API Manual of Petroleum Measurement Standards

Chapter 10.10

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

API MPMS Chapter 10.10

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Introduction

The purpose of this standard is to provide guidance for the installation and operation of an On-line Water measurement Device (OWD) for on-line measurement of water content in petroleum (crude oil and condensate) in real-time. Guidance is also provided for the collection of consistent data to allow for long term performance assessment. Applications for the OWD include pipeline and marine applications, use as an operational tool for allocation of production, or other forms of non-custody transfer process management.

When used in custody/fiscal applications the OWD should be tested for *acceptance* as described in this standard, and go through an on-going *verification* program as described herein. Operation with different crude oils or different process conditions to those originally tested may require additional testing and verification. This technology should be viewed as one of several methods to determine the water in petroleum and petroleum products. The method for measuring water in petroleum should be selected with consideration given to installation, application, and properties of the product(s) being measured.

1 Scope

To provide requirements for application, installation, operation, initial testing and ongoing verification for the use of On-line Water Devices (OWD) for custody transfer of petroleum and petroleum products to be used in conjunction with an automatic sampling system that is compliant with API MPMS Chapter 8.2

2 Normative References

API *Manual of Petroleum Measurement Standards:*

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 10.9, Standard Test Method for Water in Crude Oils by Coulometric Karl Fischer Titration

API *MPMS*, Chapter 13.1, Statistical Concepts and Procedures in Measurement

3 Terms and Definitions

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

3.**1**
acceptance testing
Initial performance testing that allows the OWD system to be qualified for use in a specific application. (see also Verification Testing)

3.2
flow weighted average (FWA)
The average of a variable weighted by incremental volume to which it relates. 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
homogenous
When a liquid droplet or solid concertation and particle size will measure the same at all points in the container, tank, or pipeline cross section.

3.4
on-line water measurement device (OWD)
A real-time measuring device that uses electronics to detect and calculate water concentrations in petroleum and petroleum products. OWD system–An OWD system may be comprised of one or more OWDs, stream conditioning, other measurement devices (e.g., temperature, pressure, density, flow, etc.), and a computer to assimilate, compile, and report the data.

3.5
pacing
The method of proportioning the measurement interval range –The maximum and minimum values attainable from a measurement device. When applied to an OWD, the units will be percent water in oil by volume (e.g., 0 %

to 5 %, or 0 % to 100 %). Units of percent water in oil by mass are also allowed if the OWD is suitably calibrated. Note uniform values must also be used in the FWA calculation.

3.6
Sample
A portion extracted from a total volume that may or may not contain the constituents in the same proportions that are present in that total volume.

3.7
secondary measurement device
Additional measurement (devices) required to allow the primary measure to be made. Typically for an OWD this may be density, temperature, salinity or other properties that may influence the primary measurement.

3.8
verification testing
Ongoing testing that verifies that the OWD system is within operating specifications.

4 Significance and Use

The OWD provides instantaneous water percent readings. When coupled with a pacing device (e.g., meter) the total amount of water can be determined (and from this the net oil volume).

5 OWD Operating Criteria

5.1. General

In this document, OWD and OWD system may be used interchangeably. The standard does not preclude any technology that meets the scope. An OWD may require additional measurement instruments, may be full bore, or an insertion device installed directly in the main pipeline or within an analyzer loop.

5.1.1. OWD Use

To use an OWD, it is recommended that the instrument be evaluated with respect to Sections 6 and 7. Annex A shows two typical OWD installations.

5.1.2. Uncertainty

If used to determine net oil volume, the OWD output must be flow weight averaged. To improve the confidence in the OWD system, it is recommended that an uncertainty evaluation be made. The evaluation can include the uncertainties of the quantities input to the OWD and the functional relationships used within the system. An example of uncertainty calculations can be found in API MPMS Chapter 13.1.

5.1.3. Secondary Measurement

All secondary measurement devices associated with the OWD system should be verified at a frequency that is consistent with the calibration verification frequencies used for other measurement components of the metering system. (See standard? (Flow measurement standard) for further guidance. If operating experience confirms stable performance, the calibration interval may be extended accordingly based on agreement between all parties

and sufficient supporting data. Table 1 lists some items that may influence the performance of the OWD. The impact of these may be dependent on the instrument technology and the manufacturer of the OWD. Consult the manufacturer for additional information.

