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ProSoft Technology, Inc. Summary Regarding Alberta Energy Regulator's Directive 017 of March 2016

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Overview

ProSoft Technology's Enhanced Gas and Liquid Flow Computer (MVIxxE-AFC) products comply with the requirements of the AER Directive 017 of March 2016 with the release of the MVIxxE-AFC version 4.04. These products are affected:

- MVIxxE-AFC (encompasses both MVI56E-AFC and MVI69E-AFC)

The EUB document may be downloaded from:
https://www.aer.ca/documents/directives/Directive017.pdf

Contents of this document:

Part A - Overview of Major MVIxxE-AFC Features
This Part gives a comprehensive overview of the features of the MVIxxE-AFC including those that support compliance with the Directive. For guidelines, caveats, and other specific statements concerning compliance, this Part may be skipped (though other Parts may refer to this Part).

Part B - Using the MVIxxE-AFC to Implement General AER Requirements
This Part presents guidelines to be followed for compliance with the Directive when:
- Configuring the MVIxxE-AFC.
- Using the results calculated and/or recorded by the MVIxxE-AFC.
- Operating features of the MVIxxE-AFC.

Part C - Notes on the AER Directive 17 of 2016-03-31
This Part gives a detailed statement of compliance, organized according to the chapters and sections of the Directive.

Details

A. Overview of Major MVIxxE-AFC Features

1. Modbus Database

A large Modbus database makes available all configuration, calculated values, and historical records. It is partitioned into two register banks (Holding and Input) of more than 65,000 registers each. Configuration is accomplished merely by writing new values to the Modbus database, which may be done online while the module is operating, without interrupting ongoing measurement.

2. Meter and Site Configuration

a) Gross Meter Characterization

1) Product Groups

Choose the general class of fluid to be measured, from among:

- Gas
- Generalized Crude Oils (MPMS Ch 11 Tables "A")
- NGLs and LPGs (MPMS Ch 11 Tables "E")
- Refined Products (MPMS Ch 11 Tables "B")
- Lubricating Oils (MPMS Ch 11 Tables "D")
- Special Applications (MPMS Ch 11 Tables "C")
- Produced/Injected Water

Also, for Generalized Crudes and NGLs, handle water content by either the trace-water traditional methods of MPMS 12 or the high-water emulsion methods of MPMS 20.1.

2) Meter Types

Besides the usual differential-pressure type (orifice &c) and the usual pulse-count type (turbine &c), integration of a flow rate or pulse frequency can also be chosen.

3) System of Units

Engineering units of process input and most meter and stream configuration settings can be of either the SI (metric) system or the US (conventional) system. Liquid density units may be chosen from among metric (kg/m^3), relative density (to water at 60°F), and API gravity.

b) Reference Conditions

Reference conditions (aka "standard" or "base" conditions) can be chosen to accommodate most or all of the base conditions commonly used throughout the world.

1) Valid Ranges

Base temperature may be chosen as any value from 0°C to 25°C (32°F to 77°F). Base pressure may be chosen as any value from 50kPaa to 110kPaa (7.3psia to 16.0psia).

2) Default Settings

For SI units, defaults are 15°C and 101.325kPaa. For US units, defaults are 60°F and 14.73psia (gas) or 14.696psia (liquid).

c) Process Input

Process inputs include Temperature, Pressure, and the "primary input" which depends upon meter type (for example, Differential Pressure for an orifice, or Gross Volume Flow Rate for flow rate integration). Pressure process input is selectable as "gauge" or "absolute". Some meter characterizations may have additional process inputs (such as Density for liquids). Except for the pulse count from meters that deliver a sensed or manufactured pulse train, all process inputs have these characteristics:

1) Ranges and Alarms

The range of each input is configured by six values specified in the engineering units of the input, grouped into three pairs:

- Transmitter range, "Xmtr min" and "Xmtr max"

  This range is the maximum supported by the transmitter. It is used to limit the "Applied value" entered during a transmitter calibration session (see section "8" below).

- Operating range, "Zero scale" and "Full scale"

  This is the normal operating range of the transmitter. The transmitter is typically calibrated for this range in order to maximize the resolution of its output for the application. An input outside this range raises an "out of range" alarm, in which case the value assumed for subsequent calculation is the last-good (within range) value.

- Alarm thresholds, "Alarm lo" and "Alarm hi"

  These thresholds may be separately enabled or disabled. An input that exceeds an enabled threshold raises a "threshold" alarm, but in this case only the alarm is raised and no substitution of value occurs (the value is still "good" for measurement purposes).

This relationship among all six values is enforced:

```
   "Xmtr min"
<= "Zero scale"
<= "Alarm lo"
<= "Alarm hi"
<= "Full scale"
<= "Xmtr max"
```

where each "Alarm" value is tested only if the corresponding threshold is enabled.

2) Format of Presentation

The value is presented by the PLC over the backplane as floating point in engineering units. Any conversion of raw input signals (e.g. 4-20ma) to this form is performed by the PLC and/or the responsible input module in the PLC rack prior to delivery to the MVIxxE-AFC.

3) Sampling Frequency

In compliance with MPMS 21 the MVIxxE-AFC samples process input values from the PLC at least once per second. The actual sample rate, of course, depends upon the PLC complying similarly. Input values sampled between meter calculation scans are time-weight averaged for those calculations, where the time-weighting factor is the number of ticks of the 1024 Hz measurement clock elapsed since the previous sample was taken.

4) Calibration

When a transmitter is to be calibrated, which procedure may induce large swings in output having no relationship to the actual value of the quantity being measured, the corresponding process input in the MVIxxE-AFC is switched into "calibration mode". This action freezes the value assumed for subsequent calculation at its current value, thereby preventing the propagation of the spurious outputs of the transmitter into measurement results.

When calibration is complete, the process input is switched out of calibration mode and use of the live input is resumed. See section "8" below.

d) Accumulations and Flow Rates

1) Calculated Quantities

For all fluids, both accumulations and instantaneous flow rates are calculated for three quantities: Mass, Gross Volume (at operating conditions), and Net Volume (corrected to reference conditions). Depending on the fluid, other quantities are also calculated:

- For gases: Energy (heating value).
- For all hydrocarbon liquids: separate Water Volume.
- For non-emulsion hydrocarbon liquids: Gross Standard Volume.
- For emulsions: Gross Clean Oil Volume.

For linear (pulse-train) meters whose primary measured quantity is volume at flowing conditions, the quantity nominally labeled "Gross Volume" may be recorded as either true Gross Volume (which includes the effect of the meter factor) or Indicated Volume (which excludes the effect of the meter factor); in either case, however, derived quantities are unaffected as they are always calculated from true Gross Volume with the effect of the meter factor included.

2) Engineering Units

Units of accumulations and flow rates can be chosen separately from a complete range of commonly used units, unrestricted by the chosen System of Units.

3) Accumulators

For all calculated quantities a complete set of non-resettable totalizers is maintained, for the meter as a whole and for each stream of that meter (see subsection "(e)" next). Each totalizer occupies 64 bits: a 32-bit unsigned integer containing the integral part of the total, and an IEEE 32-bit floating point containing the fractional part thereof. Also, four resettable totalizers are available for the meter and each stream, whose totalized quantities can be chosen for each. Reset of these may be triggered automatically or explicitly, using the same method as is used to trigger archives (see section "6" below). Accumulator rollover value is freely configurable, separately for Volumes, Mass, and Energy.

e) Streams

A "stream" is a fluid that flows through a meter; configurable items for a stream describe properties of the fluid, while those for a meter describe properties of the meter and its associated measurement.

1) Multiple Streams

Up to four streams may be configured for each meter channel. Switching streams is accomplished by writing the number of the new active stream to a Modbus register, usually done by the PLC. Fluid-dependent parameters used in measurement are those of the active stream.

