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On-line Measurement of Water Content in Petroleum and Petroleum Products

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Introduction

The purpose of this standard is to provide the requirements for the installation and operation of a water cut analyzer (WCA) for dynamic measurement of water content in petroleum and petroleum products to be used in conjunction with an automatic sampling system that is compliant with API *MPMS* Chapter 8.2.

It may not be possible, nor desirable, to inject water as a test medium into refined products. It is not a requirement to use a proven automatic sampling system in conjunction with a WCA for refined products measurement.

NOTE A "WCA" is sometimes used in this document to denote a complete system (WCA System) to provide this function or be used to describe the key instrument depending on context.

WCA technology is one of several methods to determine water content in petroleum and petroleum products. WCA technologies should be selected with consideration given to the application (properties of the product(s) being measured, the process conditions, installation, operation and maintainability).

Acceptability of the results from a WCA for operation with different petroleum or petroleum products under different process conditions to those originally tested requires ongoing verification.

The standard is applicable, by contract agreement, to the use of a water cut analyzer as a secondary measurement device while the primary sampling system is temporarily out of service, i.e. due to an equipment failure.

This standard also provides useful guidance that could be applied in the use of WCA's for non-custody transfer measurement applications, although in this instance the need for Performance Acceptance Testing (PAT) and ongoing verification may not be commercially required.

On-line Measurement of Water Content in Petroleum and Petroleum Products

1 Scope

To provide requirements for application, installation, operation, testing, and ongoing verification for the use of a water cut analyzer (WCA) for custody transfer of petroleum and petroleum products which shall be used in conjunction with an automatic sampling system that is compliant with API *MPMS* Chapter 8.2.

It is not a requirement to use a proven automatic sampling system in conjunction with a WCA for petroleum products measurement.

This standard also provides guidance that could be applied to the use of WCA's in other applications i.e. the use for quality determination.

2 Normative References

The following documents are referred to in the text in such a way that some or all of their content constitutes the 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 6.1A, *Manual of Petroleum Measurement Standards Chapter 6.1—Lease Automatic Custody Transfer (LACT) Systems*

API *MPMS* Chapter 8.2, *Standard Practice for Automatic Sampling of Petroleum and Petroleum Products*

API *MPMS* Chapter 8.3, *Standard Practice for Handling and Remixing Samples of Petroleum and Petroleum Products*

3 Terms, Definitions, and Abbreviations

For the purposes of this document, the following definitions apply.

3.1
aliquot
A small portion of a larger sample which is analyzed and assumed to represent the whole sample.

3.2
auxiliary measurement device
Additional measurement devices required to allow the primary measure to be made. For example, this can be density, temperature, salinity or other properties that may influence the primary measurement.

3.3
flow-weighted average (FWA)
The average of a variable weighted by the flow rate or incremental volume. It can be the average of the variable values sampled at uniform volume intervals, or it can be the average of variable values sampled at uniform time intervals and weighted by the incremental volume that occurred during that time interval.

3.4
performance acceptance testing (PAT)
Performance testing that allows the WCA system to be validated for use in a specific application (see also verification testing).

3.5
representative sample
A portion extracted from a total volume that contains the constituents in the same proportions that are present in that total volume.

3.6
verification testing
Ongoing testing that confirms that the WCA system is within operating specifications.

3.7
water cut analyzer (WCA)
Device that provides online, continuous measurement of water content in a hydrocarbon/water mixture and when used with a flow meter can totalize the water content over a given flow period.

3.8
WCA system
One or more WCAs, stream conditioning, other measurement devices (for example, temperature, pressure, density, flow), and a computer to assimilate, compile, and report the data.

4 Significance and Use

The WCA provides instantaneous water percentage readings. When coupled with a metering device and a flow-weight averaging calculation, the total amount of water and average water content over a given flow period can be determined.

5 System Design

5.1 Some WCA models accept a flow signal and calculate total water volume and flow weighted average "FWA" water content. Alternatively, total water volume and flow weighted average water content can be calculated within another device as described in API *MPMS* Chapter 21.2.

5.2 The standard does not preclude any technology that meets the acceptance criteria.

5.3 A WCA may require additional auxiliary measurement equipment or instruments such as temperature, pressure, or density. Consult the manufacturer for application guidance.

5.4 All auxiliary measurement devices and equipment associated with the WCA system shall be verified at a frequency that is consistent with the calibration verification frequencies recommended by the manufacturer, contract, regulatory agencies or company policy or procedures, used for other measurement instrumentation, whichever interval is more stringent.

5.5 A WCA can be a full bore (spool) or an insertion type device; the WCA can be installed directly in the primary process piping or within a slip stream. (see Annex A).

5.6 The WCA system installed should be ranged/scaled to allow optimal accuracy for normal service recognizing that excursions beyond the normal range can have significant influence on the overall accuracy, for example, where water slugging occurs.

5.7 In a worst-case scenario any "out of range" reading above the maximum scaled value could be 100 % water. Consideration may be given to the addition of another WCA to cover this exception or in sacrificing accuracy at lower concentrations (where a WCA is scaled 0 %–100 %) at the user's discretion. In the event the WCA is out of range, the volume that has passed through the pipeline for which the WCA is out of range should be recorded for analysis and estimation.

5.8 To improve the confidence in the WCA system, the effect of the uncertainties of any auxiliary instruments used for compensation (for example, density/temperature) should be considered. An example of uncertainty calculations can be found in API *MPMS* Chapter 13.3.

5.9 A WCA system should be capable of providing a secure full audit trail of changes to its configuration including alarm logging. (see Section 9—Audit Trail and Security).

5.10 The following are potential influences on the performance of the WCA. The impact of these can depend on the instrument technology and the manufacturer specifications of the WCA. Consult the manufacturer for additional information.

— Non-homogeneity of the flow in the main process and, when applicable, in the sample loop. Flow velocity operating range should be within the measuring elements acceptable design range avoiding cavitation and free gas.

— Liquid composition—For example: Chemicals including additives, sand, wax, scale, salinity, asphaltenes.

— Ambient and process temperatures and pressure variations.

— Density and viscosity of hydrocarbon.

— Installation effects, including orientation and position of measurement elements, vibration, bending moments.

6 Installation of a Water Cut Analyzer System

6.1 General

6.1.1 The WCA system shall be installed in a homogenous flowing stream as described in API *MPMS* Chapter 8.2, take care to avoid hydraulic interference with devices in close proximity; for example, between an in-line sample probe and an in-line WCA.

6.1.2 The WCA system shall be installed per the manufacturer's recommended installation guidelines.

6.1.3 For a WCA installed in a slip stream sample loop, the flow through the loop shall be representative of the main flowing stream.

6.1.4 The slip stream sample loop shall be monitored as required for the automatic sampling system in API *MPMS* Chapter 8.2.

6.1.5 A means of recording the WCA instantaneous and FWA readings shall be provided for calibration/verification/diagnostics.