Table 1—Potential Influencers

Non-homogeneity of the flow (both of the main process or when applicable in the bypass loop) Cavitation, Free gas	Ambient pressure variation
Liquid composition Chemicals including additives, sand, wax, scale, salinity, asphaltenes, etc.	Installation effects, including if applicable bypass loop design, takeoff, orientation of measurement elements, vibration, etc.
Ambient and Process temperature variation	System noise
Density and viscosity of oil	
Pressure loss	

5.1.4. Documentation

The evaluation of operating criteria should be properly documented and all information necessary for audit. Proper evaluation requires references to sources and background material, and detailed outlining of the evaluations made with respect to Sections 6 and

5.2 Installation Requirements

5.2.1 Representative Measurement

To obtain a representative measurement taken from a homogenous flowing stream, at the measurement point as described in API *MPMS* Chapter 8.2.

5.2.2 Installation

5.2.2.1 General

The OWD system should be installed per the manufacturer's recommended installation guidelines, ensuring it fulfils the requirements of 5.3.1

5.2.2.2 Analyzer Loop

For an OWD installed in an analyzer loop, the stream through the loop should be representative of the main piping stream.

5.2.2.3 Location

The optimal location of the OWD should be as close to the sample take off point as possible. Consideration should be given to minimizing interference between the devices.

5.3 Secondary Measurement Devices

5.3.1 Accuracy

OWD's may use an input from one or more secondary measurement devices to allow compensation (e.g. for measuring temperature, pressure, density, salinity, viscosity, etc.). The accuracy of these measurement devices should be verified frequently. The required frequency of verification (and recalibration as necessary) is dependent upon the application, the OWD manufacturer's recommendations, site requirements, and documentation.

5.3.2 Net Oil

Where at totalized volume (Net Oil) is to be determined the instantaneous measured water from the OWD shall be flow weight averaged.

6 Water Injection Test

6.1. General

This section describes the method for the initial field acceptance testing of OWD systems.

6.1.1. Verification

All components of the OWD system should be verified or calibrated per manufacturer's guidelines prior to initial acceptance testing.

6.1.2. Test Preparation

For test preparation see API *MPMS* Chapter 8.2 Appendix A. Also see Table 1 for other possible sources of uncertainty.

6.2. Test Procedure

NOTE: It is assumed that all OWD readings taken during the testing process are compensated by whatever secondary measurements are required so that the OWD readings are a direct representation of the expected water content. Additional raw data may be recorded, if available.

6.2.1. Water Injection Test

The Test Procedure is the standard API *MPMS* Chapter 8.2, *Water Injection Test*, and is a direct comparison of the physical sampling systems results with the OWD systems but with the addition of a third test. Oil meters are recommended with API MPMS Chapter 8.2 to reduce the expected uncertainty to provide the total test volume, but tank gauges may also be used. The OWD trend result can normally be utilized to monitor the passing of the last of the injected water through the instrument (shown as "end of test period" in Figure 1.) Repeat the water injection test at the same oil flow and water injection rates. For the third test, change the water injection rate by at

least 25 % to verify that the OWD responds properly to the change in water content. The OWD must pass all three tests sequentially (i.e. no tests in the sequence may be rejected in the evaluation process).

