs
- Verification of pulse input channel

Refer to API *MPMS* Ch. 21.2 for additional guidance related to flow computation devices.

8.11 Integrity, Auditability, and Security

Refer to API *MPMS* Ch. 6.1A for considerations regarding the integrity, auditability, and security expectations for measurement systems and components.

ANNEX A
(INFORMATIVE)
LACT SYSTEM DATA SHEET EXAMPLES[1]

LACT System Data Sheet (US Customary Units)

General Information		Site Information	
Company Name:		**Available Power:**	
Address / Location:		**Instrument Air Available:**	☐ Yes ☐ No
		Area Classification Required:	
Contact Person:		**Available Footprint:**	
Contact Phone / Email:		**Onshore / Offshore:**	☐ Onshore ☐ Offshore
Project Name / Number:		**Other Site Infomation:**	
Revision:		**Regulation / Jurisdiction:**	

Process Conditions and Product Characteristics

				Min	Nom	Max	
Fluid Description:							
Inlet Pressure Available:	psig		**Flow Rate:**				BPH
Outlet Pressure Required:	psig		**Pressure:**				psig
System Design Pressure:	psig		**Temperature:**				°F
Flange Rating:	☐ 150 ☐ 300 ☐ 600 ☐ 900 ☐ 1500		**Ambient Temperature:**				°F
Flange Face:	☐ RF ☐ RTJ		**Fluid Density:**				API @ 60°F
NACE:	☐ Yes ☐ No		**Fluid Viscosity:**				cP
Wax Appearance Temperature:	°F	☐ N/A	**Vapor Pressure:**				psia @ 100°F

Equipment Requirement

System Layout:	☐ N+0 ☐ N+1 ☐ Other:	**Air Eliminator**	☐ Yes ☐ No
Meter Type:		Type:	☐ Air Release Head ☐ Air Elimination Vessel ☐ N/A
Strainer	☐ Yes ☐ No	Location(s) for Installation:	
Location(s) for Installation:		**Charge Pump and Motor**	☐ Yes ☐ No
Differential Pressure Device:	☐ Transmitter ☐ Indicator ☐ No	Pump Type:	
DP Transmitter Type:	☐ Transmitter Only ☐ Indicating Transmitter ☐ N/A	NPSHa:	psig
Isolation Valves		Req'd Discharge Pressure:	psig
Inlet Isolation	☐ Yes ☐ No Type:	**Injection Pump and Motor:**	☐ Yes ☐ No
Outlet Isolation	☐ Yes ☐ No Type:	Pump Type:	
Prover Divert	☐ Yes ☐ No Type:	NPSHa:	psig
Prover Takeoff & Return	☐ Yes ☐ No Type:	Req'd Discharge Pressure:	psig
3-Way Divert Valve	☐ Yes ☐ No Type:	**Sampling System**	
Check Valve - Meter Stream	☐ Yes ☐ No Type:	Auto Sampler Type:	
Check Valve - Divert Line	☐ Yes ☐ No Type:	Auto Sampler Grab Size:	cc
Valve Operators		Sample Container Type:	☐ Fixed ☐ Portable
Inlet Isolation	☐ Manual ☐ Electric ☐ Other:	Sample Container Volume:	gallons
Outlet Isolation	☐ Manual ☐ Electric ☐ Other:	Quantity of Containers:	
Prover Divert	☐ Manual ☐ Electric ☐ Other:	Sample Container "U" Stamp:	☐ Yes ☐ No
Prover Takeoff & Return	☐ Manual ☐ Electric ☐ Other:	Manual Sample Probe:	☐ Yes ☐ No
3-Way Divert Valve	☐ Manual ☐ Electric ☐ Other:	**Prover**	☐ Yes ☐ No
Back Pressure Valves	☐ Yes ☐ No	Prover Type:	☐ Bi-Di ☐ SVP ☐ Other:
Location(s) for Installation:	☐ Outlet ☐ Divert Line ☐ Both ☐ No	Stationery or Portable:	
Valve Type:		Prover Connections:	
Valve Operator:	☐ Pneumatic ☐ Electric ☐ Other:	**Drip Pan Containment**	☐ Full ☐ None ☐ Other:
Control on:	☐ Flow ☐ Pressure	**Piping Insulation:**	☐ Yes ☐ No ☐ By Others
Set Pressure:	psig	**Heat Tracing**	☐ Yes ☐ No
Secondary Instrumentation		**Other Equipment:**	
Temperature Transmitter:	☐ Transmitter Only ☐ Indicating Transmitter ☐ No		
Temperature Indicator:	☐ Yes ☐ No		
Test Thermowell:	☐ Yes ☐ No		
Pressure Transmitter:	☐ Transmitter Only ☐ Indicating Transmitter ☐ No		
Pressure Indicator:	☐ Yes ☐ No		

