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Manual of Petroleum Measurement Standards

Chapter 10—Sediment & Water Determination

Section 10 — On-Line Measurement of Water Content in Petroleum and Petroleum Products

FIRST EDITION, XXX 20XX

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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.

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 additional verification.

The standard is applicable, by 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.

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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.

2 Normative References

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

- API MPMS, Chapter 8.1 *Standard Practice for Manual Sampling of Petroleum and Petroleum Products*
- API MPMS, Chapter 8.2 *Standard Practice for Automatic Sampling of Petroleum and Petroleum Products*
- API MPMS, Chapter 8.3 *Standard Practice for Handling and Remixing Samples of Petroleum and Petroleum Products*
- 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 *Standard Determination of Water and/or Sediment in Crude Oil by the Centrifuge Method (Field Procedure)*
- API MPMS, Chapter 10.9 *Standard Test Method for Water in Crude Oils by Coulometric Karl Fischer Titration*
- API MPMS, Chapter 13.3 *Measurement Uncertainty*
- API MPMS, Chapter 21.2 *Flow Measurement Using Electronic Metering Systems, Addendum to Section 2 - - Flow Measurement Using Electronic Metering Systems, Inferred Mass"*

3 Terms, Definitions, and Abbreviations

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

3.1
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.

3.2
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.

3.3
performance acceptance testing (PAT)
Performance testing that allows the WCA system to be validated for use in a specific application (see also verification testing).

3.4
representative sample
A portion extracted from a total volume that contains the constituents in the same proportions that are present in that total volume.

3.5
verification testing
Ongoing testing that confirms that the WCA system is within operating specifications.

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3.6
water cut analyzer (WCA)
Device that provides an on-line, continuous measurement of water content in a hydrocarbon/water mixture under flowing conditions.

3.7
WCA system
One or more WCAs, stream conditioning, other measurement devices (e.g., temperature, pressure, density, flow, etc.), and a computer to assimilate, compile, and report the data.

4 Significance and Use

The WCA provides instantaneous water percent 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

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 21.2.

The standard does not preclude any technology that meets the scope.

A WCA may require additional auxiliary measurement equipment or instruments such as temperature, pressure, or density. Consult the manufacturer for application guidance. 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 and/or company policy or procedures, used for other measurement instrumentation, whichever interval is more stringent.

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)

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.

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 users 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.

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.

A WCA system shall be capable of providing a secure full audit trail of changes to its configuration including alarm logging. (see section 9.0 – Audit Trail and Security).

The following are potential influences on the performance of the WCA. The impact of these can depend on the instrument technology and the manufacturer 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 over measuring elements must be within manufacturers acceptable range avoiding cavitation and free gas.
- Liquid composition: For example: Chemicals including additives, sand, wax, scale, salinity, asphaltenes, etc.
- Ambient and process temperatures and pressure variations
- Density and viscosity of hydrocarbon

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

6 Installation of a Water Cut Analyser System

6.1 General

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.

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

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

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

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

6.2 Retrofit Installations

The WCA system should be tested as soon as practicable after installation as outlined in Section 7.0.

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 8.0.

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

A manual spot sample point shall be installed to allow troubleshooting / diagnostics of the WCA.

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. The manual sample point shall be designed and operated in compliance with API MPMS Chapter 8.1, the manual sample point design should consider the following additional constraints:

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.

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.

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 at a rate and volume sufficient to clear any residual fluids immediately before drawing each sample.

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 6-10 times this volume is flushed immediately prior to drawing each sample collected for analysis.

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. Be sure to record the nominal sample flowrate used.

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The manuals sample point tubing shall be sized so that the operating flowrate is adequate to prevent any water fallout.

7 Performance Acceptance Testing (PAT)

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

7.1 General

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.

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.

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

The manual sample point shall be tested as part of the PAT procedures according to the procedure described in Figure 2. It is recommended that the manual sample point is adjusted for flowrate per the recommendation of section 6.2 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.

The testing of the manual sample point requires comparison of samples taken during the baseline sample collection periods AND during the water injection phases of the test.

Because the measurement output from a WCA is continuous and manual spot samples are taken at a specific point in time, it is also desirable to consider the short-term stability of the baseline water concentration. Generally, WCA readings that do not vary by more than +/- 0.03% water by volume over a 10 second period are considered as stable; manual samples should not be taken if the WCA readings are not stable.

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 in the piping of residual water that may have collected.

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 averaging. 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 4-6 times this volume should ensure all the water has passed. (See Note under 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.)

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.

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 calibration point.

WCA readings shall be collected only under flowing conditions.

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.

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.

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7.2 Test Procedure for PAT

The PAT comprises water injection in accordance with API MPMS Chapter 8.2. The manual sample point used to assist in diagnostics and validation/verification of the WCA shall be verified during this testing process.

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

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

- baseline test
- water injection test (1)
- baseline test
- water injection test (2)
- 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, remember that 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 7.2.5 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 described in the process diagram “Flowchart for WCA System Acceptance Testing” – 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 section 7.1 above.