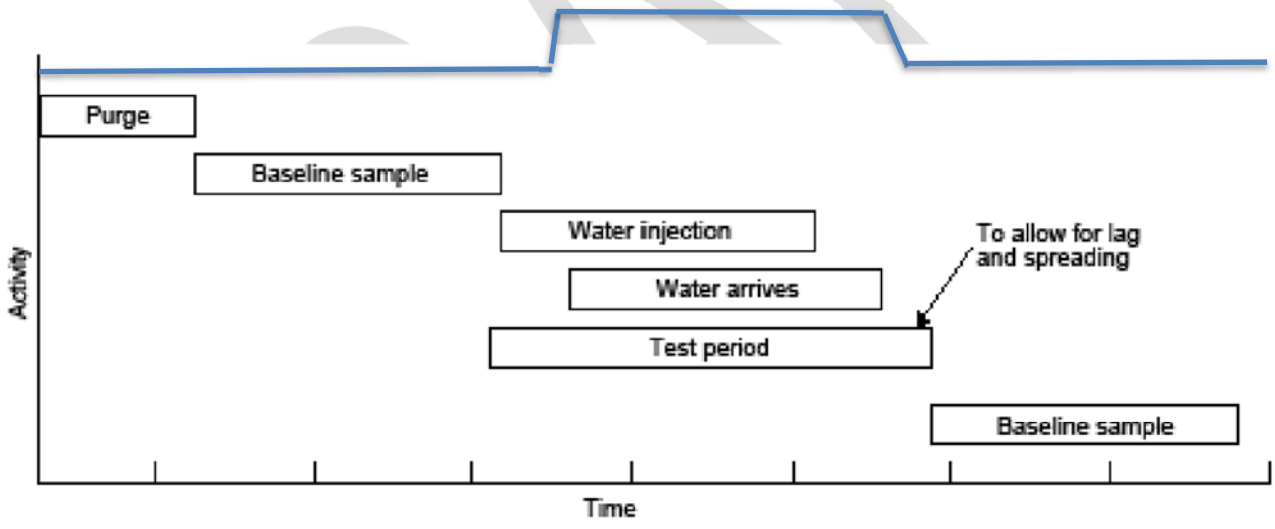
6.2.2. Readings

During each test, at the start of the Test Period (Figure 1), the OWD FWA readings should be initiated at the same time as the oil meters are read and the sampler accumulation is begun. At the end of the Test Period, the OWD FWA is read at the same time as the oil meters are read, and the sampler accumulation is ended. Under some circumstances, it may be necessary to do a higher rate purge, but still be part of the total test volume, after the water injection to assure that any water traps are swept clear.

6.2.3. Manual Sampling Point

If a manual sampling point will be used as part of the ongoing verification of the OWD, it should be verified during the Water Injection (acceptance) Test. Multiple baseline samples should be taken at the sample point, analyzed, and compared to the OWD reading. The manual sampling shall be near the OWD device utilizing the same mixing system and shall be sampled per API *MPMS* Chapter 8.1. When the water content reading reaches steady state (stabilizes) after the injection of water, additional samples should be taken from the sample point, and compared to the OWD instantaneous readings. If the sample results agree with the OWD readings, within the tolerance listed in API *MPMS* 8.2 (table3), the sample point may be used for future verification testing. The documentation of this testing should be retained, refer to Annex B for an example worksheet for OWD Acceptance Testing Using an Average of Instantaneous Samples.

Figure 1 shows the timing of one of the three tests, and Figure 2 provides a flow diagram of the test procedure.



NOTE Times are calculated based on minimum oil flow rate and distance between the injection and the sample point.