Control		Other Required Information
Controller:		
Local HMI:	☐ Yes ☐ No	
Local HOA:	☐ Yes ☐ No	
Power Distribution Panel:	☐ Yes ☐ No	
Other Control:		

[1] These examples are for illustration purposes only. They are not to be considered exclusive or exhaustive in nature. API makes no warranties, express or implied for reliance on or any omissions from the information contained in this document.

LACT System Data Sheet (Metric Units)

General Information		Site Information	
Company Name:		**Available Power:**	
Address / Location:		**Instrument Air Available:**	☐ Yes ☐ No
		Area Classification Required:	
Contact Person:		**Available Footprint:**	
Contact Phone / Email:		**Onshore / Offshore:**	☐ Onshore ☐ Offshore
Project Name / Number:		**Other Site Infomation:**	
Revision:		**Regulation / Jurisdiction:**	

Process Conditions and Product Characteristics						
Fluid Description:			**Min**	**Nom**	**Max**	
Inlet Pressure Available:	kPag	**Flow Rate:**				m^3/hr
Outlet Pressure Required:	kPag	**Pressure:**				kPag
System Design Pressure:	kPag	**Temperature:**				°C
Flange Rating:	☐ 150 ☐ 300 ☐ 600 ☐ 900 ☐ 1500	**Ambient Temperature:**				°C
Flange Face:	☐ RF ☐ RTJ	**Fluid Density:**				kg/m^3 @ 15°C
NACE:	☐ Yes ☐ No	**Fluid Viscosity:**				cP
Wax Appearance Temperature:	°C ☐ N/A	**Vapor Pressure:**				kPa @ 20°C

Equipment Requirement			
System Layout:	☐ N+0 ☐ N+1 ☐ Other:	**Air Eliminator**	☐ Yes ☐ No
Meter Type:		Type:	☐ Air Release Head ☐ Air Elimination Vessel ☐ N/A
Strainer	☐ Yes ☐ No	Location(s) for Installation:	
Location(s) for Installation:		**Charge Pump and Motor**	☐ Yes ☐ No
Differential Pressure Device:	☐ Transmitter ☐ Indicator ☐ No	Pump Type:	
DP Transmitter Type:	☐ Transmitter Only ☐ Indicating Transmitter ☐ N/A	NPSHa:	kPag
Isolation Valves		Req'd Discharge Pressure:	kPag
Inlet Isolation	☐ Yes ☐ No Type:	**Injection Pump and Motor:**	☐ Yes ☐ No
Outlet Isolation	☐ Yes ☐ No Type:	Pump Type:	
Prover Divert	☐ Yes ☐ No Type:	NPSHa:	kPag
Prover Takeoff & Return	☐ Yes ☐ No Type:	Req'd Discharge Pressure:	kPag
3-Way Divert Valve	☐ Yes ☐ No Type:	**Sampling System**	
Check Valve - Meter Stream	☐ Yes ☐ No Type:	Auto Sampler Type:	
Check Valve - Divert Line	☐ Yes ☐ No Type:	Auto Sampler Grab Size:	cc
Valve Operators		Sample Container Type:	☐ Fixed ☐ Portable
Inlet Isolation	☐ Manual ☐ Electric ☐ Other:	Sample Container Volume:	liters
Outlet Isolation	☐ Manual ☐ Electric ☐ Other:	Quantity of Containers:	
Prover Divert	☐ Manual ☐ Electric ☐ Other:	Sample Container "U" Stamp:	☐ Yes ☐ No
Prover Takeoff & Return	☐ Manual ☐ Electric ☐ Other:	Manual Sample Probe:	☐ Yes ☐ No
3-Way Divert Valve	☐ Manual ☐ Electric ☐ Other:	**Prover**	☐ Yes ☐ No
Back Pressure Valves	☐ Yes ☐ No	Prover Type:	☐ Bi-Di ☐ SVP ☐ Other:
Location(s) for Installation:	☐ Outlet ☐ Divert Line ☐ Both ☐ No	Stationery or Portable:	
Valve Type:		Prover Connections:	
Valve Operator:	☐ Pneumatic ☐ Electric ☐ Other:	**Drip Pan Containment**	☐ Full ☐ None ☐ Other:
Control on:	☐ Flow ☐ Pressure	**Piping Insulation:**	☐ Yes ☐ No ☐ By Others
Set Pressure:	kPag	**Heat Tracing**	☐ Yes ☐ No
Secondary Instrumentation		**Other Equipment:**	
Temperature Transmitter:	☐ Transmitter Only ☐ Indicating Transmitter ☐ No		
Temperature Indicator:	☐ Yes ☐ No		
Test Thermowell:	☐ Yes ☐ No		
Pressure Transmitter:	☐ Transmitter Only ☐ Indicating Transmitter ☐ No		
Pressure Indicator:	☐ Yes ☐ No		