6.2 Retrofit Installations

6.2.1 The WCA system should be tested as soon as practicable after installation as outlined in Section 7.

6.2.2 If the water injection test is not performed immediately after retrofit installation, then the WCA data collection and ongoing verification should start as outlined in Section 8.

6.2.3 During this transition period, the WCA should not be used as a fallback to the sampling system unless the interested parties agree to do so on specific conditions and for a limited time.

6.3 Manual Spot Sampling Point

6.3.1 In addition to those within API *MPMS* Chapter 8.1, the manual sample point design should consider the following.

6.3.2 A manual spot sample point shall be installed to allow troubleshooting/diagnostics of the WCA. The volume of a manual spot sample is determined as suitable to the container volume and the analytical method; typical sample sizes can be between a few milliliters and a liter.

6.3.3 To allow for diagnostics/verification of the WCA and to ensure a representative sample is taken, the manual sample point should be as close as practical to the WCA.

6.3.4 Where water is fully entrained, it can separate slowly from the oil and therefore a volume collected may be easily and reproducibly subsampled. However, this is not the case when water has been injected or for free water within low viscosity products. Therefore, it is critical that the manual sample process allows for the required volume of sample to be taken in a controlled manner.

6.3.5 A manual sample point includes a primary isolation valve and sometimes a second valve that can be used to better control the flowrate. A local pressure gauge between the primary and secondary isolation valves can prove useful to adjusting the flow rate. This may be accomplished by using the primary valve as an isolation valve to start and stop the flow of the sample and using the second valve to achieve a desired sample flow rate.

6.3.6 The interconnecting tubing between the manual sample extraction point and the sample receptacle (or glassware, whichever is used) shall be as short as possible and free of any water traps, flushed to waste at a rate and volume sufficient to clear any residual fluids immediately before drawing each sample.

6.3.7 The manual sample point tubing shall be sized so that the operating flowrate is turbulent to prevent any water fallout.

6.3.8 It is recommended that an estimate is made of the volume between the tip of the manual sample probe (if used) and the end of the tubing entering the collection vessel; and that between 6 and 10 times this volume is flushed to waste immediately prior to drawing each sample collected for analysis.

6.3.9 The adjustment of flowrate used through the manual sample point can be influential on the repeatability/reproducibility of the result. Once adjusted, this flowrate shall not be changed during the acceptance testing process.

7 Performance Acceptance Testing (PAT)

7.1 General

This section describes the method for PAT of WCA systems used in conjunction with automatic sampling system.

7.1.1 The basis of the PAT procedure is described in API *MPMS* Chapter 8.2, *Water Injection Volume-Balanced Tests* which is a direct comparison of the primary measure of metered oil and metered injected water passing the automatic sampling system. These same primary measures can be used to evaluate the performance of the WCA system.

7.1.2 After a WCA system is installed and commissioned, the WCA system performance shall be tested prior to, and at intervals that shall follow the recommendations used for the automatic sampling system as outlined in API *MPMS* Chapter 8.2.

7.1.3 The test procedure for a WCA system is shown in this section and within the flowcharts Figure 2 and Figure 3.

7.1.4 The manual sample point shall be tested as part of the PAT procedures according to the procedure shown in Figure 2. It is recommended that the manual sample point is adjusted for flowrate per the recommendation of 6.3 before the main testing is undertaken. Verifying the manual sample point requires comparing the repeatability and reproducibility of the analysis of manual samples drawn against both the results from the automatic sampler and from the WCA system.

7.1.5 The testing of the manual sample point (not from the sample extractor) requires comparison of samples taken during the baseline sample collection periods and during the water injection phases of the test.

7.1.6 Because the measurement output from a WCA is continuous and manual spot samples are taken at a specific point in time, it is also recommended to check the short-term stability of the baseline water concentration. WCA readings and short-term baseline water concentrations are considered stable if the WCA reading does not vary by more than ± 0.03 % water by volume over a 10 second period.

7.1.7 When practical, the process flow rate should be increased for a few minutes, before starting a PAT and immediately after each water injection test period and prior to stopping the automatic sample collection/WCA FWA period, to clear any low spots of residual water that may have collected in the upstream process piping.

7.1.8 When water injection starts, there will be a delay before the water reaches the sampling system due to the distance/volume of the pipeline between the water injection point and the sampling system. After the water injection stops allow adequate time/volume for this to be flushed through before ending sample collection/WCA recording. An estimate of the volume between the water injection point and the sampling system will determine the minimum volume that must pass, but generally a volume between four to six times this volume should ensure all the water has passed. (See Note in 7.2.2.1 which proposes using the reversion of the WCA “instant reading” to “baseline values” as a better indication that the water has passed.)

7.1.9 All components of the WCA system shall be verified or calibrated per manufacturer’s guidelines prior to, or in conjunction with, installation and before the execution of any PAT.

7.1.10 The WCA or any related ancillary instruments shall not be calibrated or adjusted in any manner that could affect the water content measurement during the PAT (after Step 6 of flowchart Figure 2). During subsequent operations, if the WCA calibration values require adjustment, these shall be recorded in such a way as to allow direct comparison of all WCA batch values to a single reference calibration point for the application.

7.1.11 WCA readings shall be collected only under flowing conditions.

7.1.12 All WCA system readings taken during the testing process should be compensated by any appropriate additional measurements as required (for example, density, temperature, pressure) so that the WCA readings are a direct representation of the calculated water content. Raw (uncompensated) data should also be recorded, if available.

7.1.13 All samples taken for the purpose of determining water content for a given product or crude types shall be handled and thoroughly mixed per API *MPMS* Chapter 8.3.

7.1.14 For petroleum products it may not be possible, nor desirable, to inject water as a test medium for the PAT. It is not a requirement to use a proven automatic sampling system in conjunction with a WCA for this service.

7.2 Test Procedure for PAT

The PAT comprises water injection in accordance with API *MPMS* Chapter 8.2.

The manual sample point is used to assist in diagnostics, the WCA shall be validated/verified during this testing process.

Two sequential water injection tests are required as per API *MPMS* Chapter 8.2.

The PAT comprises Baseline Testing (Figure 2) and Water Injection Testing (Figure 3). The sequence (Figure 1) is normally:

— baseline test;

— first water injection test;

— baseline test;

— second water injection test;

— baseline test.

NOTE If the runs are sequential and in short order the ending baseline from the first run is used as the starting baseline for the second run.

In seeking to determine the target water injection percentage for the PAT, the total "injected water percentage" is the total volume of water injected divided by the total volume of oil and water that flows during the collection of the sample. Calculating "injected water percentage" as only the volume of water injected divided by the total volume that passes during injection of water would result in an actual water percentage being lower than targeted for the test. The water (injection) will be turned on after the sample collection starts and turned off before the sample collection stops. There is no water injection taking place in the period before water injection starts and the period afterwards where the residual injected water is flushed through. Allow for this effect on reduction of the water content actually injected when calculating the required water percentage during the test. A graphical representation of the test sequence is shown in (Figure 1).