Figure 1—Typical Timing Diagram for One OWD System Test Run

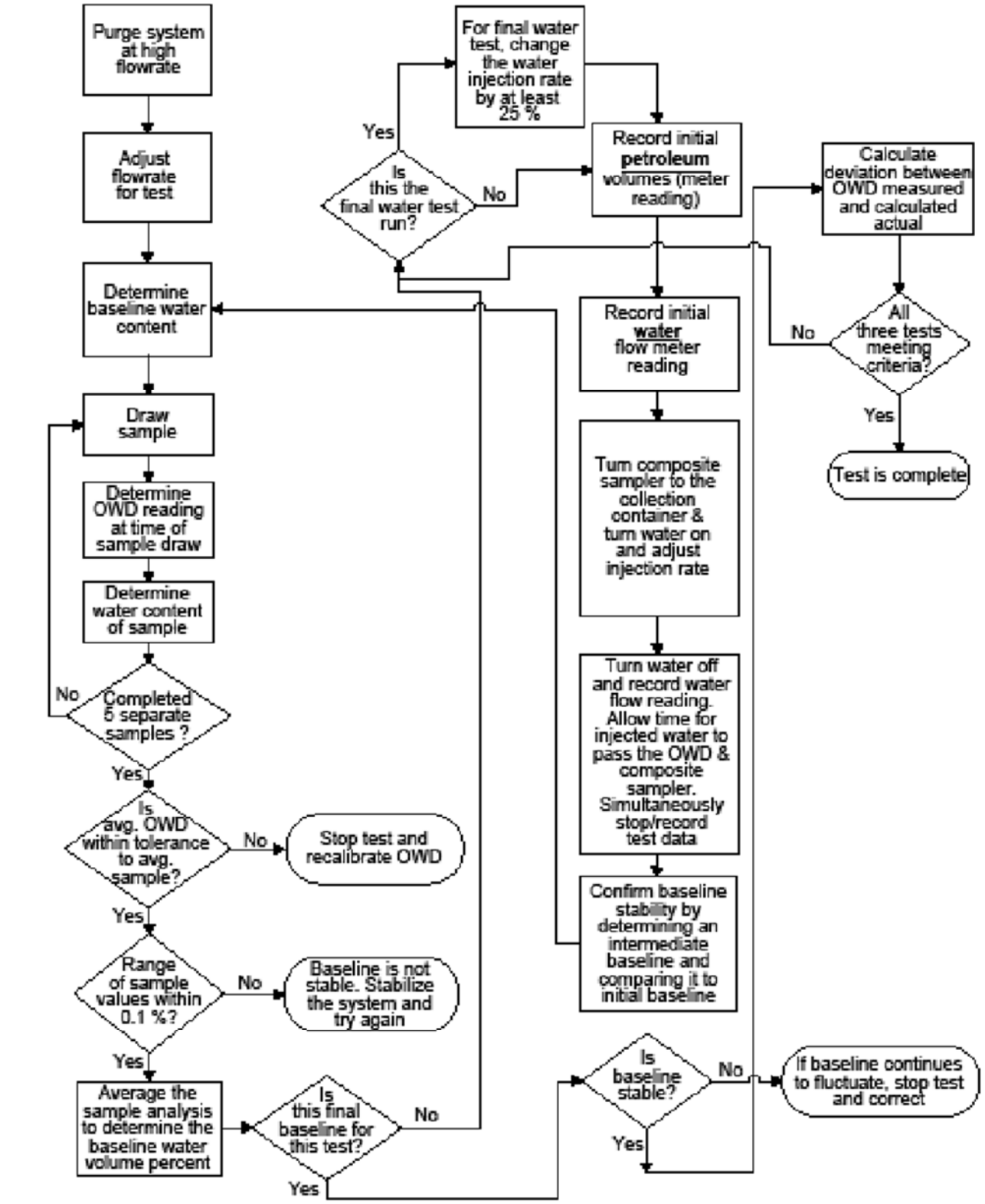


Figure 2—Flowchart of Procedure for OWD System Initial Acceptance Testing

Table 2—Typical Deviations for the OWD, System Acceptance Tests
Measurements in volume percent

Typical Deviation		
Total Water (W_{bl} + W_{inj})	**Using Meters**	**Using Tank Gauges**
0.5	0.09	0.13
1.0	0.11	0.15
1.5	0.12	0.16
2.0	0.13	0.17
2.5	0.14	0.18
3.0	0.15	0.19
3.5	0.16	0.20
4.0	0.17	0.21
4.5	0.18	0.22
5.0	0.19	0.23

NOTES:

a) Basis for the above Table 2 and the following notes is API MPMS Chapter 8.2, Second Edition (or latest) Table A-1.

b) W_{bl} is the percentage water baseline and W_{inj} is the percentage water injected.

c) The reference to meters refers to the method used to determine the volume of crude oil or petroleum in the test.

d) Deviations shown reflect use of the Karl Fischer test method described in *MPMS* Chapter 10.9 for water.

e) Interpolation is acceptable for water concentrations between values shown in the table. For example, if the total water is 2.25 %, the allowable deviation would be 0.135 % if using meters.

f) The reproducibility standard deviation calculated based on the data, at a 95 % confidence level, has been used for the values “Using Meters” shown in Table 2 in the water range 0.5 % to 2.0 %. Assigning these values to the meter is based on a model that was developed to predict standard deviations for volume determinations by tanks and meters. As there is insufficient test data for water levels over 2.0 %, values shown in the table above 2.0 % have been extrapolated on a straight-line basis using the data in the 0.5 % to 2.0 % range.