Control		Other Required Information
Controller:		
Local HMI:	☐ Yes ☐ No	
Local HOA:	☐ Yes ☐ No	
Power Distribution Panel:	☐ Yes ☐ No	
Other Control:		

ANNEX B
(INFORMATIVE)
DETERMINING NORMAL OPERATING CONDITIONS

NOTICE **This annex is not open for vote or comment for this ballot**

B.1 General

Lease automatic custody transfer (LACT) flow meters should be calibrated (i.e., proved) under conditions as close as practical to the conditions under which they normally operate as specified in API *MPMS* Chapter 4.8. This annex includes one definition and two methods to identify normal operating conditions of a LACT metering system.

Authorities having jurisdiction may use the definition of normal operating conditions as described in B.2.

Either of the two methods described in B.3 to assess normal operating conditions should be chosen by the companies, depending on suitability to individual measurement systems and each metering application.

Companies may use the definition for LACT units.

B.2 Definition for Normal Operating Conditions

Normal operating conditions: a range of operating conditions that can be expected to occur through a metering system as determined from historical data.

Two methods of determining the range of normal operating conditions are listed in B.3.

B.3 Methods for Implementation

Meter performance method: the range of process conditions measured during previous proves that have occurred within no more than the past two years where the resulting meter factors were within ±0.25 % of the mean of the meter factors, plus or minus the additional tolerances in Table B.1.

or

Frequency of occurrence method: the process conditions within the 5th percentile to 95th percentile of the operating values calculated from the frequency of occurrence (as specified in Equation B.1) based on historical data [such as data from quantity transaction records (QTRs) or proving reports] within the previous two years, excluding data from no-flow periods, plus or minus the additional tolerances in Table B.1.

Table B.1—Additional Tolerances

Variable	Additional Tolerance
Pressure	Greater of ±10 % or ±20 psi
Temperature	±10 °F
Flow Rate	±10 %
Density	±5 °API

For the purpose of this annex, negative pressure results obtained after applying the tolerances in Table B.1 should be converted to a value of zero (0). Refer to B.7 and B.8 for examples.

Additionally, for both the meter performance method and the frequency of occurrence method, if a prove at conditions beyond those from the previous data results in a meter factor (MF) within ±0.25 % of the mean of the meter factors covering the data set, those conditions are considered normal.