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 PAT: composite or spot sample.

a. **Composite Sample**
A sample is taken directly from the automatic sample extractor into a separate intermediate sample container. If the volume to be collected is greater than the SvMin (Per API MPMS Chapter 8.2), it shall be collected using the standard container type fitted to the system. If a smaller intermediate 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. 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 (3) 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 also comprise a volume collected of several sample grabs over a period of 5-10 minutes.

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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. The results of each of these three sets of analyses shall be within the allowances in API MPMS Chapter 8.2 PAT 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 is required and the short-term shift (stability) in baselines is quickly determined.

Within this testing, WCA stability is defined as a reading that within a period of 10 seconds does not change by more than ±0.03%

7.2.1.2 Manual Sample Point – Verification during Baseline Testing

Each set of three (3) baseline manual samples shall comprise the collection of three (3) separate “spot” samples. The WCA readings shall be recorded at the same points in time as the manual sample point samples are collected.

In accordance with the processes described under section 7.2.2.1a, 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).

In accordance with the process described under 7.2.2.1b 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” - Figure 3

7.2.2.1 WCA - Verification During Water Injection

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. 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.

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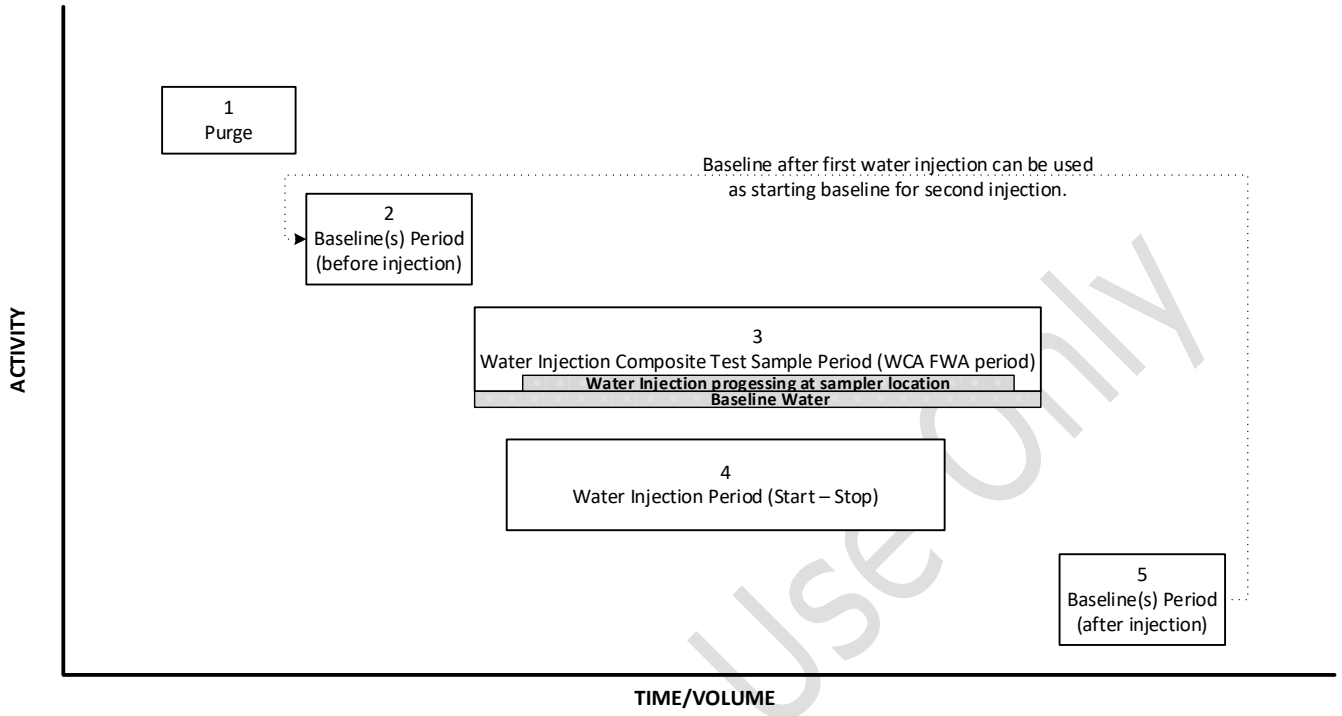

Figure 1 Example timing diagram for one WCA system test run

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

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

For each set of manual samples, a minimum of three (3) 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 a number of sample grabs over a period of time, normally 5-10 minutes. 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.

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.

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 to the calculated water injection values.

Normally, each spot sample taken shall have a minimum of two 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

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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/or process control.

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 covered here.

7.2.3.2 Evaluation of WCA compared to proven Automatic Composite Sample

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.

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

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. The results shall meet the criteria below.