7 Ongoing Verification

7.1. General

This section discusses on-going verification of on-line water measurement devices (OWDs). Verification requirements for OWDs are covered in general terms. Manufacturer's specific verification requirements shall be followed, in addition to the guidance provided within this section. After the initial setup and acceptance testing establish a program for the on-going calibration/verification of the OWD system. The frequency will vary depending on which verification procedure is chosen.

7.1.1. In- Situ Verification

In-situ verification should be performed by one or more of the following procedures:

a) against a sampling system, meeting the requirements of API *MPMS* Chapter 8.2;

b) against spot (manual) samples, sampling to meet requirements of API *MPMS* Chapter 8.1;

7.2 Verification of OWD Sensors

7.2.1 General

The verification tolerance of OWDs should reflect the reproducibility of both the OWD and the water-in-oil analysis method used to determine the reference water content during the OWD verification.

NOTE 1 The verification tolerance is a function of:

- the reproducibility of both the OWD and the water-in-oil analysis method used to determine the reference water content;
- the absolute uncertainty of the water-in-oil analysis method used to determine the reference water content during the OWD calibration;
- the uncertainty of the water-in-oil content of each of the subsamples analyzed by the OWD and laboratory procedure with respect to the main flow line.

NOTE 2 The published precision data for water-in-oil laboratory analytical methods show a non-linear relationship between absolute water content and relative percentage reproducibility. Therefore the tolerance value used when comparing OWDs and laboratory analysis should be a function of the average water content reported during the verification procedure.

7.2.2 Verification by Comparison to Automatic Sampler

If verification is by comparison to the composite sample from a sampling system; the sampling system design, installation and operation should meet the requirements of API *MPMS* Chapter 8.2 and must have successfully been proven.

7.2.2.1 FWA Water Value

Verification should be by comparison of a FWA water value reported by the OWD under test with the water content reported for a composite sample taken over the same period. (volume/batch/time). The analysis of the proportional

sample must only be for water, therefore currently analysis be distillation or Karl Fischer Titration are the only points of comparison. Centrifuge is not acceptable unless the net water concentration can be accurately determined. (i.e. not Sediment and Water "S&W"). Every batch/accounting period for which there is an acceptable composite sample result shall be recorded and the OWD FWA result verified.

If no guidance is offered by commercial or statutory requirements regarding acceptable agreement (or allowable deviation) between the OWD and flow proportional sample, then the stated reproducibility of the laboratory analytical method should be used as guidance.

7.2.2.2 Control Charts

Control charts or other company documentation should be used to compare and document the performance of the OWD against the continuous automatic sampler system.

7.2.3 Verification by Spot Sample

If verification is by spot sampling the design and operation of the sampling system should meet the requirements of API *MPMS* Chapter 8.1.

7.2.3.1 Water Value

Verification should be by comparison of the average water value recorded by the OWD during the duration of sampling for each spot sample, ensuring that the results are synchronized.

A minimum of two values should be recorded from the OWD during spot sampling.

It is recommended that the OWD output is averaged during the spot sample period.

Sampling should only take place when the OWD indicates that the water-in-oil level changes are within acceptable limits during the spot sampling period. Each test consists of a minimum of two manual spot samples and two sets of OWD readings.

The data from a test should be rejected and the test should be repeated if:

$$\frac{\sum_0^n ABS(OWD_n - MSS_n)}{n} < 1.5 \times R$$

Where

OWD_n is the average OWD reading during manual

Sample n,

MSS_n is the analysis water result for manual sample n,

R is the stated reproducibility of the laboratory

Procedure used to determine the water content of the manual spot samples,

ABS is the absolute value.

7.2.3.2 Frequency

The frequency of initial on-going verification checks should be Weekly for the OWD and monthly for each product passing through the OWD. If acceptable stability is achieved a reduced verification frequency can be implemented.

7.2.4 Records and Documentation

7.2.4.1 Verification

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

7.2.4.2 Conditions

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

7.2.4.3 Review

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

8. Audit Trail and Security

8.1. Audit Trail

8.1.1. General

An OWD system should be capable of establishing an audit trail by compiling and retaining sufficient information to verify the OWD results. Since the accuracy of an OWD system is affected by the verification and calibration of the device and the commodity characteristics the device is registering, the audit trail should include the quantity of transaction, configuration logs, and event, alarm, and test records. All changes to the OWD and access should be documented.