The equation for the frequency of occurrence for a desired percentile point is:

$$Y_P = Y_L + \left(\left(\frac{P_{(n)} - cF_{Below}}{F_i}\right) \times i\right) \quad \text{(B.1)}$$

Where:

- Y_P is the frequency of occurrence;
- Y_L is the true lower limit of the class interval containing the percentile point;
- $P_{(n)}$ is the percentile point expressed as a decimal;
- n is the total number of scores in the distribution;
- cF_{Below} is the cumulative frequency for the class interval immediately below the class interval containing the percentile point;
- F_i is the number of scores within the class interval containing the percentile point;
- i is the width of the class interval containing the percentile point

B.4 Implementation Guidance

A year can be defined as a calendar year or a rolling 12-month period, but in no case should the data set contain more than 35 months of data. For example, data from calendar years 2017 and 2018 can be used in the calculation of normal operating conditions throughout 2019, but data from calendar year 2017 cannot be used in the calculation for calendar year 2020.

To address short-term abnormal process conditions that could expand the range to excessive limits, the lower 5 % and upper 5 % of the process data is excluded from the range calculation when using QTR data. Calculations shall use the most granular average QTR data available, with bins set up at the discrimination levels prescribed in API *MPMS* Chapter 12. In the case of a meter zero, transmitter adjustment, or similar indication adjustment, the calculation shall only use QTR data for that variable from that point in time forward. Users may set a new start point for some or all variables for known changes in process conditions. When using a limited number of QTR data sets, it is possible that the resulting range will be wider than the range from the minimum and maximum values used for the calculation. The final results can be rounded to one more significant figure than the discrimination of the input data for ease of use.

When using QTR data to determine flow rates for the purposes of calculating normal operating conditions, the use of the best available data is acceptable. This could include using the flow time and total quantity to calculate an average flow rate.

NOTE “Bin” is the term used in histograms to designate the interval for each set of data in the histogram. In the examples below, the intervals for pressure, temperature, and density are all set to 1.0.

B.5 Frequency of Calculation

Normal operating conditions should be updated at least once per calendar year. The results of the most recent calculation of normal operating conditions should be readily available. Calculation results should be stored according to company policy or any applicable regulation.

B.6 Mechanical Recorders

For LACT units with mechanical recorders, the most granular average data available is likely to be monthly or semi-monthly data. This may introduce difficulty in ensuring proving conditions are within normal operating conditions, as the averaged data will not be representative of the highs and lows encountered at the meter throughout the averaged time period. As such, it is recommended to use the meter performance method for mechanical recorders.

B.7 Meter Performance Method—Example Calculations[2]

The following examples are based on the 10-month data set of temperature, pressure, flow rate, and API gravity in Table B.2.

Table B.2—Sample Data Set

Period	Meter Temperature (°F)	Meter Pressure (psig)	Meter Flow Rate (bbl/h)	Product Gravity (°API)	Meter Factor	Meter Factor Deviation %
Month 1	59.4	20.6	514.3	53.5	1.0015	
Month 2	77.6	21.4	582.6	64.9	1.0008	–0.07
Month 3	42.4	29.2	559.4	34.7	1.002	0.12
Month 4	84.8	53.3	444.3	42.2	1.0004	–0.16
Month 5	81.9	14.0	414.0	41.8	1.0007	0.03
Month 6	82.5	18.1	458.0	46.5	1.0012	0.05
Month 7	94.4	21.6	479.0	42.0	1.0006	–0.06
Month 8	95.0	19.1	573.0	36.3	1.0001	–0.05
Month 9	83.1	20.5	559.0	37.8	1.0004	0.03
Month 10	70.7	18.0	477.0	42.2	1.0005	0.01
				MF mean (average)	1.0008	
				MF mean –0.25 %	0.9983	
				MF mean +0.25 %	1.0033	

All data is within the mean MF ±0.25 %.

[2] The examples are for illustration purposes only. They are not to be considered exclusive or exhaustive in nature. API makes no warranties, express or implied, for reliance on or any omissions from the information contained in this document.