2) Analysis (Gas)

The full suite of 21 AGA-8 components are selectable for each meter (applicable to all streams). Analyses for the selected components are specifiable separately for each stream; analyses may be "static" (entered as necessary by an external host from a lab report) or "dynamic" (transferred across the backplane by the PLC from the results of an online gas chromatograph).

3) Five-point Meter Factor Linearization Curve (Pulse)

To accommodate dependencies of meter factor upon fluid and flow rate, the meter factor used in measurement is determined by linear interpolation over the primary input's "measured quantity" (typically Gross Volume) flow rate upon a per-stream table containing up to five data points.

f) Site Settings

Barometric (atmospheric) Pressure is configured for the site as a whole, in either SI or US units. Absolute Pressure required for measurement calculations is the sum of the Pressure process input (if "gauge") plus this value.

3. Calculation Standards and Frequency

Measurement Standards supported by the MVIxxE-AFC include, without limitation:

- MPMS 14.2 (AGA 8 (1994)) [gases, including energy calculations]
- MPMS 14.3 (AGA 3 (2013)) [orifice meters]
- ISO 5167-2/3/4/5 (2003) [orifice meters, nozzles, Venturi tubes, cones]
- MPMS 11.1 (2004) [higher-density hydrocarbon liquids]
- MPMS 11.2.5 (GPA TP-15) [vapor pressure]
- MPMS 11.2.4 (GPA TP-27) [lower-density hydrocarbon liquids]
- MPMS 11.2.1 and 11.2.2 [lower-density hydrocarbon liquids]
- MPMS 21 [historical records and auditability]
- MPMS 20.1 [oil-water emulsions, produced/injected water]
- McCrometer Lit# 24509-54 rev 3.0 [V-cone meters]

All meter results, including correction factors, accumulations, and flow rates, are completely recalculated each Meter Calculation Scan, whose frequency depends on several factors such as number of enabled meters, meter configuration (selects Standard calculations which differ in complexity), backplane communication, Modbus communication, and essential non-MVIxxE-AFC processes of the Linux OS. This scan is not scheduled according to any specific Quantity Calculation Period but instead is executed as fast as possible; the MVIxxE-AFC's processing loop scans one meter each iteration, interleaving this scan with other services such as backplane I/O and Modbus transactions, and rotating round-robin through the meters in successive iterations. For a fully loaded 16-meter MVI56E-AFC with light Modbus traffic (e.g. polling with EAFC Manager's "Meter Monitor"), typical scan frequency for any one meter is about twice each second. A fully loaded 12-meter MVI69E-AFC performs similarly.

4. The Event Log

A circular file of up to 2000 "events" logs changes to environment and to most configuration, especially those that may affect measurement. Each event record consists of timestamp, identification of the event (e.g. meter number and configuration element), old value, new value, identification of the responsible operator, and the Modbus address of the relevant database point. Recorded events include, without limitation:

- Changes to "sealable parameters", that is, values that may affect measurement calculations.
- Changes to process input calibration mode.
- Optionally, changes to component analysis.
- Environmental changes, such as power-up, PLC off-line, set wallclock.

The log is typically "downloaded" periodically to more permanent storage, and a "download point" is maintained indicating which records have been so retrieved and which have not. When the log is full (all records not yet downloaded), behavior is selectable between "unlocked", in which a new record overwrites the oldest one so that the overwritten never-downloaded record is lost, and "locked", in which a new record is treated in one of these three ways:

- A "high-priority" event is recorded regardless, overwriting the oldest one which is then lost; these include most of the environmental ones.
- An attempt to change a sealable parameter is disallowed and its Modbus transaction rejected, so that the event does not occur.
- A "low-priority" event that cannot be rejected is ignored and its record lost.

A "lost event" count is incremented each time a never-downloaded event is overwritten or a new event ignored by any of the above actions; the next log-download session reports this count before resetting it to 0.

5. The Alarm Log

A circular file of up to 2000 "alarms" logs alarms of two kinds. For each meter there is maintained:

- A bitmap of detailed "process input" alarms, one map for each input.
- A single bitmap of "calculation" alarms.

These bitmaps maintain the state of the alarm conditions that their bits represent; the log records changes to these bitmaps, i.e. all transitions of any condition either "into alarm" or "out of alarm". Each alarm record consists of timestamp, identification of the alarm (meter, kind, input &c), old bitmap, new bitmap, and (for process input alarms) the "raw value" (as received from the PLC) and the "sane value" (after any substitution of value for the purpose of measurement). Behavior and management of this log is very similar to that of the Event Log, including support for downloading with its "download point" and the "lost alarm" count. However, this log has no concept of being "locked"; every new alarm record is always logged, overwriting the oldest one whether or not it has already been downloaded.

The meter channel may optionally require that alarms be acknowledged, offering several protocols for managing or controlling such acknowledgement. If alarm acknowledgement is required then changes to acknowledgement states are also logged in the Alarm Log.

6. Meter Archives

Two independent archive (timestamped historical record) files are supplied for each meter channel, one triggered nominally once per day (the "daily" file) and the other triggered nominally once per hour (the "hourly" file). The ends of the periods (minute of the day or of the hour) are configured as meter-level parameters, or, if those are not enabled, as site-level parameters. Archives are also triggered upon the occurrence of most events (including changes to sealable parameters) and upon the occurrence of signals issued explicitly from an external host or the PLC (useful in some applications such as batch processing). Each archive file is extensively configurable:

- Size of record and of file (10 thru 100 words, up to 1440+ records)
- Record contents (points selectable from the meter database)
- Method of automatic triggering (period end, events)

The values recorded for meter points depend on the natures of those points, such as:

- Snapshot (accumulators)
- ORed bitmap (meter alarms)
- Averaged (process inputs, flow rates, correction factors).

The default configuration for each file is arranged to comply with the historical data recording requirements of MPMS 21, and includes a record of time on flow.

7. Meter Monitoring and Audit

a) Monitoring

As all ongoing measurement results are present in the Modbus database, monitoring the measurement at a meter is as simple as formatting the data returned by Modbus polls. EAFC Manager provides a convenient interface for this.

b) Audit

The MVIxxE-AFC can capture complete results from up to eight consecutive calculation scans of any single meter. These data, together with the configuration report for that meter, can be used to verify compliance of calculations with applicable Standards. EAFC Manager provides a convenient interface for using this feature.

8. Transmitter Calibration

While the MVIxxE-AFC cannot calibrate transmitters directly, it has full support for the management and recording of transmitter calibration sessions, as well as support via PLC logic of actual calibration of "smart" transmitters such as those that are calibrated by writing revised values to a Modbus database resident on the transmitter. Features:

- Retention for each process input of calibration files for each of two "classes":
  - The latest verification-only, or the currently active, session.
  - The latest "true" calibration session.
- Several recordable "actions", including without limitation:
  - Verify
  - Zero Shift
  - Set Zero
  - Set Span
  - Set Mid 1
  - Set Mid 2
  - Set Mid 3

All actions except "Verify" are "true" calibration actions.

- Up to 59 recordable calibration "entries", each with:
  - Action
  - Applied value
  - Measured value
  - "As-found" and "As-left" flags
  - Number of responsible operator
  - Timestamp

Deviation values (both absolute and percentage) can be calculated from the "applied" and "measured" values in conjunction with the operating range of the input.

- Calibration file "header" for each class, with:
  - Identification of the process input and its meter run.
  - Transmitter range and operating range of the input.
  - Count of recorded entries.
  - Calibration session "state", including without limitation:
    - None

      No file exists. This is the normal case for both file classes when the input has never undergone a session. It is also normal for the verification file class when the latest session was a properly reported "true" calibration.

    - Active

      A session in in progress. Possible only for the verification file class.