8.2. Security

8.2.1. General

Restrict access to authorized personnel responsible for the OWD. All access should be recorded and made available for review by internal or external auditors. Units should either be physically sealed or password protected as necessary to prevent unauthorized access, changes to calibration and setup functions. OWD's used for custody transfer may be subject regulatory security requirements.

Annex A
(Informative)

Typical OWD Installation Diagrams

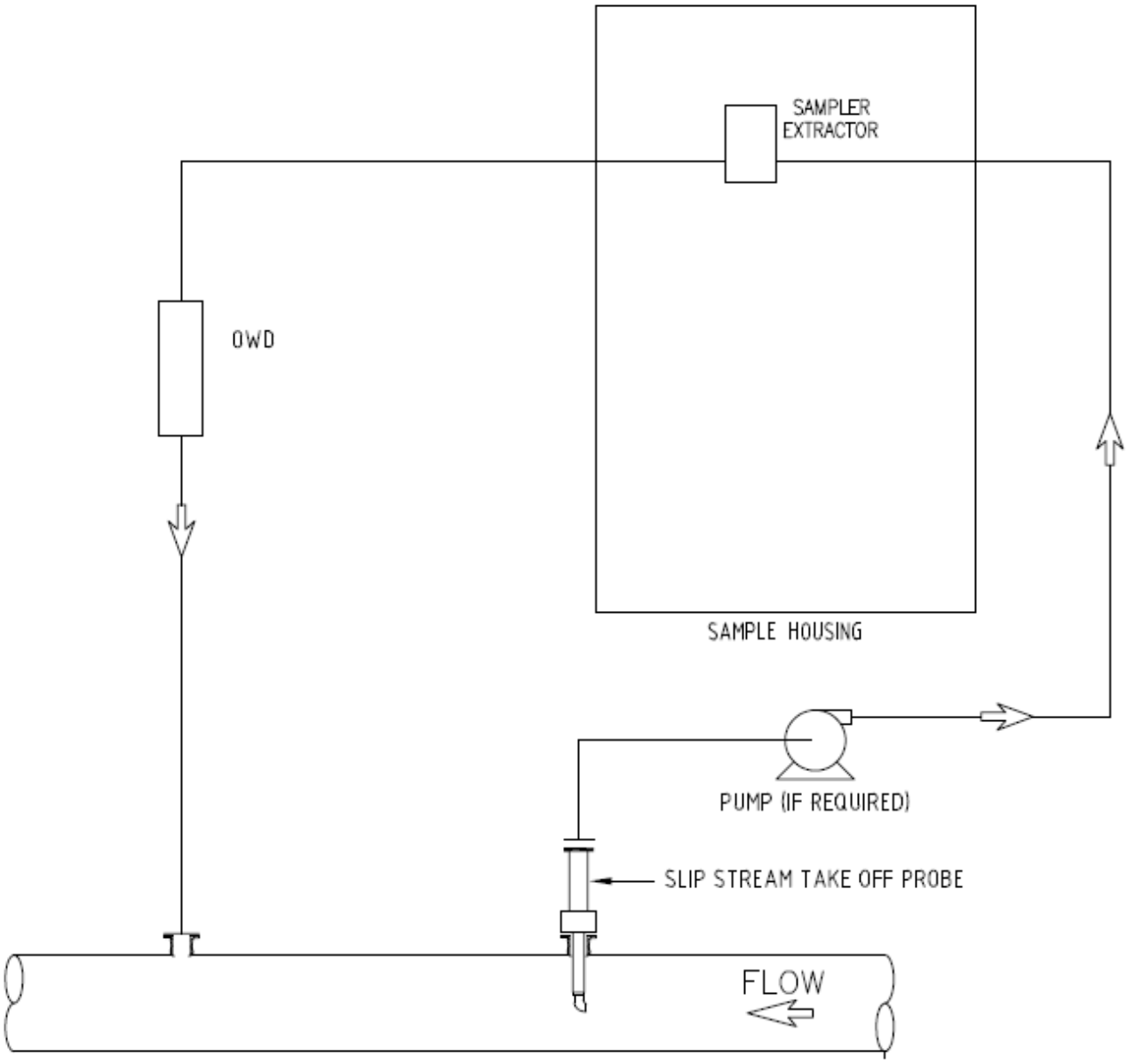


Figure B.1—Typical Fast Loop OWD Installation
(Refer to vendor recommendations for further detail.)