B.7.1 Example Calculation of Normal Operating Conditions (Flow Rate)

Meter flow rate range = min to max = 414.0 bbl/h to 582.6 bbl/h

Normal operating meter flow rate = Range ±Table B.1 tolerance (±10 %)

Low end = 414.0 – 10 % = 372.6 bbl/h

High end = 582.6 + 10 % = 640.9 bbl/h

Normal operating meter flow rate = 372.6 to 640.9 bbl/h

B.7.2 Example Calculations of Normal Operating Conditions (Temperature)

Meter temperature range = min to max = 42.4 °F to 95.0 °F

Normal operating meter temperature = Range ±Table B.1 tolerance (±10 °F)

Low end = 42.4 – 10.0 = 32.4 °F

High end = 95.0 + 10.0 = 105.0 °F

Normal operating meter temperature = 32.4 °F to 105.0 °F

B.7.3 Example Calculations of Normal Operating Conditions (Pressure)

Meter pressure range = min to max = 14.0 psig to 53.3 psig

Normal operating meter pressure = Range ±Table B.1 tolerance (greater of ±10 % or ±20 psig)

Low end = 14.0 – 20.0 = –6.0 psig → Convert negative pressure value to 0.0 psig

High end = 53.3 + 20.0 = 73.3 psig

Normal operating meter pressure = 0.0 psig to 73.3 psig

B.7.4 Example Calculations of Normal Operating Conditions (Density)

API gravity range = min to max = 34.7 °API to 64.9 °API

Normal operating API gravity = Range ±Table B.1 tolerance (±5 °API)

Low end = 34.7 – 5.0 = 29.7 °API

High end = 64.9 + 5.0 = 69.9 °API

Normal operating API gravity = 29.7 °API to 69.9 °API

B.8 Frequency of Occurrence Method—Example Calculations[3]

The following examples are based on the 12-month data set of flow rate, pressure, temperature, and density in Table B.3.

NOTE Other calculation methods and routines that achieve similar results, such as a spreadsheet function, can be used.

Table B.3—Sample Data Set

Data Point	Flow Rate (bbl/h)	Pressure (psig)	Temperature (°F)	Density (°API)
Month 1	35.00	215	78.0	35.0
Month 2	31.00	227	65.0	34.0
Month 3	30.00	230	68.0	35.0
Month 4	28.00	243	47.0	36.0
Month 5	33.00	254	44.0	36.0
Month 6	32.00	265	55.0	37.0
Month 7	34.00	237	58.0	35.0
Month 8	45.00	226	70.0	35.0
Month 9	42.00	231	71.0	37.0
Month 10	40.00	230	63.0	34.0
Month 11	39.00	224	64.0	37.0
Month 12	40.00	268	66.0	36.0

B.8.1 Example Calculation of Normal Operating Conditions (Flow Rate)

STEP 1: Determine the data range.

[3] The examples are for illustration purposes only. They are not to be considered exclusive or exhaustive in nature. API makes no warranties, express or implied for reliance on or any omissions from the information contained in this document.

Table B.4—Sample Data Range: Flow Rate (bbl/h)

28.00	39.00
29.00	40.00
30.00	41.00
31.00	42.00
32.00	43.00
33.00	44.00
34.00	45.00
35.00	46.00
36.00	
37.00	
38.00	

STEP 2: Compile frequency F_i and cumulative frequency cF.

Table B.5—Frequency and Cumulative Frequency: Flow Rate (bbl/h)

Y	F_i	cF	Y	F_i	cF
27.00	0	0	38.00	0	7
28.00	1	1	39.00	1	8
29.00	0	1	40.00	2	10
30.00	1	2	41.00	0	10
31.00	1	3	42.00	1	11
32.00	1	4	43.00	0	11
33.00	1	5	44.00	0	11
34.00	1	6	45.00	1	12
35.00	1	7	46.00	0	12
36.00	0	7			
37.00	0	7			

STEP 3: Calculate percentile $P_{(n)}$.

$$P_{(n)} = \text{Percentile} \times n$$

95th percentile:

$P_{(n-95)}$ = 0.95 * 12 = 11.4

5th percentile:

$P_{(n-05)}$ = 0.05 * 12 = 0.6

STEP 4: Lookup Y_L. Select the interval with the value of cF that is less than or equal to $P_{(n)}$ that has an F value greater than 0. If the value of $P_{(n\text{-}05)}$ is less than 1, select the lowest value.

Y_{L-95} = 42

Y_{L-05} = 28

STEP 5: Lookup F_i. Find the number of scores in the interval containing the percentile score (rounded up).