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

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

Under Method A. “Composite”, the result being the average of three aliquots from the mixed composite sample that will be compared with the average of at least three sets of manual samples taken during the period over which the composite sample has been taken.

Under Method B. “Spot Samples”, ideally manual samples will be extracted from the manual sample point synchronized with the samples drawn directly from the sample extractor.

Each individual sample analyzed shall be within the acceptable repeatability of the analytical method.

There is no allowance for deviation beyond the repeatability allowances of the analytical method.

7.2.3.5 Evaluation of manual sampling point using water injection testing

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

CIW = [(WIF / TF) * 100] + BWC]

where:

CIW Calculated Instantaneous Watercut (%)

WIF Water Injection Flow Rate

TF Total Flow Rate

BWC Baseline Watercut (%)

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

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The manual sample analytical results shall be within the acceptance criteria outlined in Table 1.

The manual sample results should also be compared to 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

Per API MPMS Chapter 8.2, the primary reference for this testing is the metered oil/water. The table ! below reflects the requirements of API MPMS Chapter 8.2 with additional information to reflect the concurrent testing of a WCA system.

Table 1. Performance Acceptance Criteria

Method	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	Per section 7.2.3.4
Method B Sample from Extractor	Small container or direct to lab 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	Per section 7.2.3.4
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 section 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:

Reference – MPMS Chapter 8.2
Comparison

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.

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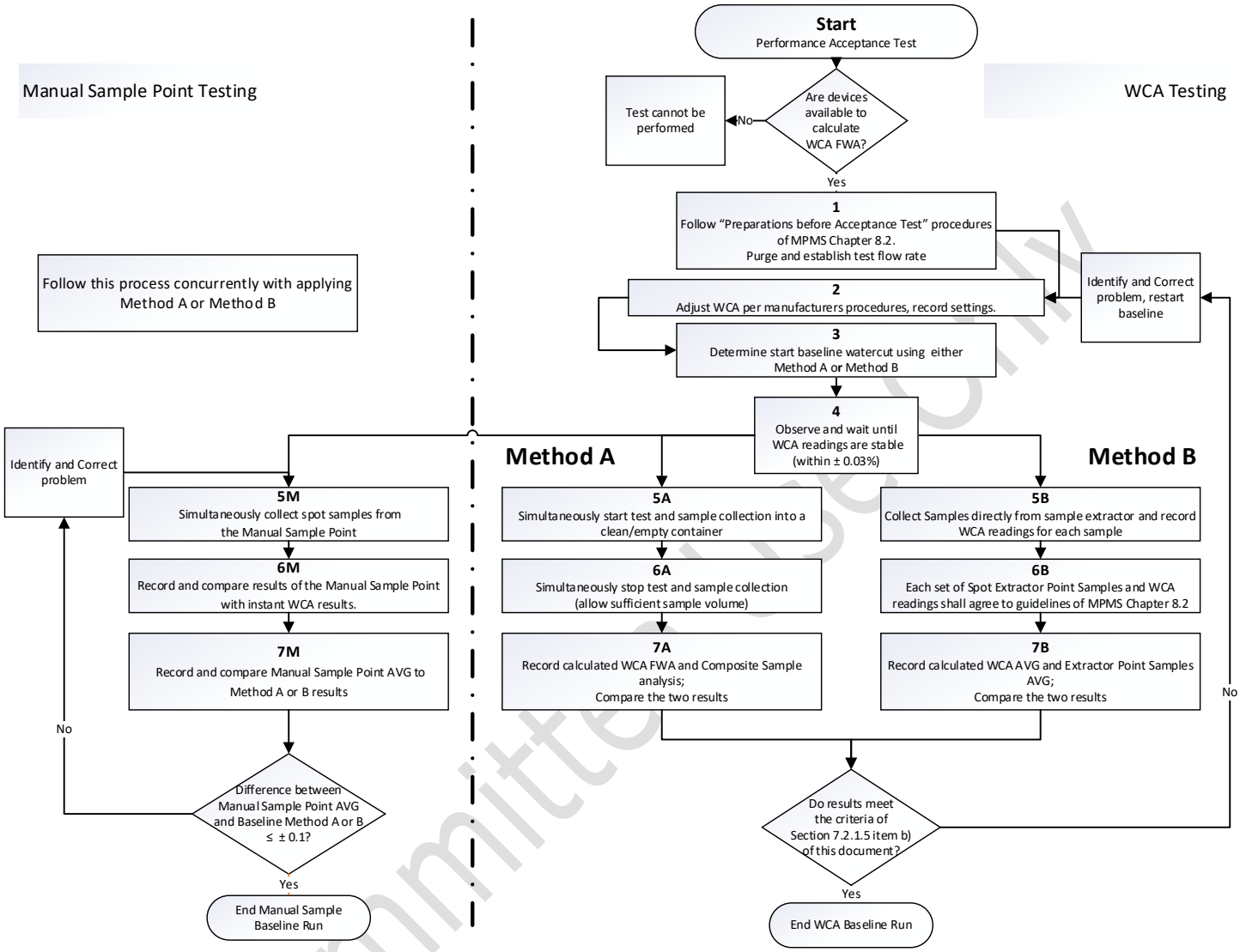