The baseline refers to the water concentration present in the crude oil being tested. API *MPMS* Chapter 8.2 defines limits for a shift in baseline across each individual test. The overall acceptance criteria depend upon the assumption that if the baseline water concentration changes, it will do so linearly over the duration of the test and therefore an average value may be used.

Section 7.2.4 and Table 1 shows the test comparisons used for PAT and summary of acceptance criteria.

7.2.1 Baseline Testing

Baseline testing process is also shown in the process diagram Flowchart for WCA System Acceptance Testing, see Figure 2.

The baseline shall be "stable" over the duration of the PAT. API *MPMS* Chapter 8.2 defines acceptance criteria. It does not define the difference between baseline stability and baseline shift. Stability is defined in 7.1.

7.2.1.1 WCA Verification During Baseline

Under API *MPMS* Chapter 8.2 baseline sampling, there are two methods available to determine the baseline at the start and end of the performance acceptance test by the composite or spot sample.

a) Composite Sample—A sample is taken directly from the automatic sample extractor into a sample container.

   The volume to be collected shall be equal or greater than the Sv_{Min} (Per API *MPMS* Chapter 8.2) and it shall be collected using the standard container type fitted to the system [Method A in Figure 2, Flowchart for WCA System Acceptance Testing (Baselines)].

   If a smaller container is being used, then it is desirable to connect the container as closely as possible to the sample extractor to reduce the volume between the sample extractor and the container [Method B in Figure 2, Flowchart for WCA System Acceptance Testing (Baselines)].

   If a baseline composite is taken, the WCA result is to be flow-weighted averaged over the same volume (i.e. the FWA shall be initiated simultaneously with the start of the sample and end when the sample is stopped].

b) Spot Sample—A minimum of three consecutive spot samples are taken directly from the outlet of the automatic sample extractor into separate intermediate sample containers which are then analyzed. These three samples may comprise a volume collected of several sample grabs over a period of 5–10 minutes. [Method B in Figure 2, Flowchart for WCA System Acceptance Testing (Baselines)]. Whereas in this latter example, the sample collection period is extended, if possible, the WCA readings shall be flow-weighted

averaged (FWA). If this is not possible, note the WCA reading several times during the sample collection period and average the WCA result. The results of each of these three sets of analyses shall be within the allowances in API *MPMS* Chapter 8.2 performance acceptance test procedure.

The spot sample method of baseline sampling in many cases has an advantage in that the overall volume of oil passed through the process stream used for the performance acceptance testing is lower, less sample processing and container cleaning are required and the short-term shift (stability) in baselines is quickly determined.

7.2.1.2 Manual Sample Point—Verification during Baseline Testing

7.2.1.2.1 Each set of three baseline manual samples shall comprise the collection of three separate "spot" samples.

7.2.1.2.2 The WCA readings shall be recorded at the same points in time as the manual sample point samples are collected.

7.2.1.2.3 In accordance with the processes described in 7.2.1.1 Method a), a set of three "spot" samples shall be collected from the manual sample point while the composite baseline is being collected (where, for example, a composite sample collection can take perhaps up to an hour).

7.2.1.2.4 In accordance with the process described in 7.2.1.1 Method b), a set of three "spot" samples shall be collected from the manual sample point described concurrent with the collection of samples from the sample extractor.

7.2.2 Water Injection Testing

This section describes the main water injection testing period and is reflected in the "Flowchart for WCA System Acceptance Testing" in Figure 3.

7.2.2.1 WCA—Verification During Water Injection

7.2.2.1.1 At the start of each Test Sample Period, the WCA FWA readings shall be initiated at the same time as the oil volume measurement is recorded, and the automatic sample collection is started.

7.2.2.1.2 At the end of the Test Sample Period, the WCA FWA is read at the same time as the oil volume is recorded, and the automatic sample collection is stopped.

NOTE The WCA trend (i.e. water values returning to baseline levels) can normally be used to monitor the passing of the last of the injected water through the system (shown as "Test Sample Period" in Figure 1).

Figure 1 shows the timing of one of the tests, and Figure 2 and Figure 3 provide a flow diagram of the test procedures for both baseline and water injection phases including the procedure required to validate a manual sample point.

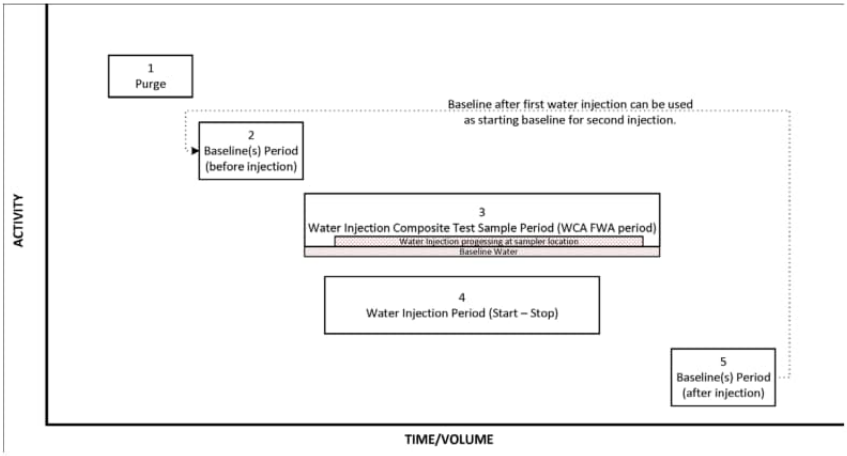


Figure 1—Example Timing Diagram for One WCA System Test Run

NOTE Since the water injection point is upstream of the sample point, the composite test sample (FWA averaging period) should be started before the water injection is started and stopped after the water injection stops with an allowance for all the water to have passed the sample point.

7.2.2.2 Manual Sample Point—Verification During Water Injection

7.2.2.2.1 Manual samples shall NOT be drawn from the sample extractor during the water injection phase of the PAT as this would negate the integrity of the composite sample collected.

7.2.2.2.2 Manual samples shall only be collected from the Manual sample point.

7.2.2.2.3 For each set of manual samples, a minimum of three consecutive spot samples are taken directly from the manual sample point into a separate sample container which is then analyzed. These samples may also comprise a volume collected from several sample grabs over a period of time, normally 5 to 10 minutes.

7.2.2.2.4 Where, as in this latter example, the sample collection period is extended, if possible, the WCA readings shall be flow-weighted averaged. If this is not possible, note the WCA reading several times during the sample collection period and average the WCA result.

7.2.2.2.5 When feasible, taking more than one set of test samples during the water injection phase improves the confidence in the overall repeatability of the manual sample point.

7.2.2.2.6 The results of each of these three sets of analyses shall be within the allowances in API *MPMS* Chapter 8.2—Performance Acceptance Test, when compared with the calculated water injection values.