F_{i-95} = 1

F_{i-05} = 1

STEP 6: Lookup cF_{Below}. Find the cumulative frequency of the interval immediately below the $Y_{L\text{-}95}/Y_{L-05}$.

$cF_{Below-95}$ = 10

$cF_{Below-05}$ = 0

STEP 7: Calculate Y_P.

Y_{P-95} = 42 + (((11.4 – 10)/1)*1)

= 42 + 1.4 = 43.4

Y_{P-05} = 28 + (((0.6 – 0)/1)*1)

= 28 + 0.6 = 28.6

Low end = 28.6 – 10 % = 25.7

High end = 43.4 + 10 % = 47.7

Normal operating conditions (flow rate) = 25.7 to 47.7

B.8.2 Example Calculation of Normal Operating Conditions (Pressure)

Table B.6—Sample Data Range: Pressure (psig)

215	226	237	248	259
216	227	238	249	260
217	228	239	250	261
218	229	240	251	262
219	230	241	252	263
220	231	242	253	264
221	232	243	254	265
222	233	244	255	266
223	234	245	256	267
224	235	246	257	268
225	236	247	258	269

Table B.7—Frequency and Cumulative Frequency: Pressure (psig)

Y	F_i	cF
214	0	0
215	1	1
216	0	1
217	0	1
218	0	1
219	0	1
220	0	1
221	0	1
222	0	1
223	0	1
224	1	2
225	0	2
226	1	3
227	1	4
228	0	4
229	0	4
230	2	6
231	1	7
232	0	7
233	0	7
234	0	7
235	0	7
236	0	7
237	1	8
238	0	8
239	0	8
240	0	8
241	0	8
242	0	8
243	1	9
244	0	9
245	0	9
246	0	9
247	0	9
248	0	9
249	0	9
250	0	9
251	0	9
252	0	9
253	0	9
254	1	10
255	0	10
256	0	10
257	1	10
258	0	10
259	0	10
260	0	10
261	0	10
262	0	10
263	0	10
264	0	10
265	1	11
266	0	11
267	0	11
268	1	12
269	0	12

Y_{L-95} = 265

Y_{L-05} = 215

F_{i-95} = 1

F_{i-05} = 1

$cF_{Below-95}$ = 10

$cF_{Below-05}$ = 0

Y_{P-95} = 265 + (((11.4 – 10)/1)*1)

= 265 + 1.4 = 266.4

Y_{P-05} = 215 + (((0.6 – 0)/1)*1)

= 215 + 0.6 = 215.6

Low end = 215.6 – 10 % = 194

High end = 266.4 + 10 % = 293

Normal operating conditions (pressure) = 194 to 293

B.8.3 Example Calculation of Normal Operating Conditions (Temperature)

Table B.8—Sample Data Range: Temperature (°F)

44.0	55.0	66.0	77.0
45.0	56.0	67.0	78.0
46.0	57.0	68.0	79.0
47.0	58.0	69.0	
48.0	59.0	70.0	
49.0	60.0	71.0	
50.0	61.0	72.0	
51.0	62.0	73.0	
52.0	63.0	74.0	
53.0	64.0	75.0	
54.0	65.0	76.0	

Table B.9—Frequency and Cumulative Frequency: Temperature (°F)

Y	F_i	cF	Y	F_i	cF
43.0	0	0	54.0	0	2
44.0	1	1	55.0	1	3
45.0	0	1	56.0	0	3
46.0	0	1	57.0	0	3
47.0	1	2	58.0	1	4
48.0	0	2	59.0	0	4
49.0	0	2	60.0	0	4
50.0	0	2	61.0	0	4
51.0	0	2	62.0	0	4
52.0	0	2	63.0	1	5
53.0	0	2	64.0	1	6

Y	F_i	cF	Y	F_i	cF
65.0	1	7	76.0	0	11
66.0	1	8	77.0	0	11
67.0	0	8	78.0	1	12
68.0	1	9	79.0	0	12
69.0	0	9			
70.0	1	10			
71.0	1	11			
72.0	0	11			
73.0	0	11			
74.0	0	11			
75.0	0	11			