Figure 2 Flowchart for WCA System Acceptance Testing (Baselines)

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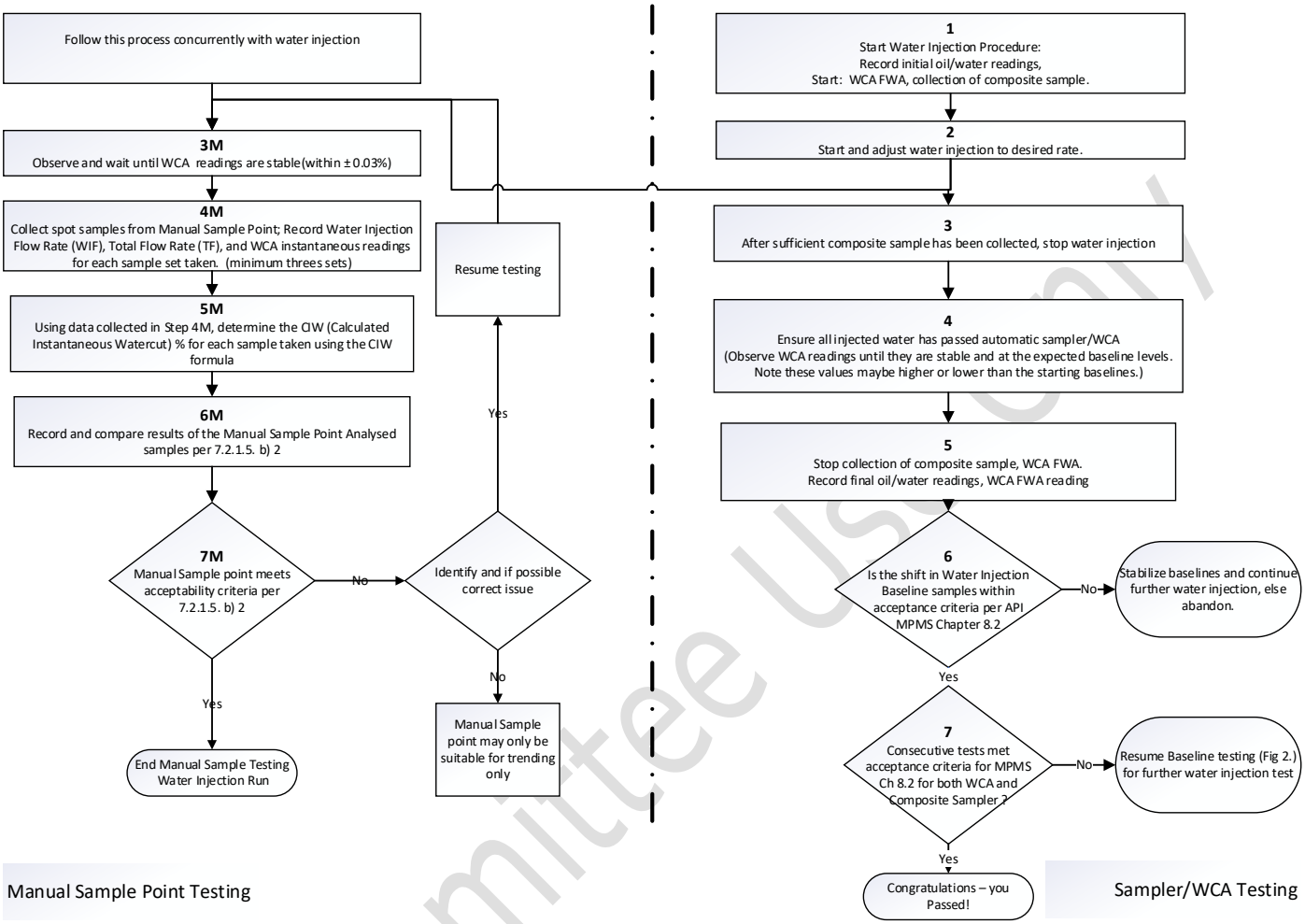

Figure 3 Flowchart for WCA System Acceptance Testing (Water Injection)

8 Ongoing Verification

8.1 General

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.

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

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

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.

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

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

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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 in section 8.3 i. to k. below.

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.

Utilize separate control charts for each product/crude group,

Retain control charts per industry accepted practices or operator requirements and make available upon request by interested parties.

8.2 Verification by Comparison to Automatic Composite Sample

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

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

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.

Refer to API MPMS, Chapter 10.2 “Standard Test Method for Water in Crude Oil by Distillation”, 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”, for guidance in using one or more of these approved methods to determine water content.

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

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 (MPE's) for the sampling system and the WCA can be based on results of testing per API MPMS 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. Thereafter 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.