7.2.2.2.7 Normally, each spot sample taken shall have a minimum of three aliquot samples analyzed, the results of which shall be within the repeatability of the testing method.

NOTE Where a spot sample is taken from a manual sample valve or directly from the outlet of an automatic sample extractor, there will be a tendency for water to settle in the container and unless the aliquots can be drawn immediately (as opposed to minutes later), it is recommended that the container is re-homogenized using an insertion shear mixer.

7.2.3 Evaluation of Results

This section defines acceptance criteria for the WCA and the manual sample point including for diagnostics for the WCA.

7.2.3.1 General

7.2.3.1.1 Where a WCA does not meet or cannot be modified to meet the acceptance criteria below, the device shall not be used for custody transfer but can still be extremely useful for trending and process control.

7.2.3.1.2 The evaluation criteria for the standard Performance Acceptance Testing (water injection testing) for the automatic sampler are defined within API *MPMS* Chapter 8.2 and are not addressed in this document.

7.2.3.2 Evaluation of WCA Compared with Proven Automatic Composite Sample

7.2.3.2.1 The WCA baseline results shall be compared, and within, the baseline tolerances allowed by API *MPMS* Chapter 8.2 in terms of each composite sample baseline taken, or the average of each spot sample baseline set. The deviation (drift) of baselines over the testing process must also be within the limits as defined in API *MPMS* Chapter 8.2.

7.2.3.2.2 The WCA FWA result for the water injected sample shall meet the same acceptance criteria as required for an automatic sampler as denoted in API *MPMS* Chapter 8.2 by direct comparison with the metered percentage water in oil over the baseline values.

7.2.3.3 Evaluation of Manual Sample Point Suitability for Diagnostics

7.2.3.3.1 When the manual sampling point and sampling process is being validated during the Field Performance Acceptance Test (PAT), there are several comparison points to be made.

7.2.3.3.2 The results shall meet the criteria in 7.2.3.4 and 7.2.3.5 (and Table 1).

7.2.3.3.3 Even a manual sample point evaluation that does not pass can still prove useful for diagnostics, provided that it is quantified for both repeatability and bias.

7.2.3.4 Evaluation of Manual Sampling Point using Baseline Samples

7.2.3.4.1 Each set of baseline sample results (collected by Method A or Method B. Refer to Figure 2) shall be directly compared with the averages of each set of manual sample point baseline results and to the WCA readings taken.

7.2.3.4.2 Under Method B—"Spot Samples", manual samples will be extracted from the manual sample point synchronized with the samples drawn directly from the sample extractor.

7.2.3.4.3 Each individual sample analyzed shall be within the acceptable repeatability per API *MPMS* Chapter 8.2.

7.2.3.5 Evaluation of Manual Sampling Point using Water Injection Testing

7.2.3.5.1 The samples taken from the manual sample point during the water injection phase shall be compared with the Calculated Instantaneous Water injection (CIW) percentage.

$$CIW = [(WIF / TF) * 100] + BWC] \quad (1)$$

where

CIW Calculated Instantaneous Watercut (%);

WIF Water Injection Flow Rate;

TF Total Flow Rate; and

BWC Baseline Watercut (%).

NOTE Flowrates for WIF and TF are in the same units of measure.

7.2.3.5.2 The manual sample results should also be compared with the WCA instantaneous readings, such comparisons are recommended but should not be used for verification of the manual sample point.

7.2.4 Summary of Testing and Acceptance Criteria for PAT

7.2.4.1 Per API *MPMS* Chapter 8.2, the primary reference for this testing is the metered oil/water. Table 1 reflects the requirements of API *MPMS* Chapter 8.2 with additional information to reflect the concurrent testing of a WCA system.

7.2.4.2 All results shall be recorded as per API *MPMS* Chapter 8.2 and the additional data for the WCA and Manual Spot samples per Annex B.

Table 1—Performance Acceptance Criteria

	Sample Extractor (Auto Sampler)	WCA	Manual Sample Point
Baseline Test			
Method A Composite	Container, mixed. 3 aliquots removed and averaged	FWA Reading	Spot samples averaged, 2–3 sets (3 per set) over duration of baseline
Acceptance Criteria	Per API *MPMS* Chapter 8.2	Per API *MPMS* Chapter 8.2	NOTE: 7.2.3.4 Per API *MPMS* Chapter 8.2
Method B Sample from Extractor	Small container or direct to laboratory glassware, 2–3 sets of samples from extractor until repeatable results derived	FWA reading or observation average of readings	Spot samples averaged, synchronized with samples drawn from extractor (at least one set of 3).
Acceptance Criteria	Per API *MPMS* Chapter 8.2	Per API *MPMS* Chapter 8.2	NOTE: 7.2.3.4 Per API *MPMS* Chapter 8.2
Water Injection Test			
Water Injection Test (Metered Oil/Water)	Container, mixed. 3 aliquots removed and averaged.	FWA Reading	Spot samples averaged, synchronized with CIW readings (per 7.2.3.5), 2–3 sets (3 per set) over duration of water injection test.
Acceptance Criteria	Per API *MPMS* Chapter 8.2	Per API *MPMS* Chapter 8.2	Per API *MPMS* Chapter 8.2