    - Closed

      The session has been finalized but not yet reported. Possible only for the verification file class.

    - Reported

      A closed session must be "reported" to off-line storage before a new session may be started for this input. If the session includes calibration actions, this procedure moves the file from verification class to calibration class.

  - Identification of the latest responsible operator. Some procedures do not create entries in the file, including those that terminate the session, hence relying on the operator recorded in the latest entry is insufficient.
  - Timestamp.

- Automatic management of the input's "calibration mode" flags. This mode freezes the input for measurement purposes while a calibration session is in progress.
- Ability to "link" multiple inputs as a group, such as may be needed for multivariable transmitters (MVTs), causing their calibration mode flags to be toggled in unison, and permitting the operator to step through the linked inputs for their calibration while all remain in calibration mode. Each meter run may have up to two independent such linkages.
- Ability to request the PLC to "mediate" the calibration of any input. Using this feature requires the PLC to be programmed with appropriate logic that is specific to the transmitter concerned.

9. Meter Proving

Within the scope of applicability of MPMS 12.2.3 the MVIxxE-AFC's meter proving support complies with all management, data collection, calculation, and reporting requirements of that Standard. (Outside that scope the MVIxxE-AFC's proving support is limited; see Part B section "5" below.) In addition, the MVIxxE-AFC has many features that can make meter proving simple, flexible, and even automatic:

- The MVIxxE-AFC's meter proving logic is a service engine that operates as a state machine. It receives parameters from outside for setup &c, and signals from outside to direct its operation. Those parameters and signals can come from any external source: PLC, EAFC Manager, or even direct writing to the relevant Modbus registers by a third-party external Modbus client. It is even the case that in a single proving session some parameters or signals can come from the PLC and others from a Modbus client, and even the same signal can come from different sources at different times, i.e. the engine does not care about the source of the parameter or signal. The engine was designed this way specifically to enable very flexible configuration of the user's proving operation, from detailed hands-on run-by-run management of the proving session by using e.g. EAFC Manager all the way to unattended, fully automatic management of the session by the PLC from prove enable through prove acceptance. A few signals should come from the PLC and not from a Modbus client; one of these is the "Run Complete" signal that is accompanied by pulse counts for the run for delivery into the engine; as only the PLC knows when those counts are present and has them readily available, the PLC should issue that signal. It is the user's responsibility to decide for his operation which external source is to deliver which parameter or signal and under what circumstances.

- These prover types are supported by the MVIxxE-AFC (see notes below):
  - Unidirectional prover (UDP)

    The classic large-volume prover (LVP) in which the displacer (typically a flexible ball) travels the length of the prover for each run.

  - Bidirectional prover (BDP)

    Similar to the UDP, but the displacer travels the prover length twice for each run, once in each direction.

  - Compact (small-volume) prover (SVP)

    Much shorter than a LVP, in which the displacer is typically a piston instead of a ball. Each stroke of the piston constitutes a "pass", several of which are typically combined to constitute a run. As a pass rarely can accumulate enough pulses for required precision of meter factor, the technique of "double chronometry" is used to determine a fractional pulse count of the necessary precision.

    NOTE: While the MVIxxE-AFC has full procedural and computational support for SVPs, the necessary double-chronometry hardware support is not available natively for the Rockwell platforms at this time but may be available from third-party devices; see Part B section 5(e) below.

  - Master meter (MM)

    The line meter is compared to another, "master" meter that has itself been proved to a high accuracy.

- Several configuration elements support variations of proving hardware and its instrumentation, including:
  - Whether the prover is double-walled.
  - Optional dual process inputs for T & P (inlet and outlet).
  - Explicit coefficients of thermal expansion of the prover materials instead of identifying the materials themselves, like the similar coefficients of meter configuration.

- Almost two dozen optional "variation limits" may be used for verifying that the proving session remains within specified tolerances, each of which raises an alarm when its tolerance is exceeded which causes the offending run to be marked unacceptable for a valid prove. Most of these apply to operational conditions, such as a temperature input, with the purpose of verifying that the temperature remains sufficiently steady throughout the prove. A few apply to the prove itself, such as "repeatability" and "change in factor".

- Several configuration elements support automation of the proving session, including:
  - Number of runs required for a completed prove.
  - Whether to automatically "accept" a prove upon successful completion, and if so whether to automatically update the meter factor.
  - Maximum seconds per run. Allows recovery when the proving logic and the hardware get out of step, due to such as a missed switch transition.
  - Maximum attempted runs before abort. Permits a proving session to be eventually terminated (with an "abort" signal) even if almost all runs are rejected for the prove due to alarm conditions.
- For convenience, process inputs for the line meter (and also for the master meter if MM type) are copied directly from those delivered from the PLC to the meter and averaged for delivery to the prover scan. This averaging is straight linear, without weighting for either time or flow, as during a prove they should be (close to) steady and any other weighting factor would have negligible effect.
- All readings and values calculated therefrom are accumulated into the non-volatile "Prove results" region of the Modbus database, which contains the data for the current session if one is in progress and if no session is in progress for the latest completed session whether it was accepted or rejected:
  - They include all data for each individual run, and for a SVP the pulse counts for each pass.
  - They include all calculated results, so that they provide almost all the information needed for producing a prove report. The remaining reportable information is available in the non-volatile "Meter previous prove summary" region of the Modbus database for the line meter being proved. When a new proving session is started and the previous session was accepted, the summary for the previous line meter is updated from the latest results before those results are overwritten.
  - Measurement calculations are performed according to MPMS 11 (using subsections thereof according to product type) directly from the process inputs of the line meter and the prover. No use is made of any results from the meter calculation scan; in particular, any shrinkage factor configured for the meter's stream is not used in these calculations.
  - Proving calculations are performed according to MPMS 12.2.3, including the option to select the meter factor calculation method as "average data" or "average MF".

  - All calculations are performed in their entirety after every run, including the calculations of the final meter factor and associated quantities. The results database may be inspected and reported at any time, in particular between runs of an ongoing prove, with the meter factor displayed therein being the one that would be final should the session be ended at that point.
- EAFC Manager has a convenient interface for managing, monitoring, and reporting a proving session.

10. Reports

As all configuration, measurement, and historical data are available from the Modbus database, an application can obtain reports merely by formatting data polled via Modbus. EAFC Manager can create reports for most such data in two forms: formatted text for printing, and delimited values (CSV) for import into spreadsheets. These reports include, without limitation:

- Configuration Log (formatted text only)
- Event Log
- Alarm Log
- Meter Archives
- Meter Monitor
- Transmitter Calibration
- Meter Proving (formatted text only)
- Audit Scans

11. Enron Support

The MVIxxE-AFC fully supports the fetching of log files (events and alarms) and archive files (historical records) using the ancient Enron protocol, subject to these caveats:

- The Enron "fetch-register" addresses reside in the "Enron access" window, a block of 120 Modbus holding registers starting at address 36800, and not in the traditional region beginning at address 700. Not all registers in this window are Enron fetch-registers; other registers contain values necessary for operating the protocol such as record counts and indexes, and still other registers are unassigned.

- While infrastructure exists for the future fetching of the Event Log and the Alarm Log separately, only the fetching of the "combined log" is currently implemented. The combined log returns, in sequence:

  - All not-yet-downloaded Alarms.

  - All not-yet-downloaded Events.

  The traditional Enron fetch-register for the combined log, Modbus holding register 32, may also be used for this function; it is not necessary to use for the combined log the fetch-register address in the Enron access window. Download of the log files is acknowledged by using Modbus function 5 to write "true" to the traditional Enron "log-download acknowledge" register, coil 32 (function 15 with count 1 is not supported).