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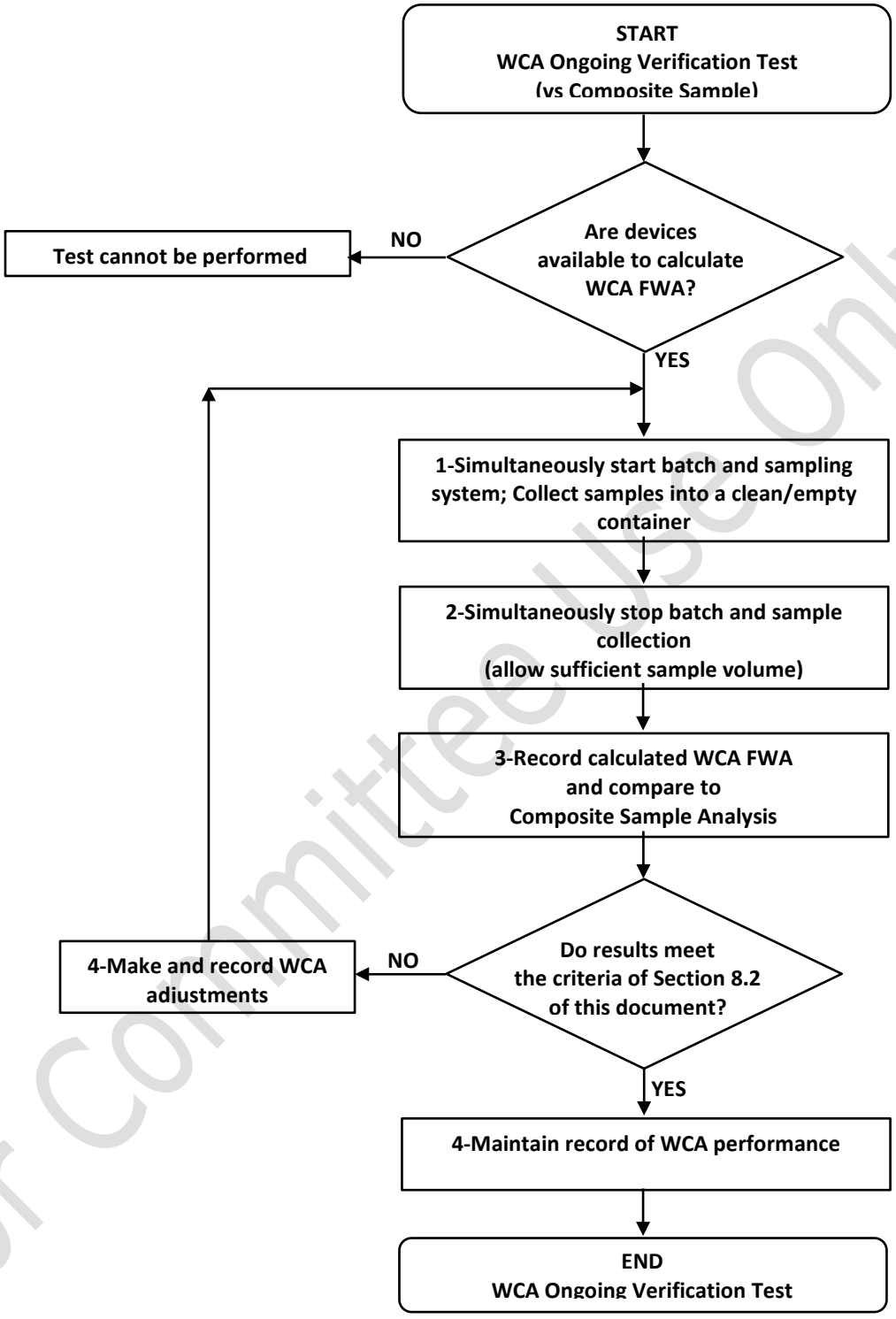

Figure 4 WCA FWA Reading Compared to Automatic Samples

8.3 Verification of a WCA by Comparison to Manual Spot Sampling

The design and operation of the manual sample point shall at a minimum meet the requirements of API MPMS Chapter 8.1 and as stated in section 6.2 of this document. The process is also shown in Figure 5.

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NOTE Ensure that the flow is adequate to prevent separation of hydrocarbon/water in the manual sample point.

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.

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 4 reflects an example of a diagnostic process.

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

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

The manual sample point used shall be verified as described in the Manual Sample Point Verification section 7.2.1.1

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 3 consecutive samples be taken. The variation in the WCA reading during the sampling period determines the uncertainty of the measurement (see Table 2).

Sample ID	Date/Time	Name of Operator	Flowing Density kg/m3	Fluid Temp °F	WCA Offset (if any)	WCA Water %	Sample Water %	Difference %
							Average % Difference	

It is recommended 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.

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.

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

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.