Legend:
Blue Cells: Reference—API *MPMS* Chapter 8.2
Gray Cells: Comparison

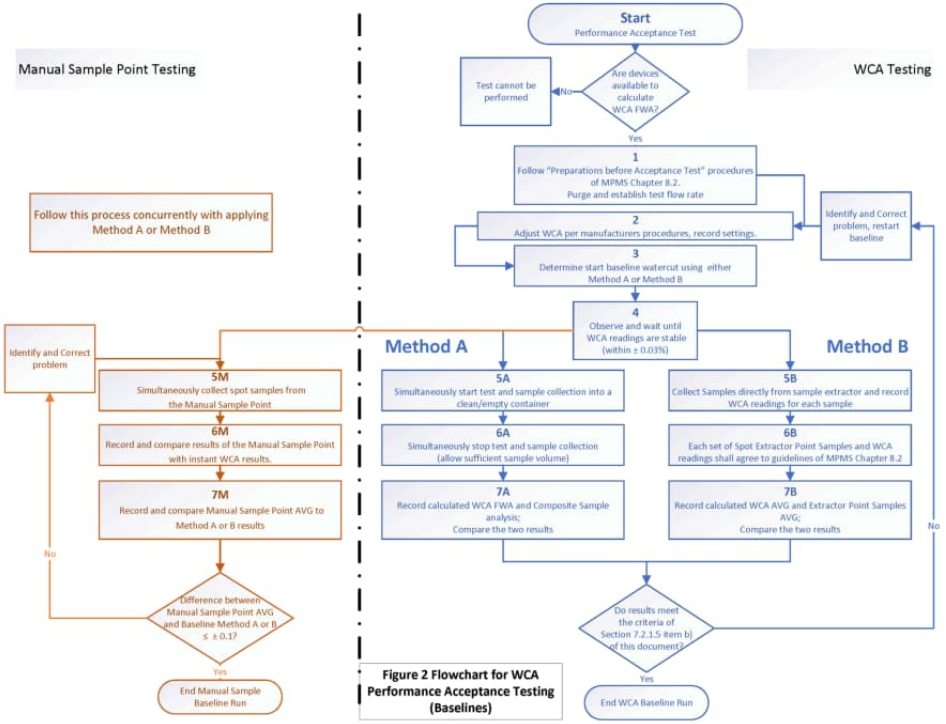
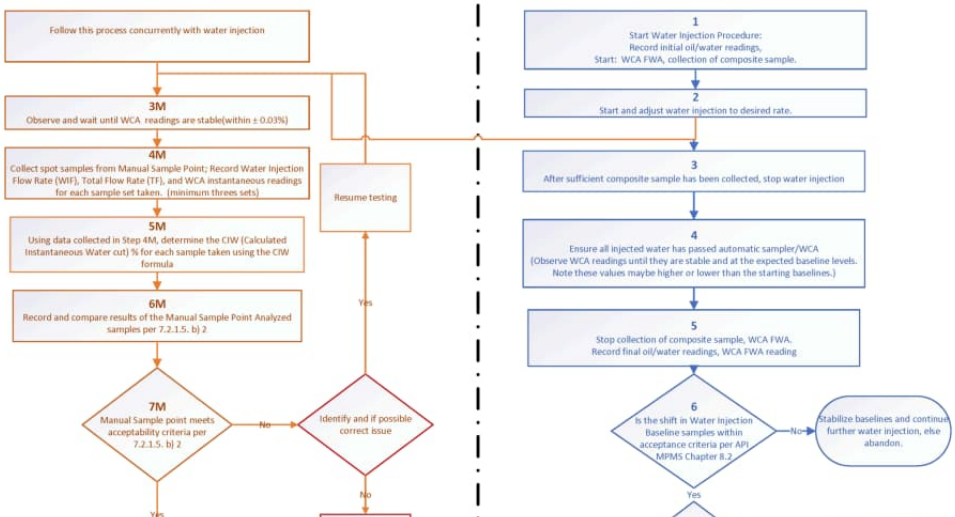


Figure 2 Flowchart for WCA Performance Acceptance Testing (Baselines)

Figure 2—Flowchart for WCA System Acceptance Testing (Baselines)



8 Ongoing Verification

8.1 General

This section discusses ongoing verification of the WCA in general terms.

8.1.1 The WCA FWA (flow-weighted average) results shall be compared on an ongoing basis to the automatic sampling system results to develop a level of confidence in WCA system performance.

8.1.2 Refer to Annex C for examples of control charts that could be used to document the WCA ongoing performance.

8.1.3 Manufacturer's specific verification requirements shall be followed in addition to the guidance provided in this section. After the setup and acceptance testing (PAT, "proving" or Validation), establish a routine frequency of verification.

8.1.4 For a WCA installed in a sample loop, continuous flow stream monitoring should take place throughout the sampling period and alarming on low flow.

8.1.5 Ongoing verification shall be performed by the collection and comparison of FWA WCA batch data against the sampling system composite result.

8.1.6 Additional data collection and diagnostics may be derived by comparing spot samples taken from a manual spot sampling point against the instantaneous WCA readings. It is recommended that until adequate control charts and data sets are developed, that for each batch a manual spot sample is collected and analyzed against an instantaneous WCA reading. Pass/fail criteria are stated in 8.3.

8.1.7 Correlation of data is simplified if the data collected from the WCA is in a form where any changes in calibration offsets can be reversed. Any changes to the calibration shall be clearly recorded in a control chart.

8.1.8 Use separate control charts for each product/crude group.

8.1.9 Retain control charts per the industry's accepted practices or operator requirements and make them available upon request by interested parties.

8.2 Verification by Comparison to Automatic Composite Sample System

8.2.1 The sampling system design, installation and operation shall meet the requirements of API *MPMS* Chapter 8.2 and shall have successfully been proven.

8.2.2 Verification shall be by comparison of FWA water values reported by the WCA under test with the water content reported for an automatic composite sample taken over the same period (volume/batch/time; refer to Figure 4.)

8.2.3 This analysis of the automatic sample shall only be for water; therefore, analysis method shall be distillation or Karl Fischer titration (coulometric is preferred). The Centrifuge (field or laboratory) methods are also acceptable if agreed upon by all interested parties and the net water concentration can be accurately determined. The WCA FWA results shall be verified against automatic sample results.

8.2.4 Refer to the following documents for guidance in using one or more of these approved methods to determine water content:

— API *MPMS*, Chapter 10.2, *Standard Test Method for Water in Crude Oil by Distillation*,

— API *MPMS* Chapter 10.3, *Centrifuge Method (Laboratory Procedure)*,

— API *MPMS* Chapter 10.4, *Centrifuge Method (Field Procedure)*, and

— API *MPMS* Chapter 10.9, *Coulometric Karl Fischer Titration*.

NOTE API *MPMS* Chapter 10.4 does not currently contain a precision or bias statement.

8.2.5 To determine that the FWA is within acceptable tolerance of the automatic sample, the results shall be compared as follows.

— The automatic sampler is the reference on an ongoing basis while the WCA is a secondary measurement.

— The Maximum Permissible Errors (MPEs) for the sampling system and the WCA can be based on results of testing per API *MPMS* Chapter 8.2 or manufacturer's specified MPE for this application. For the purposes of this verification test, MPE is defined as the extreme value of an error permitted between the indication of a measuring instrument and the indication of the reference instrument used during verification or calibration of the measuring instrument.

— A WCA is deemed suitable as a secondary measurement device while the primary sampling system is temporarily out of service, i.e. due to an equipment failure, when the magnitude of the measured error (WCA FWA vs sampling results) is not greater than the maximum permissible error (MPE) for 10 consecutive batches. Therefore, to maintain a minimum sensitivity, the number of running points (or batches) used for comparison shall be no less than 5.

— The ongoing performance control chart also includes control limits [green dashed line(s)]. When a measured error is within the MPE and has exceeded these control limits, the cause should be investigated, including verification of the WCA.

— If there is a bias between the averaged FWA WCA results and the corresponding averaged automatic sample results, then an adjustment to the WCA should be made and recorded.

If these systems are not within the acceptance criteria, then an investigation is needed to ascertain the root cause and corrective actions taken.