- No support is present for Enron-style access to configuration and calculated results; in particular:

  - The traditional Enron partitioning of the Modbus database into four regions according to address (bits at 1xxx, 16-bit integers at 3xxx, 32-bit integers at 5xxx, and floats at 7xxx), and the Enron assumption of only one address space (no distinction between "holding" and "input") is not supported natively. Such address assignment may be partially simulated by appropriate mapping via the MVIxxE-AFC's virtual slave, though the Enron region at 1xxx cannot be simulated as the MVIxxE-AFC's Modbus database has no bit-register address banks and so does not support Modbus functions 1, 2, 5, or 15 (except for the special case of coil 32 mentioned above).

  - Accessing 32-bit quantities Enron-style as single registers is not supported, even under a virtual-slave mapping; all such quantities must be accessed as pairs of 16-bit registers.

- The contents of the Enron history records are derived from the MVIxxE-AFC's archive records. This derivation is a dynamic mapping from the respective archive record’s configured layout. Changing the layout of an archive record will affect the contents of the Enron history record accordingly; see other comments in this document, in particular Part B section "4" below.

- "Enron" privilege is required for this access; see section "13" below.

12. Communications

The MVIxxE-AFC provides an extensive set of communication features.

a) Virtual Slave

The Modbus database (summarized in section "1" above) is termed the "Primary Slave" and has a fixed layout. As this layout may not be efficient for polling by an external host such as a SCADA system, a second slave, the "Virtual Slave", provides up to 20,000 registers (10,000 Holding and 10,000 Input) each of which can be mapped to any register in the Primary Slave, permitting optimization of polling.

Virtual Slave registers can be tagged read-only (to write-protect writable Primary Slave registers) or made writable (effective only if the Primary Slave register is itself writable).

b) Communication Channels

External Modbus masters may access the MVIxxE-AFC's slaves over two distinct physical paths:

- Network Servers

  The MVIxxE-AFC's extensive network configuration supports up to four TCP servers having separate IP/port settings operating independently over the same physical NIC, with a pool of up to eight concurrent TCP connections allocated as needed among the enabled servers.

  The servers implement the Modbus TCP/IP protocol with the MBAP header ("well-known" TCP port 502); the "encapsulated Modbus" protocol that merely wraps an RTU message in an IP frame is not supported. Per-server configuration includes support for security concerns, such as:

  - Maximum number of simultaneous connections.
  - IP whitelist for filtering incoming connection attempts.

- Serial Ports

  Two serial ports provide classic Modbus accessibility, supporting both RTU and ASCII transmission modes. One port can instead be configured as a Modbus master for polling of external slaves such as a gas chromatograph.

All these communication channels (network servers and serial ports) may be individually configured with several attributes, including:

- Default operator and privilege waivers (see section "13" below).
- Word-swapping (the host sees 32-bit quantities as either "big-endian" or "little-endian").
- Isolation (visibility of the Primary Slave).

c) Backplane

Besides the expected transfer of process inputs to the MVIxxE-AFC and of calculated values from the MVIxxE-AFC, the backplane interface enables other actions such as:

- Set the MVIxxE-AFC's wallclock.
- Poll Modbus slaves via the MVIxxE-AFC's Modbus master port.
- Fetch archive records.
- Execute arbitrary transactions against either of the MVIxxE-AFC's two Modbus slaves.

The backplane interface is robust and complete enough to permit the MVIxxE-AFC to be managed entirely from the PLC, including configuration, archiving, transmitter calibration, meter proving, and retrieval of data, without ever having to connect a cable into the module for access.

13. Access Control

The MVIxxE-AFC implements access control with both a "login" mechanism and a physical lock.

a) Operator Database

Almost all access to the MVIxxE-AFC requires a Modbus client to log into the module by supplying an operator ID with a (correct) password. The Operator Database stores up to 40 entries, each of which configures a different operator. Entries may be added, edited, and deleted. Each entry has these elements:

- Operator Number

  This number, a value between 100 and 32767, is the primary means of identifying an operator. The operator supplies this Number when he logs into the module (see subsection "b)" below). This number is recorded as the "responsible operator" in persistent records such as in the Event Log.

- Operator Tag

  This is a short string that may be used as an alternate means of identifying the operator. It is analogous to the "user ID" typically employed by other systems (Windows, websites, &c) for establishing credentials of access.

- Operator Name

  A more "friendly" way of identifying the operator, available for inclusion in "welcome" messages and similar. It is not used for any access control.

- Privileges

  A bitmap that confers privileges for exercising various functions of the MVIxxE-AFC, such as configuration, logging, archiving, &c. Two such privileges are:

  - "Logged in"

    This privilege is granted automatically for every successful operator login. It permits reading of most (not all) of the Modbus database without the need for additional privileges, in particular meter configuration and live calculated results.

  - "Administrator"

    This privilege implies all other privileges. It is required for editing this Database or viewing it in full detail.

- Inherited Roles

  This feature is a means of encapsulating groups of privileges that may be assigned to several operators, for convenience of privilege management.

- Lockout Flag

  A means of prohibiting the operator from logging in without needing to delete his entry from the Database.

- Password

  A number between 0 and 65535. Value 0 is the "null" password; see subsection "b)" next. A password is never exported in any way; only its "null"ness is exported, and then only to the configuring administrator. A logged-in operator can change his own password.

Three "special operators" are always present, with Numbers 1 thru 3. They all have "administrator" privilege, and they cannot be edited, deleted, or logged into by an external Modbus client, except for #3 that permits logging in and limited editing:

- #1, the MVIxxE-AFC itself

  This entry is used primarily for supplying its Number for inclusion in persistent records made as a consequence of actions initiated by the MVIxxE-AFC firmware, such as some Events.

  This "operator" is always logged in.

- #2, the Backplane

  This entry is used primarily for supplying its Number for inclusion in persistent records made as a consequence of actions initiated by the PLC, such as Events that record configuration changes made via Modbus Gateway.

  This "operator" is always logged in.

- #3, the Default Administrator

  This entry is the only means of logging into a cold-started (out of the box) module, as at this point the Database is empty. Its password is initially "null".

This summary is necessarily incomplete; for full detail see MVIxxE-AFC documentation.

b) Logging In and the "Null" Password

A Modbus client logs into the MVIxxE-AFC by writing a packet containing operator ID and password to a specific region in the Modbus database. The MVIxxE-AFC then verifies the password in the operator's Database entry and prepares that same Modbus region with the "session attributes" that includes the map of privileges granted. The client can then read back that region to learn whether his login was successful and the actions that he can perform. A password value of 0 in the Database is "null"; it acts as a wild card so that an otherwise successful login request succeeds regardless of the password submitted. The configuring administrator should keep the presence of "null" passwords in the Database to an absolute minimum, ideally none.

c) Communication Authorization Defaults

For supporting access by third-party clients that cannot easily exercise the MVIxxE-AFC's login protocol (such as some data-collection packages), and for other conveniences that the user may desire, each communication channel (section "12" above) can be configured with two properties:

- Default Operator

  This is the Number of the operator to be assumed if the login packet delivered over this channel contains no operator ID. To be effective, this operator must be valid for logins (his record must exist and not be locked out).

- Privilege Waivers

  These privileges are granted to any logged-in session over this channel in addition to those normally granted from the operator's Database record. The above "logged in" privilege is reinterpreted here as "no password required"; if set, then the password in the Database entry for the logging-in operator is deemed to be "null" regardless of what is actually stored in the entry, so that any password given in the login request is valid.

If both the Default Operator is valid for logins and his password is "null", then no login sequence is required and the Default Operator is automatically logged in upon establishing the connection. Editing or viewing these properties requires administrator privilege.

d) Weights & Measures Lock

The module is equipped with a "W&M Lock" switch which may be fixed in the "locked" position by a wire seal. That switch position prevents any changes to sealable parameters, regardless of any privileges otherwise granted, including over the backplane. Writing changed values to such points, in addition to any privileges required, is possible only if the switch is moved to the "unlocked" position, thus breaking any wire seal. Writing back the identical value to a protected point is not inhibited by the W&M Lock.