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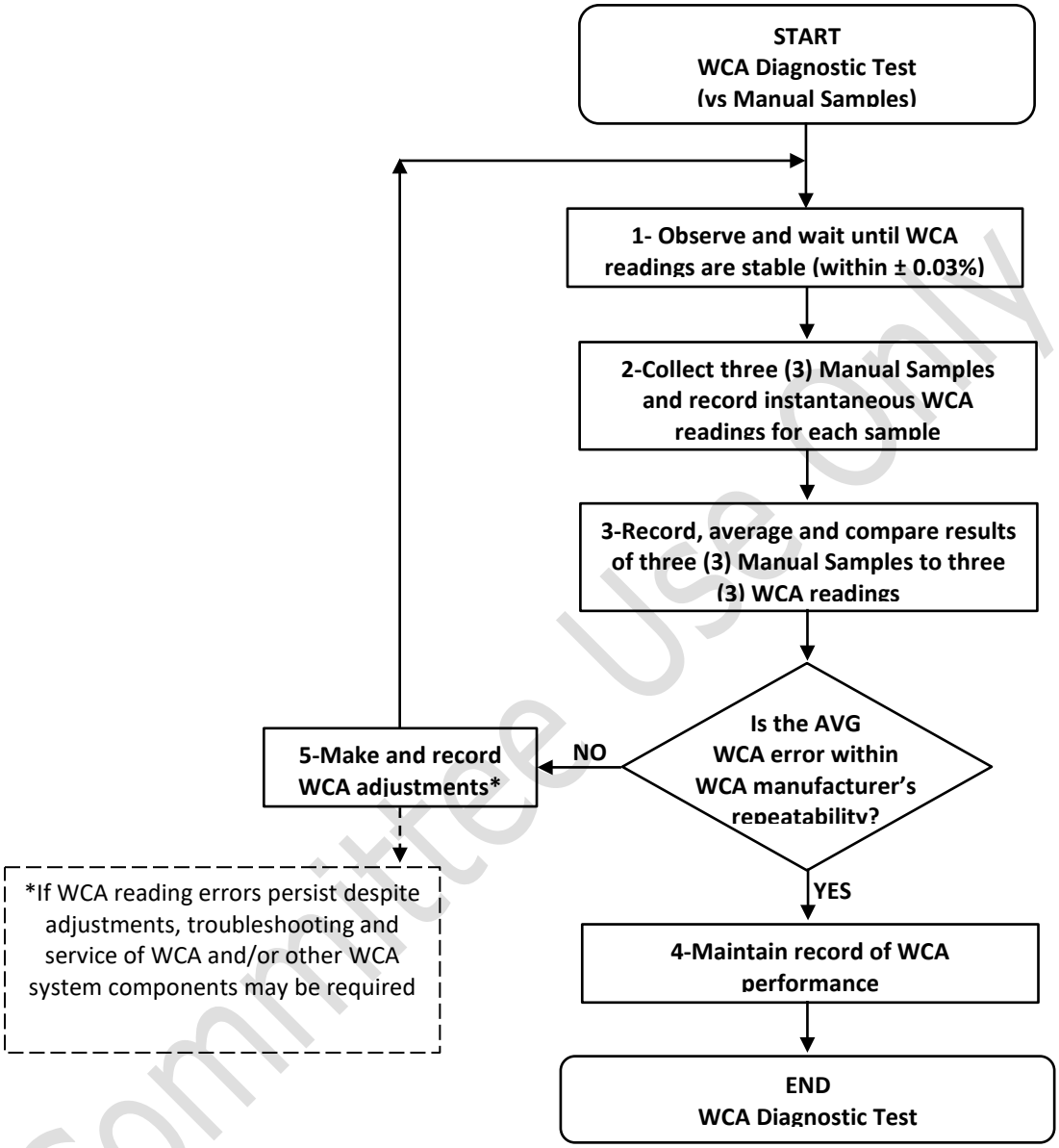

Figure 5 WCA (Diagnostics) Compared to Manual Samples

8.4 WCA Records and Documentation

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

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

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

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

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9 Audit Trail and Security

9.1 Audit Trail

The evaluation of operating criteria should be properly documented with all information necessary for audit. Proper evaluation requires references to sources, background material and a detailed outlining of the evaluations made with respect to sections 7.0 and 8.0.

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

A WCA system should be capable of alarming and logging error and/or 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. At a minimum, an alarm shall be logged whenever any input exceeds its defined span of operation.