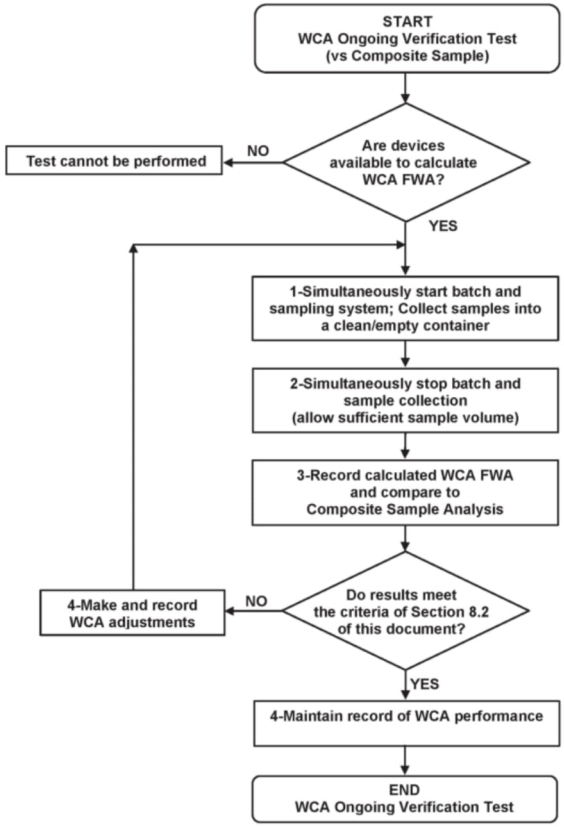


Figure 4—WCA FWA Reading Compared with Automatic Samples

8.3 Verification of a WCA by Comparison to Manual Spot Sampling

8.3.1 The manual sample point can be used as a diagnostic tool to trend or check the instantaneous performance of a WCA. This does not supersede the use of automatic sample versus WCA FWA control charts as the primary verification method.

8.3.2 Diagnostics shall be by comparison of the instantaneous water value recorded by the WCA when each manual spot sample is taken, allowing for any timing/volume offsets as the sample is collected. For example, should the WCA be volume offset from the manual sample point either in line or within a bypass loop. Figure 5 reflects an example of a diagnostic process.

8.3.3 A minimum of three values shall be recorded from the WCA during spot sampling.

8.3.4 The WCA output should be averaged during the period when manual spot samples are taken.

8.3.5 The manual sample point used shall be verified as described in the Manual Sample Point Verification in 7.2.3.3.

8.3.6 Pulling the sample—WCA results shall be monitored (or logged in the WCA) and averaged during the time the sample was taken. It is recommended that a minimum of three consecutive samples be taken. The variation in the WCA reading during the sampling period determines the uncertainty of the measurement (see Table 2).

Table 2—WCA Data Logging

Sample ID	Date/Time	Name of Operator	Flowing Density kg/m^3	Fluid Temp °F	WCA Offset (if any)	WCA Water %	Sample Water %	Difference %
							Average % Difference	

8.3.7 It is recommended that a historical trend of the manual sample diagnostic data is kept relevant to the WCA. The data can be recorded as shown in the example in Annex C.

8.3.8 Calculate the error by taking the Laboratory analysis result for the water percentage (water cut) of the manual sample and subtracting the observed water percentage (water cut) on the analyzer. Determine the average error by summing the error column and dividing by the number of samples.

8.3.9 If the average error is within the repeatability of the manufacturer's claimed performance, and the data shows no bias then no changes are required.

8.3.10 In the event the average of the manual samples is outside of the WCA manufacturer's stated uncertainty, continue to take manual samples. If the trend persists, contact the WCA manufacturer for troubleshooting assistance.

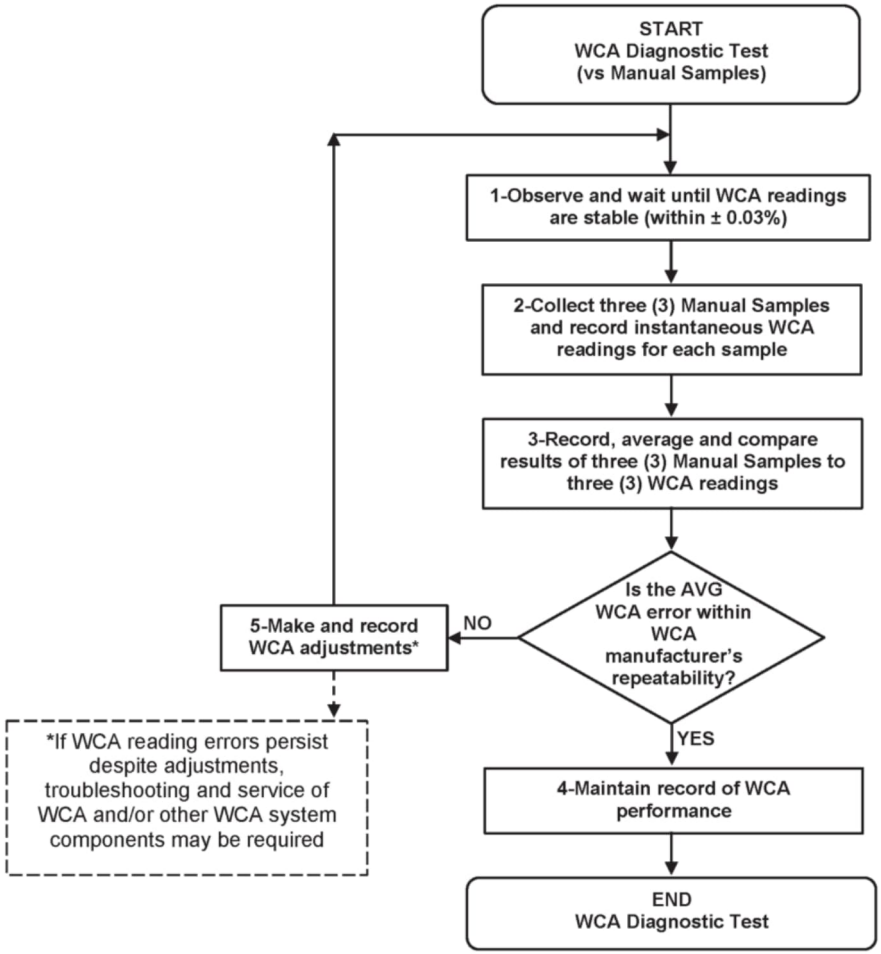


Figure 5—WCA (Diagnostics) Compared with Manual Samples

8.4 WCA Records and Documentation

8.4.1 Regardless of the method of verification, the difference between the WCA and the verification value (sample test result) should be retained.

8.4.2 For systems that handle different commodity grades, separate documentation for each grade and varying operating condition (temperature, pressure) is required to show how the WCA responds to the different conditions.

8.4.3 All verification and performance records for the WCA system should be available for review by all parties interested.

8.4.4 Refer to Annex C for examples of control charts that could be used to document the WCA performance.

9 Audit Trail and Security

9.1 Audit Trail

9.1.1 The evaluation of operating criteria should be properly documented with all the information necessary for audit. Proper evaluation requires references to sources, background material and a detailed outlining of the evaluations made with respect to Section 7 and Section 8.