14. CAUTION

The MVIxxE-AFC is a highly configurable device, some of its features are highly flexible in their operation, and some of its behavior is dependent on the behavior of accompanying equipment. Consequently it is not possible for the MVIxxE-AFC to enforce compliance over all possible configurations, usages, and physical or regulatory environments. Examples of such non-compliance that may arise are:

a. Reconfiguring a meter channel's archive record to remove elements of the QTR whose presence is required by applicable Standards.

b. Failure of the operator of a Transmitter Calibration session to issue a sequence of "as-found" verification actions at least as strict as those mandated by applicable Standards.

c. Failure of the PLC to deliver to the MVIxxE-AFC process-input values at a rate that complies with sample-period requirements of applicable Standards.

d. Configuring a gas meter channel to use a Coriolis meter that delivers volume flow as the channel's primary input; Directive 17 requires such a meter to deliver mass flow.

It is the responsibility of systems integration, operations, and/or administrative personnel to install, configure, and operate the MVIxxE-AFC in a manner that does not induce non-compliance except as may be permitted by regulation or statute and is agreeable to the parties concerned.

B. Using the MVIxxE-AFC to Implement General EUB Requirements

1. *Standard or Base Conditions*

The AER base conditions of 15°C and 101.325kPaa are default for the SI System of Units.

2. *Meter Types*

The MVIxxE-AFC supports most primary measurement devices used in the field, including orifice, turbine, nozzle, Venturi tube, V-cone, wedge, ultrasonic, and coriolis meters.

3. *Periodic Volumes*

Periodic volumes may be calculated by appropriate arithmetic on recorded accumulator values from all the archive records spanning the period, which values may be specified by appropriate configuration of the archive file. Great effort has been expended to make the default archive configuration comply with the Directive for all meter characterizations; in particular, the reportable “net” (corrected) volume is archived at full precision for all such.

4. *Caveats Concerning MPMS 21.2*

When designing the default layouts of the MVIxxE-AFC's archive records (the QTRs of the Standards) for the various meter characterizations, great effort was expended to reach for, simultaneously and to the greatest extent possible, several goals:

- To include all points necessary for compliance with Standards (MPMS 21, both sections) and regulations (e.g. this Directive).
- To include as many points as might be desired by users of third-party data collection packages such as FlowCal.
- To include all such desired points in the Enron history record for users of that protocol.
- To reduce user errors arising from differences in layouts by assigning the same or similar quantities to the same record locations across all meter characterizations.
- To anticipate changes and additions for supporting new features while continuing to strive for the other goals.

These goals were not all fully attained due to several constraints upon the design, such as maximum size of the archive record and extant layout of the Modbus database. Consequently some tradeoffs were made, including two that may affect strict compliance with MPMS 21.2. While the choices made for these tradeoffs still comply with our perceived intent of the Standard concerning QTRs, which is to include sufficient data to permit the QTR to be evaluated for validity and to enable corrected values to be calculated when the QTR is in error, strict interpretation of the Standard may deem those choices to constitute non-compliance. These tradeoffs are:

a) CTL, CPL, and CTPL

The MVIxxE-AFC implements MPMS 11.1 (2004), which introduced CTPL, the "Correction for the effect of Temperature and Pressure on Liquids", i.e. the product of CTL and CPL. All three values appear in the Meter Results section of the Modbus database, where CTPL is rounded per the Standard but CTL and CPL are unrounded retaining their full precision.

By default, the MVIxxE-AFC records in the QTR the single CTPL point instead of the two separate points CTL and CPL as required by MPMS 21.2.

To obtain strict compliance with API MPMS 21.2 a user must reconfigure the default archive record to contain the traditional CTL and CPL as separate points.

b) "Gross" vs "Indicated" volume

The MVIxxE-AFC computes up to six "calculated values" for flow increments and flow rates, which are "mass", "energy", three Standard "volumes", and "water" volume, and which are used across all meter characterizations where those "values" are relevant. One of these "volumes" represents volume at operating conditions; this could be either "Indicated Volume" which is calculated before applying the meter factor, or "Gross Volume" whose calculation includes the effect of the meter factor.

By default, for volume at operating conditions the MVIxxE-AFC records the "Gross Volume" in all database points and historical records. For the QTR of MPMS 21.2, this corresponds to the "(meter) readings". Since some meter types do not have a meter factor or do not have "volume" as primary input measured quantity, there is no distinction between "Gross" and "Indicated" volumes. For consistency, "Gross" was chosen across all types.

For some meter characterizations, including those to which MPMS 21.2 applies, setting the "Indicated volume" Meter Calculation Option causes recorded volumes nominally labeled as "Gross" to receive the "Indicated" volume instead, effecting strict compliance with the "readings" requirement of the MPMS 21.2 QTR. This option only selects the volume to be recorded; calculations are unaffected as all derived quantities such as "net volume" continue to use gross volume with the effect of the meter factor included.

5. *Meter Proving*

The proving support currently offered by the MVIxxE-AFC is limited in these respects:

a) For a line meter to be provable it must:
  - Measure a "classic" liquid hydrocarbon product (excluding gas, the emulsions, and water).
  - Deliver a pulse count representing volume at flowing conditions.
  - Not be in calibration mode.
  - Be configured with pressure input as "gauge".
  - Be enabled.

b) For a prover to be able to prove the line meter, it must be configured to match the line meter with the same:
  - System of Units and Density units.
  - Base temperature.

  For compliance with the Directive we recommend leaving these settings at their default values; this implies that a provable line meter must be configured accordingly.

c) For a master meter, it must be configured:
  - To match the line meter and prover constraints above.
  - For the same specific product as the line meter.
  - For the same reference conditions (base T and P) as the line meter.
  - With the same thermal expansion coefficient "alpha" (parameter of the active stream), if the product is a "special application" (MPMS 11.1 Tables "C").

d) Live oil proving: See the Note for sec 2.7.1 pages 2-18[72]ff below.

e) The necessary double-chronometry hardware support for SVPs is not natively available for the Rockwell platforms. At the present time such support is available only from third-party devices (such as the Swinton ST-103 counter module), use of which may require additional logic in the PLC program and additional communication modules in the PLC rack.

If all these constraints are satisfied then the management, calculation, and reporting of proving sessions is fully compliant when the configuration of the prover sets:
- System of Units to SI.
- Base temperature to 15°C.
- "Runs per prove" to be at least the minimum required by Table 2.2 of the Directive (sec 2.6, pages 2-15[69]).
- Prover option "Calculation method" to select "Average meter factor".
- Variation limit "Change in factor" to a non-zero value not exceeding that required by the "Maximum MF deviation" column of Table 2.2 (note difference in scaling: MVIxxE-AFC is "fraction" while Directive is "%").

To obtain the initial single "as found" run required by the Directive:

1. Disable any PLC logic that fully automates the proving session; in particular, any part that automatically:
   - Starts the next run when the previous run is complete.
   - Accepts (or rejects) the prove at session end.
2. Start a proving session and complete the first (successful) run.
3. Issue the "Reject prove" signal; this terminates the session without updating either the meter's configured meter factor or (later) its "Previous Prove Summary".
4. Report the results.

Then, to perform the "real" prove:

1. Start another proving session and run it to completion, including its final disposition of accept or reject. For this, PLC logic that fully automates the session may be re-enabled.
2. Report the results.