Y_{L-95} = 44

Y_{L-05} = 71

F_{i-95} = 1

F_{i-05} = 1

$cF_{Below-95}$ = 10

$cF_{Below-05}$ = 0

Y_{P-95} = 71 + (((11.4 – 10)/1)*1)

= 71 + 1.4 = 72.4

Y_{P-05} = 44 + (((0.6 – 0)/1)*1)

= 44 + 0.6 = 44.6

Low end = 44.6 – 10 = 34.6

High end = 72.4 + 10 = 82.4

Normal operating conditions (temperature) = 34.6 to 82.4

B.8.4 Example Calculation of Normal Operating Conditions (Density)

Table B.10—Sample Data Range: Density (°API)

34.0
35.0
36.0
37.0
38.0

Table B.11—Frequency and Cumulative Frequency: Density (°API)

Y	F_i	cF
33.0	0	0
34.0	2	2
35.0	4	6
36.0	3	9
37.0	3	12
38.0	0	12

Y_{L-95} = 36

Y_{L-05} = 34

F_{i-95} = 3

F_{i-05} = 2

$cF_{Below-95}$ = 6

$cF_{Below-05}$ = 0

Y_{P-95} = 36 + (((11.4 – 6)/3)*1)

= 36 + 1.8 = 37.8

Y_{P-05} = 34 + (((0.6 – 0)/2)*1)

= 34 + 0.3 = 34.3

Low end = 34.3 – 5 = 29.3

High end = 37.8 + 5 = 42.8

Normal operating conditions (density) = 29.3 to 42.8

BIBLIOGRAPHY

[1] API *MPMS* Chapter 4.1, *Proving Systems – Introduction*

[2] API *MPMS* Chapter 4.6, *Proving Systems – Pulse Interpolation*

[3] API *MPMS* Chapter 5.1, *Metering – General Considerations for Measurement by Meters*

[4] API *MPMS* Chapter 5.2, *Metering – Measurement of Liquid Hydrocarbons by Displacement Meters*

[5] API *MPMS* Chapter 5.3, *Metering – Measurement of Liquid Hydrocarbons by Turbine Meters*

[6] API *MPMS* Chapter 5.6, *Metering – Measurement of Liquid Hydrocarbons by Coriolis Meters*

[7] API *MPMS* Chapter 5.8, *Metering – Measurement of Liquid Hydrocarbons by Ultrasonic Flow Meters*

[8] API *MPMS* Chapter 8.3, *Standard Practice for Mixing and Handling of Liquid Samples of Petroleum and Petroleum Products*

[9] API *MPMS* Chapter 12 (all sections), *Calculation of Petroleum Quantities Using Dynamic Measurement Methods*

[10] API Std 610, *Centrifugal Pumps for Petroleum, Petrochemical and Natural Gas Industries*

[11] API Std 674, *Positive Displacement Pumps – Reciprocating*

[12] API Std 676, *Positive Displacement Pumps – Rotary*

[13] API RP 686, *Recommended Practice for Machinery Installation and Installation Design*

[14] API TR 2570, *Continuous On-line Measurement of Water Content in Petroleum (Crude Oil and Condensate)*

[15] API TR 2578, *Flow Conditioner Installation and Effects on Turbine Meters*

[16] ASTM D1265, *Standard Practice for Sampling Liquified Petroleum (LP) Gases, Manual Method*

[17] ASTM D3700, *Standard Practice for Obtaining LPG Samples Using a Floating Piston Cylinder*

[18] ASTM D4057, *Standard Practice for Manual Sampling of Petroleum and Petroleum Products*

[19] ASTM D4177, *Standard Practice for Automatic Sampling of Petroleum and Petroleum Products*

[20] GPA 2174, *Obtaining Pressurized Liquid Hydrocarbons Samples*

[21] GPA 2177, *Analysis of Natural Gas Liquids by Gas Chromatography*

[22] GPA 8173, *Standard for Converting Mass of Natural Gas Liquids and Vapors to Equivalent Liquid Volumes*

[23] GPA 8182, *Standard for Mass Measurement of Natural Gas Liquids and Other Hydrocarbons*