9.1.2 An audit trail of WCA data used to determine custody transfer quantities shall be maintained by compiling and retaining sufficient information to verify custody transfer quantities in accordance with API *MPMS* Chapter 21.2.

9.1.3 The audit trail shall include the product moved, quantity of transaction, configuration logs, events, alarms, and test records.

9.1.4 Other WCA data should be included in the audit trail since the accuracy of a WCA system is affected by the verification and calibration of the device.

9.1.5 A WCA system should be capable of alarming and logging error and failure. This log is used to note any system alarm or user-defined alarm or error conditions (for example, “out of range”) that occur. This includes a description of each alarm condition and the times and totalized volumes when the condition occurred and cleared. This log is primarily used to provide the user with process information and information on equipment failure.

9.1.6 At a minimum, an alarm shall be logged whenever any input exceeds its defined span of operation.

9.2 Security

9.2.1 The WCA system security shall be in accordance with API *MPMS* Chapter 6.1A.

9.2.2 If a WCA is used for custody transfer by agreement between parties, it may be subject to regulatory security requirements.

Annex A
(informative)

Example WCA Installation Diagrams

Figure A.1 and Figure A.2 are example installations for both sample loop based and in-line WCA systems. Refer to vendor recommendations for further installation details.

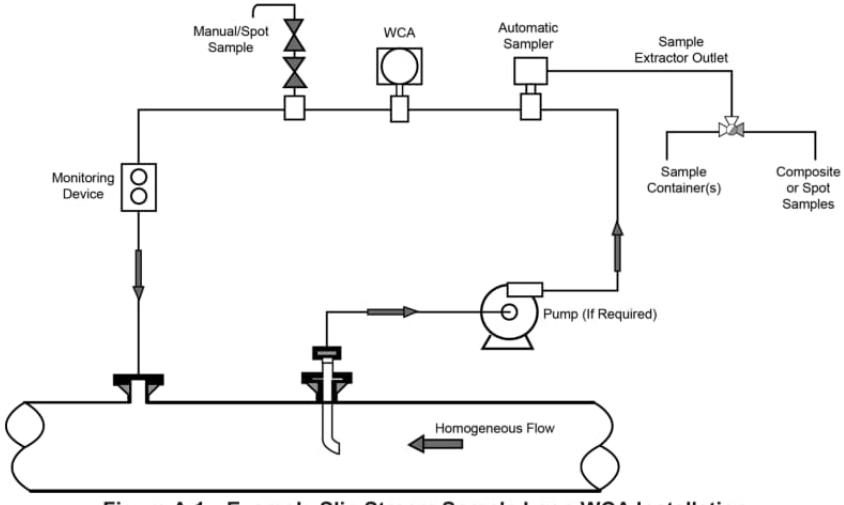


Figure A.1—Example Slip Stream Sample Loop WCA Installation

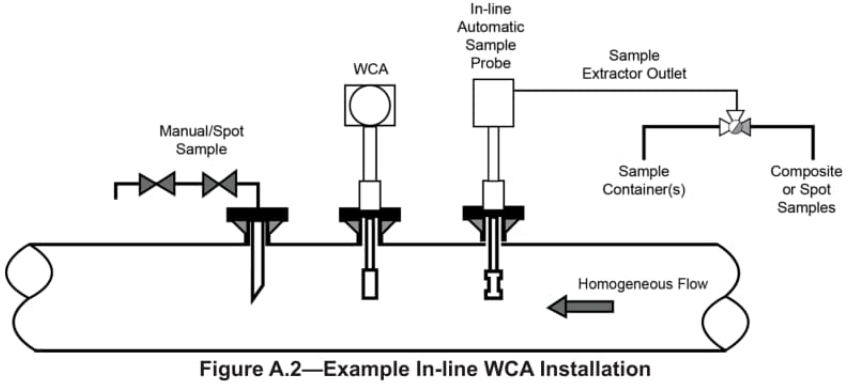


Figure A.2—Example In-line WCA Installation

Annex B
(informative)

Example Worksheet WCA Performance Acceptance Test (PAT)

A spreadsheet template is available. Figure B.1 is an extract from the spreadsheet.

Location	Station XYZ
Installation Type	Insertion
Type of Sampling System	In Line
Line Size (inches)	12"
Service	LACT
WCA Technology	Microwave
WCA ID	WCA 1
Sampling System ID	Metering System ABC Sampling
Product Group	WTI
Product used during PAT	ANS
Date of last PAT	9/29/2023
Average Flow Rate (BPH) during PAT	3000
Average Fluid Density (API) during PAT	32.5
Complies with API MPMS 10.10 Section 6?	Yes
Lab Analytical Method used for PAT	Coulometric KF Mass

Legend
Input
Calculation

Absolute Test Results	Total Water%	C. Sampler%	Sampler Test	WCA FWA %	WCA Test
Water Injection Test 1	0.4925	0.5036	Pass	0.5040	Pass
Water Injection Test 2	0.4999	0.5036	Pass	0.5040	Pass

Comments related to PAT here (if any)

Baseline Start

Sample #	Time (hh:mm:ss)	Composite Sample Av Vol % Water	WCA FWA Vol % Water	WCA Sample Avg Vol % Water	Manual Spot Avg Vol % Water
1	11:50:00			0.0100	0.1157
2	12:00:00			0.1500	0.1153
3	12:10:00			0.1100	0.1013
4	12:20:00			0.1100	0.0887
5	12:30:00			0.1200	0.0946
6	12:40:00			0.1010	0.0919
Averages		0.1033	0.1050	0.1002	0.1013

Baseline Start — Manual Spot Sample Results

Result #1	Result #2	Result #3
0.1100	0.1250	0.1120
0.1192	0.1144	0.1124
0.1037	0.0991	0.1010
0.0882	0.0893	0.0887
0.0976	0.0926	0.0936
0.0916	0.0906	0.0936

Baseline Start — Composite Sample Results

Result #1	0.1000
Result #2	0.1100
Result #3	0.1000

Water Injection 1

Sample #	Time (hh:mm:ss)	Composite Sample Av Vol % Water	WCA FWA Vol % Water	WCA Sample Avg Vol % Water	Manual Spot Avg Vol % Water	Calc Water Injection Avg Vol % Water
1	11:50:00			0.4999	0.4955	
2	12:00:00			0.4985	0.4957	
3	12:10:00			0.5101	0.5109	
4	12:20:00			0.5201	0.5197	
5	12:30:00			0.5401	0.5286	
6	12:40:00			0.5305	0.5203	
Averages		0.5036	0.5040	0.5165	0.5118	0.5500

Water Injection 1 — Manual Spot Sample Results

Result #1	Result #2	Result #3
0.4900	0.4978	0.4988
0.4898	0.4985	0.4989
0.5100	0.5123	0.5104
0.5200	0.5201	0.5189
0.5300	0.5285	0.5274
0.5200	0.5211	0.5199