C. Notes on the AER Directive 017 of March 2016

General

- The MVIxxE-AFC cannot measure a multiphase stream (gas and liquid together); each meter channel can measure only single-phase fluids. Multiphase streams must be measured by other means. However, an "emulsion" stream (a "multiphase" liquid stream with hydrocarbon and water commingled) is measured using the techniques of MPMS 20.1, with accumulations, flow rates, and correction factors calculated separately for both the hydrocarbon and water components.

- The MVIxxE-AFC treats each meter channel as an independent entity and performs no calculations that utilize data from two or more channels; such calculations belong more appropriately to a plant-balancing or similar system. Even for an emulsion stream no value is computed that relates the flows of the two components. Consequently several factors, ratios, &c that appear in various locations throughout the Directive are not available from the MVIxxE-AFC but must be computed by other means, and calculations utilizing such values are not supported. These values include, without limitation:

  - Proration factors (including GPF, CPF, WPF)
  - Allocation factors
  - Metering differences, including "measurement by difference" techniques
  - Factors effecting battery-balancing calculations
  - ECF, effluent correction factor
  - GIS, gas-in-solution ("flash") factor
  - WGR, water-gas ratio
  - GOR, gas-oil ratio

- CGR, condensate-gas ratio
- LGR, liquid-gas ratio
- OGR, oil-gas ratio

Some of these values may be computable by suitable logic programmed into the PLC.

- The MVIxxE-AFC does not calculate a GEF (gas equivalent factor) or GEV (gas equivalent volume) for a liquid stream; this calculation, which requires a component analysis of the liquid, must be done by other means.
- The MVIxxE-AFC has no support for tracking inventory, such as changes to tank contents over an accounting period.
- The MVIxxE-AFC is a calculation device only, therefore all requirements concerning design, assembly, and installation are inapplicable.
- The MVIxxE-AFC is a communication server that is polled by external clients for reportable data and has no control over the subsequent presentation and/or disposition of that data, therefore all such requirements are inapplicable.
- The MVIxxE-AFC cannot estimate flows or adjust already recorded values and has no support for recording such estimations and/or adjustments; records thereof with any associated indicating flags must be created and maintained by other means.
- Concerning any requirement(s) of the Directive that refer, directly or indirectly, to MPMS 5.5 (pulse fidelity and security), or imply reference thereto:
  - The MVIxxE-AFC is natively capable of compliance with that Standard only to Level E. If the meter under consideration is equipped with a physical readout (e.g. of a non-resettable count of pulses issued) then Level D may be attainable using appropriate operational procedures. Higher Levels (C through A) are not possible natively on the Rockwell platforms which lack the necessary hardware for timely comparison of dual pulse trains.
  - However, the MVIxxE-AFC can raise a “pulse fidelity” alarm delivered from the PLC, so Level A is attainable via use of an appropriate third-party device. One such device is the Swinton ST-103 counter module, a stand-alone device that delivers its results via Modbus. An AOI (Add-On Instruction) is available for the PLC program that implements use of this device for Level A compliance.

  Mentions by the Directive of Measurement Canada requirements may constitute such references.
- **Where applicable, these caveats above are implicitly incorporated into all statements given below.**

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	MVIxxE-AFC ver. 4.03 Compliance
Chapter 1 - Standards of Accuracy	**Compliant**
The AFC module is covered by adherence to requirements in subsequent sections. (See bold text in the directive, Sec 1.2, p 1-1[19]).	
Chapter 2 - Calibration and Proving	**See Detail**

All requirements concern methods, procedures, scheduling, and reporting of meter physical inspection, transmitter calibration, meter proving, and tank gauging. Most of this is inapplicable to the MVIxxE-AFC, with these exceptions:

- Transmitter calibration –
  The transmitter calibration support of the MVIxxE-AFC enables compliance with the procedural and reporting requirements of the Directive; see Part A section "8" above.
- Meter proving (general) --
  Subject to limitations, the meter proving support of the MVIxxE-AFC enables compliance with the procedural and reporting requirements of the Directive; see Part B section "5" above.
- Live oil proving; sec 2.7.1 pages 2-18[72]ff
  The MVIxxE-AFC's proving calculations do not account for any transition between "live oil" at the meter and "dead oil" at the prover (physical or conceptual). No shrinkage factor (see sec 14.3.1 page 14-6[346] below) is applied at any stage. The Directive describes these cases:
  - Physical degassing
    In this scenario the oil is physically "dead" at the prover and the Directive requires the use of a tank prover. The MVIxxE-AFC's UDP prover type (see Part A section "9" above) may be applicable; if so, then the calculated meter factor will include the effect of the shrinkage and the "flashing" component of the SF for the meter's stream must be configured as 1 in order to prevent that shrinkage from being applied a second time by the meter calculations (any "blending" component of the SF should remain unchanged).
  - Application of a SF
    If the oil is physically "live" at the prover (no degassing has occurred) then the MVIxxE-AFC's calculated meter factor will be "clean" without including the effect of any other corrections such as shrinkage. It is unclear why a proving procedure might need a SF "to adjust the prover volume to atmospheric conditions"; the MVIxxE-AFC adjusts the prover volume according to correction factors computed per Standard without considering the nature of the fluid contained therein except as needed for those calculations; but the need might arise from the fact that the CPL of "live oil" would correct only to equilibrium pressure which would be higher than atmospheric.

Depending on the interpretation of the Directive's requirements, and in particular its reasoning behind case #2 above, it may or may not be possible to use the MVIxxE-AFC to support proving of "live oil" meters.

<table>
<tr><td>Chapter 3 - Proration Factors, Allocation Factors, and Metering Differences</td><td>See Detail</td></tr>
<tr><td colspan="2">Mostly inapplicable to the MVIxxE-AFC. However, see the Note below for sec 14.3 pages 14-6[346]ff.</td></tr>
<tr><td>Chapter 4 - Gas Measurement</td><td>See Detail</td></tr>
<tr><td>Sec 4.3.1 page 4-14[102] paragraph 4</td><td>See Detail</td></tr>
<tr><td colspan="2">The MVIxxE-AFC implements non-resettable counters (accumulators), accessible via Modbus; they can be displayed using an appropriately programmed Modbus master such as EAFC Manager, and they can also be displayed by the “Monitor” page of the module’s on-board website, but a permanent physical display thereof is outside the scope of the MVIxxE-AFC.</td></tr>
<tr><td>Sec 4.3.1 page 4-15[103] items “2”, “3”, “4”, and “5”</td><td>Compliant</td></tr>
<tr><td colspan="2">The MVIxxE-AFC can measure flow through an ultrasonic or coriolis meter, provided that it can issue a pulse train that represents gross volume or mass flow (configure the channel as "linear/pulse count"), or supply an output that represents gross volume or mass flow rate (configure the channel as "differential/flow rate integration"). For compliance with the Directive, the "measured quantity" of these outputs (the module’s “K-factor Characteristics” or “Primary Input Characteristics”) should be configured as "Volume" for ultrasonic meters and must be configured as "Mass" for coriolis meters.

The MVIxxE-AFC can measure flow through a nozzle, Venturi tube, V-cone or wedge meter (configure the channel as "differential/differential pressure", set the “Physical device” drop-down to the appropriate selection, and enter values from the device's calibration sheet or calculated therefrom by a spreadsheet from ProSoft).
Temperature, pressure, and compressibility corrections are calculated using AGA 8 (1994) Detail Characterization Method in conjunction with the real gas law.</td></tr>
</table>

Sec 4.3.2 pages 4-16[104]ff	***Compliant; See Detail***

All meter types provide as primary input one of:

- Differential pressure:

  Mass flow rate is calculated using the Bernoulli equation with diameter ratio "Beta", expansion factor "Y", and coefficient of discharge "Cd" determined according to meter type:

  - Orifice:
    - Beta calculated from entered pipe and orifice diameters, both diameters compensated for temperature.
    - Y and Cd calculated using AGA 3 (1992 or 2012) or ISO 5167-2 (2003).
  - Nozzle, Venturi tube, V-cone, Wedge:
    - Enter pipe and throat or cone diameters.
    - Set “Physical device” drop-down to the appropriate selection; this causes the MVIxxE-AFC to use the correct "orifice-equivalent" Beta (temperature-compensated) in its calculations and to use a Standard calculation for Y.
    - Let the system use the Cd from the Standard, or override it from the meter's calibration sheet.
    - For a wedge device, use a ProSoft-supplied spreadsheet to calculate from data on the calibration sheet the equivalent "cone diameter" and "coefficient of discharge", and enter those values; calculation then proceeds as for a V-cone.