9.2 Security

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

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

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Annex A
(informative)

Below are example installations for both sample loop based and in-line WCA systems

Example WCA Installation Diagrams

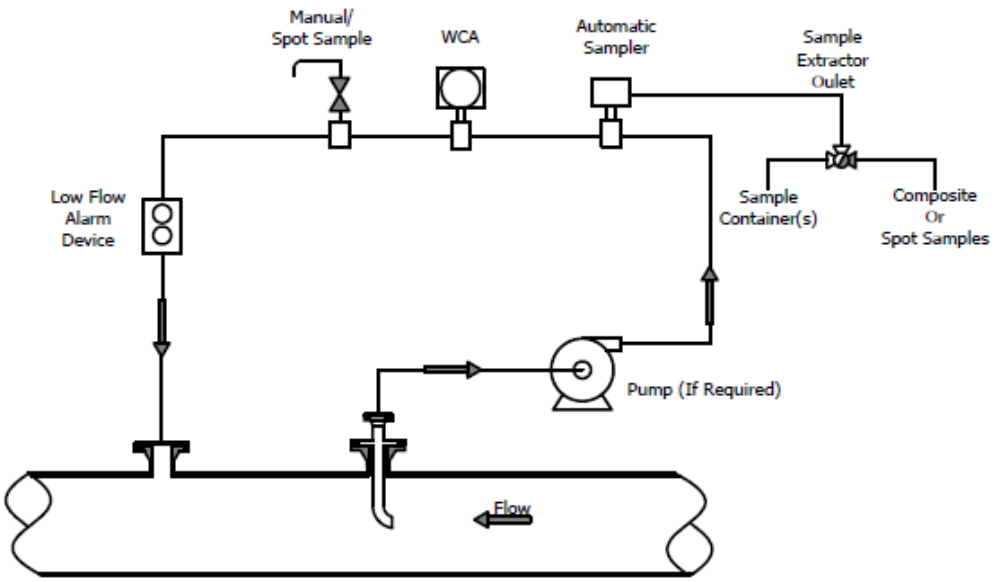

Figure A.1 Example Slip Stream Sample Loop WCA Installation

Refer to vendor recommendations for further detail.

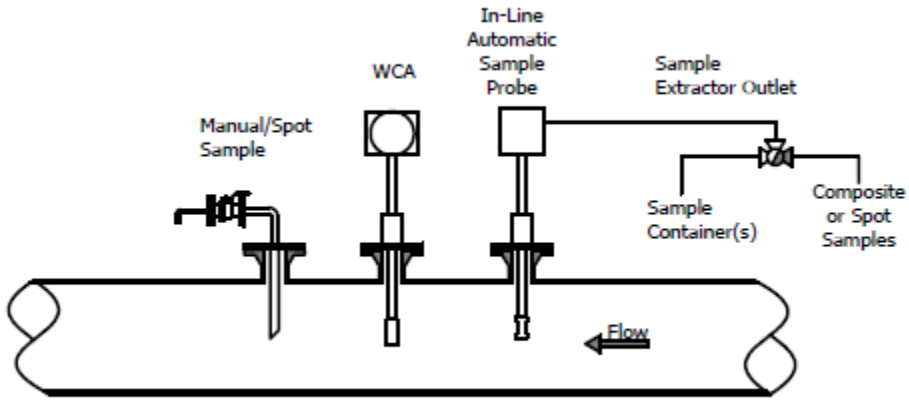

Figure A.2 Example In-line WCA Installation

Refer to vendor recommendations for further detail.

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Annex B

(informative)

A spreadsheet template is available, the below is an extract from the spreadsheet.

Example Worksheet for WCA Acceptance Testing Using an Average of Instantaneous Samples

Annex B - Example Worksheet WCA Performance Acceptance Test (PAT)

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 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	Potentiometric KF Mass

Legend
Input
Calculation

Absolute Test Results	**Total Water%**	**Composite Sampler Av %**	**WCA FWA %**	**Pass/Fail**
Water Injection Test 1	0.4925	0.5036	0.5040	Pass
Water Injection Test 2	0.4999	0.5036	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