Water Injection 1 — Composite Sample Results

Result #1	0.5000
Result #2	0.4999
Result #3	0.5109

Baseline Mid

Sample #	Time (hh:mm:ss)	Composite Sample Av Vol % Water	WCA FWA Vol % Water	WCA Sample Avg Vol % Water	Manual Spot Avg Vol % Water
1	11:50:00			0.0100	0.1157
2	12:00:00			0.1500	0.1153
3	12:10:00			0.1100	0.1013
4	12:20:00			0.1100	0.0887
5	12:30:00			0.1200	0.0946
6	12:40:00			0.1010	0.0919
Averages		0.1033	0.1050	0.1002	0.1013

Baseline Mid — Manual Spot Sample Results

Result #1	Result #2	Result #3
0.1100	0.1250	0.1120
0.1192	0.1144	0.1124
0.1037	0.0991	0.1010
0.0882	0.0893	0.0887
0.0976	0.0926	0.0936
0.0916	0.0906	0.0936

Baseline Mid — Composite Sample Results

Result #1	0.1000
Result #2	0.1100
Result #3	0.1000

Water Injection 2

Sample #	Time (hh:mm:ss)	Composite Sample Av Vol % Water	WCA FWA Vol % Water	WCA Sample Avg Vol % Water	Manual Spot Avg Vol % Water	Calc Water Injection Avg Vol % Water
1	11:50:00			0.4999	0.4955	
2	12:00:00			0.4985	0.4957	
3	12:10:00			0.5101	0.5109	
4	12:20:00			0.5201	0.5197	
5	12:30:00			0.5401	0.5286	
6	12:40:00			0.5305	0.5203	
Averages		0.5036	0.5040	0.5165	0.5118	0.5500

Water Injection 2 — Manual Spot Sample Results

Result #1	Result #2	Result #3
0.4900	0.4978	0.4988
0.4898	0.4985	0.4989
0.5100	0.5123	0.5104
0.5200	0.5201	0.5189
0.5300	0.5285	0.5274
0.5200	0.5211	0.5199

Water Injection 2 — Composite Sample Results

Result #1	0.5000
Result #2	0.4999
Result #3	0.5109

Baseline End

Sample #	Time (hh:mm:ss)	Composite Sample Av Vol % Water	WCA FWA Vol % Water	WCA Sample Avg Vol % Water	Manual Spot Avg Vol % Water
1	11:50:00			0.0100	0.1157
2	12:00:00			0.1500	0.1153
3	12:10:00			0.1100	0.1013
4	12:20:00			0.1100	0.0887
5	12:30:00			0.1200	0.0946
6	12:40:00			0.1010	0.0919
Averages		0.1033	0.1050	0.1002	0.1013

Baseline End — Manual Spot Sample Results

Result #1	Result #2	Result #3
0.1100	0.1250	0.1120
0.1192	0.1144	0.1124
0.1037	0.0991	0.1010
0.0882	0.0893	0.0887
0.0976	0.0926	0.0936
0.0916	0.0906	0.0936

Baseline End — Composite Sample Results

Result #1	0.1000
Result #2	0.1100
Result #3	0.1000

Figure B.1—Example Worksheet for WCA Acceptance Testing using an Average of Instantaneous Samples

Annex C
(informative)

Examples of Ongoing Performance Verification Control Charts

Figure C.1 and Figure C.2 are examples of the graphical output from the spreadsheet provided in Annex B. Refer to the accompanying Data Collection spreadsheet.

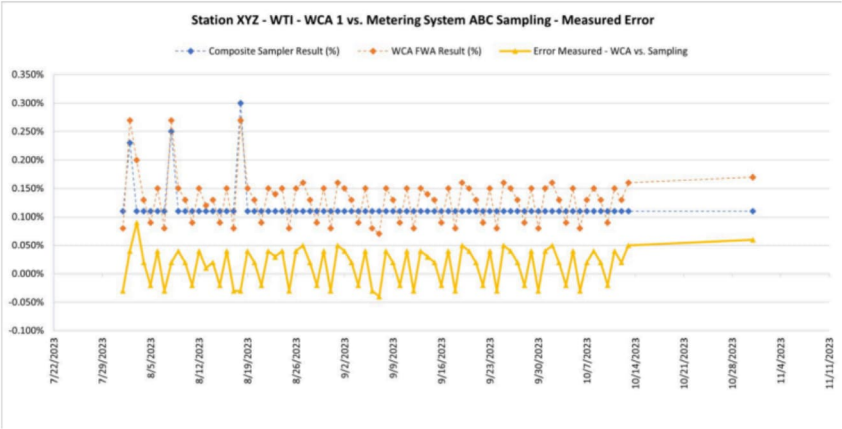


Figure C.1—Example WCA Ongoing Performance Verification Control Chart

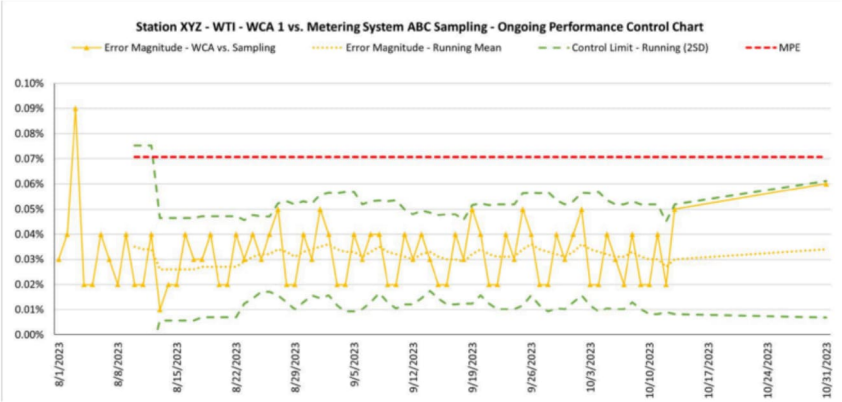


Figure C.2—Example WCA Ongoing Performance Verification Control Chart

Bibliography

[1] API *MPMS* Chapter 8.1, *Standard Practice for Manual Sampling of Petroleum and Petroleum Products*

[2] API *MPMS* Chapter 10.2, *Standard Test Method for Water in Crude Oil by Distillation*

[3] API *MPMS* Chapter 10.3, *Centrifuge Method (Laboratory Procedure)*

[4] API *MPMS* Chapter 10.4, *Determination of Water and/or Sediment in Crude Oil by the Centrifuge Method (Field Procedure)*

[5] API *MPMS* Chapter 10.9, *Standard Test Method for Water in Crude Oils by Coulometric Karl Fischer Titration*

[6] API *MPMS* Chapter 13.3, *Measurement Uncertainty*

[7] API *MPMS* Chapter 21.2-A1, Addendum 1 to *Flow Measurement Using Electronic Metering Systems, Inferred Mass*

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

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