- Pulse count and/or frequency representing Gross Volume or Mass flow:

  Flow increments and/or rates are calculated as (pulses)/(K-factor)*(meter factor). If pulse count is supplied then pulse frequency must also be supplied in order to calculate flow rate; this is to avoid irregularities in flow rate that would occur should the MVIxxE-AFC attempt to differentiate the increment over time.

- Gross Volume or Mass flow rate: Used directly.

The primary input thus yields either or both of a flow increment and a flow rate, measuring either Gross Volume or Mass. If the increment is not yet available (pulse count not supplied), then the increment is calculated by integrating the rate over time. Calculation of the other quantity of Gross Volume or Mass, and of Net Volume, is accomplished using the real gas law PV=ZNRT and the mass-volume-density relation M=VD, with compressibilities Z and densities D derived from molar analysis via the Detail Characterization Method of AGA 8 (1994); any gas densities available from the meter are not used. Updating the physical constants used by the MVIxxE-AFC to the latest values from the GPSA Engineering Data Book or GPA-2145 can be accomplished by replacing the MVIxxE-AFC's firmware with an updated version that contains those latest values; the MVIxxE-AFC version 4.03 uses values from GPA-2145-16 which now incorporates the GPSA values.

All meter types supply a meter factor derivable via a 5-point linearization curve (optionally “K-factor” for linear meters); Flow rate unit is that of the output flow rate for the primary input’s measured quantity.

Sec 4.3.3 pages 4-18[106]ff	***Compliant***
The MVIxxE-AFC complies with all requirements of MPMS 21.1, hence complies with the Directive's reporting and audit trail requirements. It has extensive on-board support for recording historical data, in particular for all data that are required but cannot be obtained from outside the MVIxxE-AFC itself. The MVIxxE-AFC's historical records include its event and alarm logs, archive files, and transmitter calibration files, from which required data can be obtained directly or calculated therefrom.	
Sec 4.3.4 pages 4-23[111]ff	***Inapplicable***
Inapplicable to the MVIxxE-AFC.	
Sec 4.3.5 pages 4-28[116]ff	***See Detail***
While nether a GIS nor a GOR is computed by the MVIxxE-AFC, some support for the complementary measurement (of the degassed liquid) is available via use of the "Shrinkage factor" configurable parameter; see the Note below for sec 14.3 pages 14-6[346]ff.	

Sec 4.3.6.1 page 4-36[124]	*Compliant within scope; See Detail*

By bullet:

1. Retention period
   - Event and Alarm logs store up to 2000 records each. Retention period will depend on the rate at which those events or alarms occur.
   - Archive files are sized by default for 35 days of both daily and hourly records; this extent may be increased. Actual duration may be shorter, depending on how many additional "exception" records are written as a consequence of e.g. events that occur.
   - The latest transmitter calibration files as described in Part A section "8" above are retained indefinitely (until replaced with new latest ones).
   - All records may be offloaded to more permanent storage at any time.
2. Persistent storage
   - All configuration, accumulators, and historical records are kept in non-volatile storage.
3. Security levels
   - See Part A section "13" above.
4. Alarms
   - See Part A section "5" above.
   - Flow:

     There is no separate "flow" alarm. Flow alarms for the primary input (low and high) can be effected using the "threshold" settings in the Process Input Scaling configuration. There is no support within the MVIxxE-AFC itself for alarming computed (output) flow rates; however, as the net volume flow rate is continuously updated to the PLC that device could raise such alarms.
   - Low power:

     The MVIxxE-AFC by itself does not have the capability for alarming this condition; however, as it obtains its power from the PLC backplane the PLC itself may support this alarm.
   - Communication failure:

     Such alarms are not issued for loss of external communications as the MVIxxE-AFC is a Modbus slave and does not initiate such, while loss of internal communications (with the PLC) is logged as an event.
5. Configuration changes and forced inputs
   - Changes to "sealable" parameters are recorded in the Event Log.
   - Process inputs are delivered from the PLC and the MVIxxE-AFC cannot distinguish between forced and live, hence forced inputs must be identified by other means. However, inputs that are "frozen" for transmitter calibration are recorded in the Event Log as changes to the "process input calibration mode" flags in Meter Configuration.
6. Identification of forced-data effects

   The document "Dependencies of outputs upon process inputs.xlsx", available separately, lists the outputs that must be potentially "identified" as calculated from forced inputs. As the MVIxxE-AFC cannot know whether an input is forced (except in the specific case above) it cannot itself flag such outputs as "identified".

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<table>
<tr><td>4.3.6.2 Test cases pages 4-37[125] to 4-47[135]</td><td>Compliant</td></tr>
<tr><td colspan="2">Compliance of the MVIxxE-AFC's calculations with the requirements of the AER Test Cases is available in a separate document.</td></tr>
<tr><td>Sec 4.3.6.2 EFM Reports pages 4-48[136] to 4-50[138]</td><td>Compliant</td></tr>
<tr><td colspan="2">All information required for these reports can be obtained via the MVIxxE-AFC's Modbus database or can be calculated therefrom, with these exceptions:
For differential-pressure meters (e.g. orifice), the two "materials" (of meter tube and orifice plate) are not configured as such but each is instead configured directly as its thermal expansion coefficient which is the only property of the material that is relevant to the calculation. Accepted coefficient values for commonly used materials are available from within EAFC Manager without requiring reference to the relevant measurement Standards.
For the primary input (e.g. differential pressure), a low-flow cutoff may be configured such that input less than that value is deemed to be zero. However, there is no corresponding high-flow cutoff; instead, one can use the high operating range limit (which alarms and causes substitution of the last-good value) or the high threshold alarm (which alarms but causes no substitution); see Part A section "2(c)(1)" above.
As the MVIxxE-AFC does not calculate an ECF it cannot log changes thereto; similarly, changes to "other manual inputs" that are not available to the MVIxxE-AFC (such as forced inputs) are not logged by the MVIxxE-AFC.
MTU and RTU failures are not logged as alarms; however, restarts of the MVIxxE-AFC firmware are logged as events ("power-up").
Logging of communication, low-power, and output flow-rate alarms is limited; see the Note against sec 4.3.6.1 bullet #4 above.</td></tr>
</table>

Chapter 5 - Site-specific Deviation from Base Requirements	**Inapplicable**
Outside the scope of the MVIxxE-AFC.	
Chapter 6 - Conventional Oil Measurement	**Compliant, See Detail**
Sec 6.1 page 6-1 [175]	***Inapplicable***
The MVIxxE-AFC does not implement tank gauging.	
Sec 6.3.1 page 6-4 [178]	***Compliant, See Detail***
Except for caveats detailed in Part B section "4" above, the MVIxxE-AFC complies with all requirements of MPMS 21.2, hence complies with the Directive's reporting and audit trail requirements. It has extensive on-board support for recording historical data, in particular for all data that are required but cannot be obtained from outside the MVIxxE-AFC itself. The MVIxxE-AFC's historical records include its event and alarm logs, archive files, and transmitter calibration files, from which required data can be obtained directly or calculated therefrom.	
Chapter 7 – Gas Proration Batteries	**Inapplicable**
Outside the scope of the MVIxxE-AFC.	
Chapter 8 – Gas Liquid Sampling and Analysis	**Inapplicable**
Outside the scope of the MVIxxE-AFC.	
Chapter 9 – Cross-Border Measurement	**Inapplicable**
Outside the scope of the MVIxxE-AFC.	
Chapter 10 – Trucked Liquid Measurement	**Compliant**
Compliant, when within the scope of the MVI56xxE-AFC.	
Chapter 11 – Acid Gas and Sulphur Measurement	**Inapplicable**
Outside the scope of the MVIxxE-AFC.	