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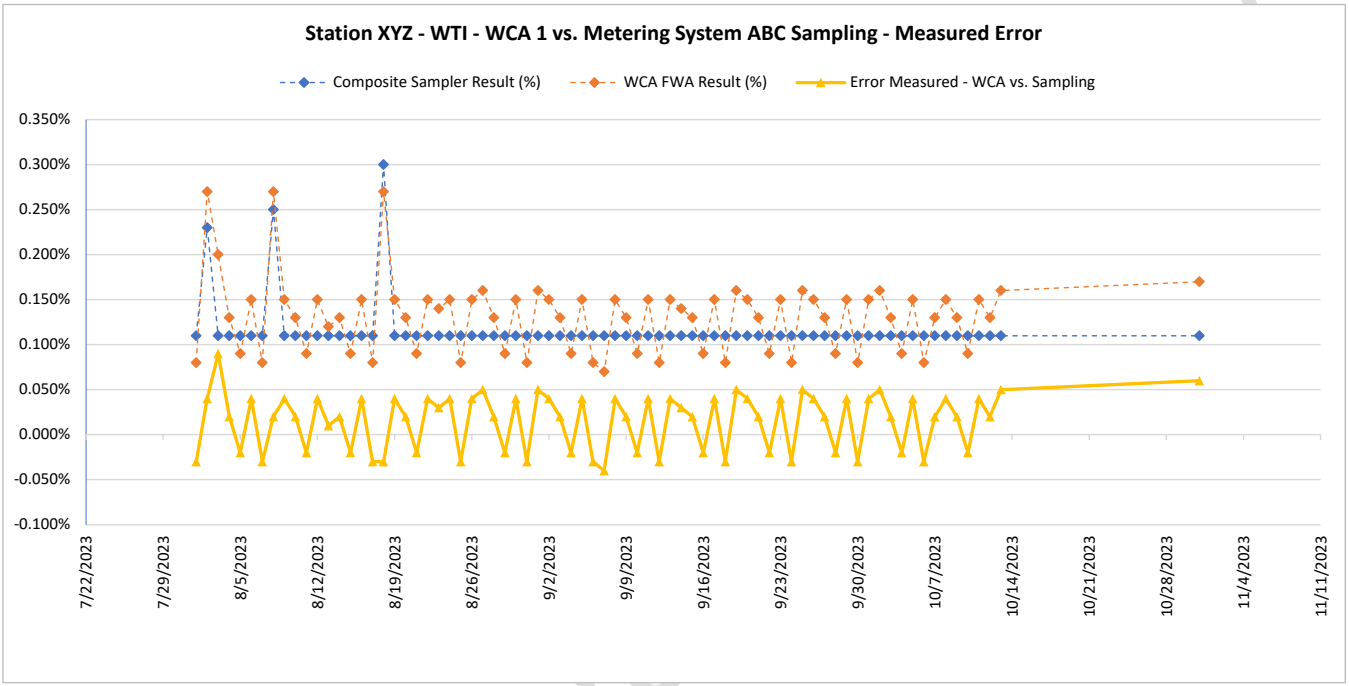
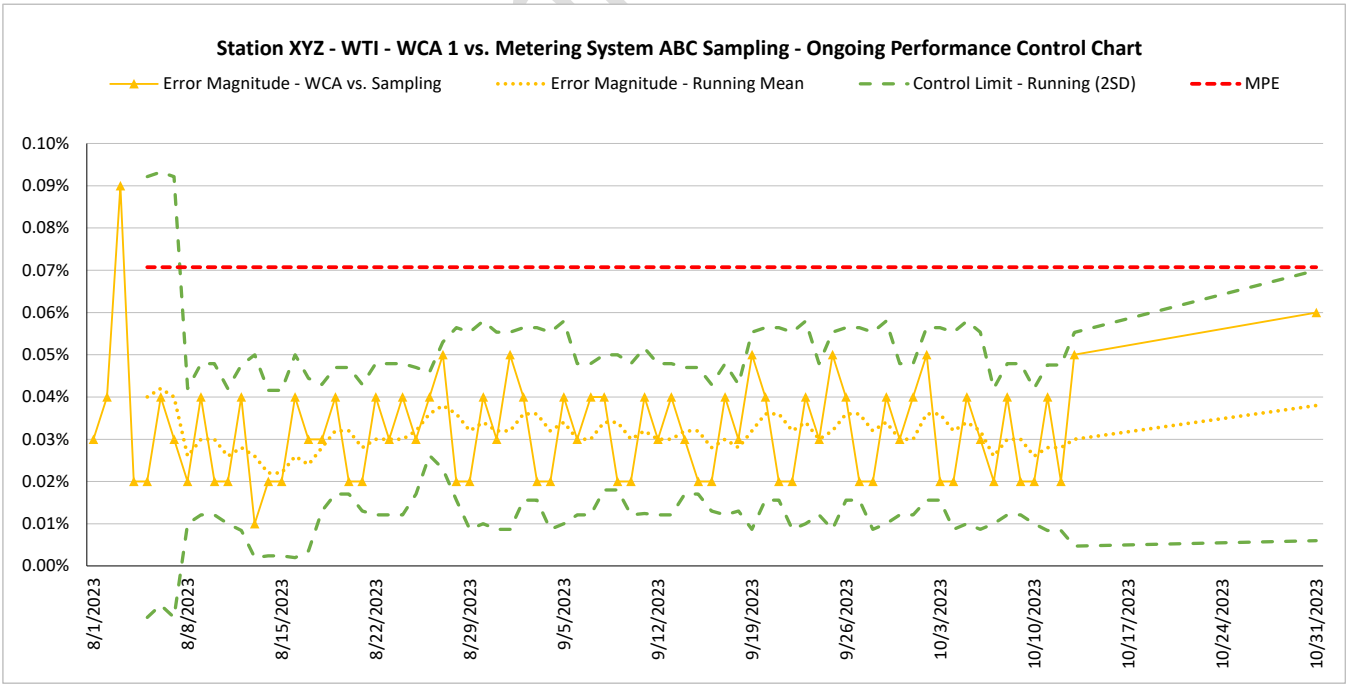
Annex C
(Informative)

Annex C is an example of the graphical output from the provided spreadsheet Annex B

Example WCA Ongoing Performance Verification Control Chart





Refer to accompanying Data Collection spreadsheet.

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