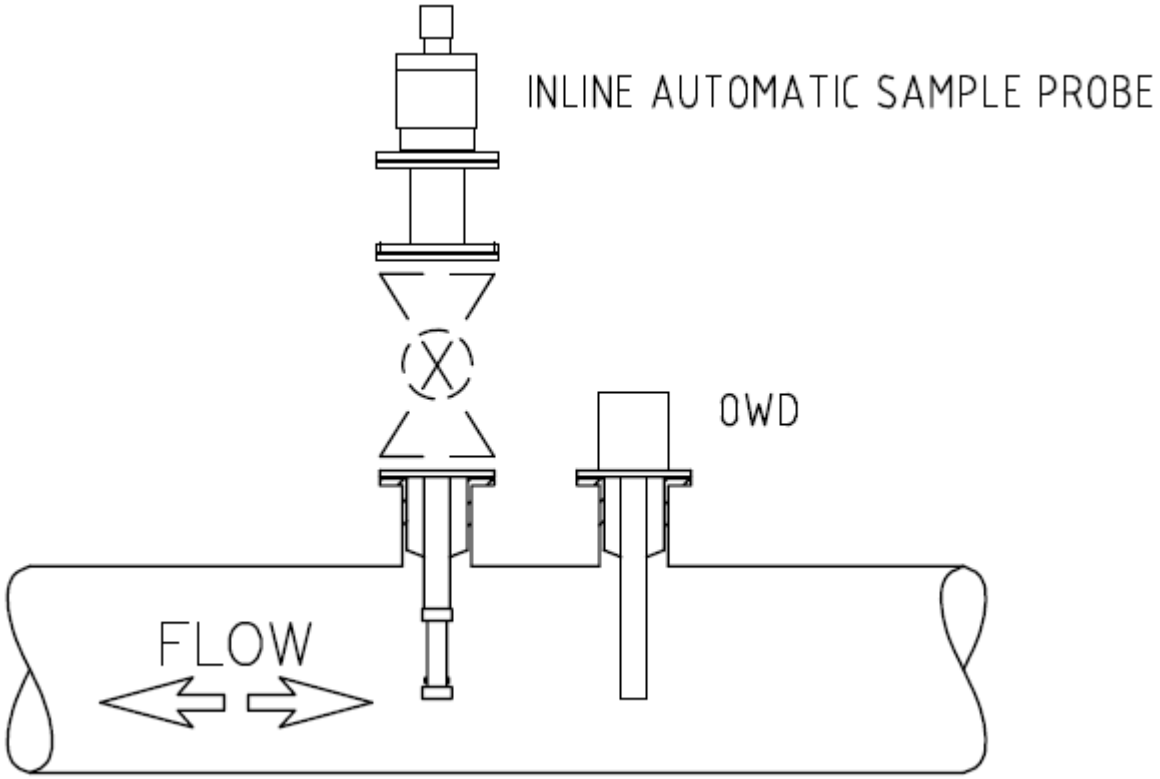


Figure B.2—Typical In-line OWD Installation
(Refer to vendor recommendations for further detail.)

Note: The sample probe and the OWD should not influence the flow (streamlines) of the other device.

Annex B
(Informative)

EXAMPLE Worksheet for OWD Acceptance Testing Using an Average of Instantaneous Samples

Equipment Functional Tag:

Date: _____ Start Time: _____ End Time: _____

Avg. Temp.: _____ Avg. Gravity: _____ Water Analysis Method: _____

Baseline

Sample #	Time (hh:mm:ss)	Sample Result (Vol % Water)	OWD Result (Vol % Water)
1			
2			
3			
4			
5			
6			
Baseline Average			

Water Injection Test

Sample #	Time (hh:mm:ss)	Sample Result (Vol % Water)	OWD Result (Vol % Water)
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
12			
Averages			

Results _____

% Difference _____

Acceptance: Pass/Fail _____

BY: _____ _____ DATE: _____