Chapter 12 – Heavy Oil Measurement	**See Detail**
Section 12.3.4 pages 12-12 [326]ff	***Compliant, See Detail***
While the MVIxxE-AFC can measure hydrocarbon (including emulsion and gas) and water streams, it cannot measure steam.	
Chapter 13 – Condensate and High-Vapour-Pressure Liquid Measurement and Reporting	**Compliant**
Compliant when within the scope of the MVIxxE-AFC.	
Chapter 14 – Liquid Measurement	**See Detail**
Section 14.1.3 page 14-1 [341]	***Compliant, See Detail***
See note for section 6.3.1 page 6-4 [178] above.	
Section 14.3 pages 14-6 [346] ff	***Compliant***

The MVIxxE-AFC provides a "Shrinkage Factor" parameter as described in MPMS 20.1 that is configurable for each stream of each meter channel that measures hydrocarbon liquids. This factor may be used to account for reduction in volume due to flashing of dissolved gas and/or blending of products having dissimilar densities.
• In the MVIxxE-AFC, this factor is equivalent to: (final volume) / (original volume) where the volume loss occurs during the transition from "original" to "final" and a factor value of 1 means "no shrinkage". This meaning may differ from the Directive's meaning, which in places appears to be the factor that represents the volume loss itself, so that: (MVIxxE-AFC's SF) = 1 - (Directive's SF)
• The MVIxxE-AFC applies its SF to the final Net Volume increment and flow rate, after all other corrections and conversions. The SF is not applied to other derived quantities such as "mass". The MVIxxE-AFC cannot distinguish the two sources of shrinkage, which have different effects upon mass:
  ◦ Flashing: loses the mass of the flashed gas.
  ◦ Blending: loses no mass.
• The MVIxxE-AFC does not balance this shrinkage by e.g. separately accumulating the loss; that quantity merely disappears.
• The MVIxxE-AFC's SF is configured, not calculated.
• For "live oil" meter proving considerations (sec 14.3.1), see the Note above for sec 2.7.1 pages 2-18 [72]ff.	

Section 14.4 and 14.5 pages 14-8 [348] ff	***Compliant***
Calculation and application of correction factors (CTL, CPL, CTPL) can be configured for a wide range of scenarios. All calculations are per MPMS 11.	

Section 14.9.1.1 page 14-16 [356] to 14-19 [359]	*Compliant*

All values and computations are supported, subject to these comments:

- Also see Part B section "4" above.
- Internally, the MVIxxE-AFC implements all equations given here, as appropriate for the meter configuration. Calculations suggested below are for use off-line when verifying and/or correcting QTRs.
- Indicated Volume:
    - For meters delivering a pulse train representing volume at operating conditions, all terms in equation #2 can be calculated from values in a single archive record having the default configuration together with the "Pulse count rollover" of Meter Configuration; calculating the IV itself does not need the rollover (the archive contains the pulse increment directly). To use equation #1 the meter must have the "Indicated Volume" option set and two successive archive records must be used.
    - For other meters the IV is unavailable. In such cases equation #1 can calculate GV instead (from two successive archive records), with the understanding that the MF is already included and should not be applied a second time when calculating GSV.
- Gross Standard Volume:
    - The MVIxxE-AFC uses CTPL instead of separate CTL and CPL.
    - The MVIxxE-AFC does not employ equation #3.
    - For mass meters (e.g. coriolis delivering mass-pulses), the form of equation #4 is used to calculate GV (= Mass / DEN_o).
- Net Standard Volume:
    - Called just "Net Volume" by the MVIxxE-AFC.
    - Calculation is as given.
- Water Cut
    - The MVIxxE-AFC does not calculate a water cut. However, for emulsions it uses a rearrangement of these equations to calculate the split of the two components from inputs of temperature, pressure, $DEN_{obs,e}$, $DEN_{b,w}$, and WaterCut, with byproducts $DEN_{obs,o}$ and $DEN_{obs,w}$. So that this rearranged calculation can remain sufficiently distant from a mathematical singularity at least 1% hydrocarbon content is required in the emulsion stream.
- Composite Meter Factors
    - The MVIxxE-AFC supports CMFs by appropriate configuration (e.g. settings of Meter Calculation Options to enable/disable CTL/CPL).

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Section 14.9.1.2 pages 14-19 [359] to 14-20 [360]	*Compliant*
The MVIxxE-AFC uses the fundamental Bernoulli equation (of MPMS 14.3) to calculate Q_m, from which it calculates Q_f (same as GV) by dividing by ρ_f (RHO), then Q_b by applying the linear-meter corrections. For emulsions, the inverted WaterCut calculation given above is applied, where $DEN_{obs,e} = \rho_f$ (RHO).	
Section 14.9.1.3 pages 14-20 [360] to 14-21 [361]	***Compliant***
The MVIxxE-AFC is fully compliant with the current Standards, provided that for NGL product groups the Meter Calculation Option "Strict MPMS 11.2M" is set.	
Section 14.10 pages 14-21 [361] to 14-22 [362]	***Compliant, See Detail***
For "Hardware and software requirements" see the Note above for sec 4.3.6.1 page 4-36 [124], all of which applies here.	
Section 14.10 Test Cases ***pages 14-22 [362] to 14-26 [366]***	***Compliant***
• The hydrometer correction calculated by the MVIxxE-AFC conforms to the method specified in the current MPMS 11.2.4 (GPA TP-27); the MVIxxE-AFC does not implement any other hydrometer correction calculation. • Compliance of the MVIxxE-AFC's calculations with the requirements of the AER Test Cases is available in a separate document.	
Section 14.11 Records and Reports ***pages 14-27 [367] to 14-30 [370]***	***Compliant***
See the Note above for section 4.3.6.2 page 4-48 [136] to 4-50 [138], all of which applies here.	
Chapter 15 – Water Measurement	**See Detail**
• The MVIxxE-AFC can measure liquid water with the "Produced/injected water" product group, with optional correction for temperature (not pressure). • The MVIxxE-AFC cannot measure steam (water in the vapor phase).	
Appendix 1 – AER Documents Replaced	**Inapplicable**
Outside the scope of the MVIxxE-AFC.	
Appendix 2 – Glossary	**Inapplicable**
Not applicable to the MVIxxE-AFC.	

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Appendix 3 – Water-Cut (S&W) Procedures	**Inapplicable**
Outside the scope of the MVIxxE-AFC.	
Appendix 4 – On-Site Analytical Techniques for H2S Measurement	**Inapplicable**
Outside the scope of the MVIxxE-AFC.	
Appendix 5 – Gas Equivalent Volume Determination	**Inapplicable**
Outside the scope of the MVIxxE-AFC.	
Appendix 6 – Calculated Compositional Analysis Examples	**Inapplicable**
Outside the scope of the MVIxxE-AFC.	
Appendix 7 – Blending Shrinkage Calculation Example	**Inapplicable**
Outside the scope of the MVIxxE-AFC.	
Appendix 8 – Schematic Example	**Inapplicable**
Outside the scope of the MVIxxE-AFC.	
Appendix 9 – Gas Group Delineation	**Inapplicable**
Outside the scope of the MVIxxE-AFC.	