Designation: D4177 – 15

Manualof Petroleum Measurement Standards (MPMS), Chapter 8.2

Standard Practice for Automatic Sampling of Petroleum and Petroleum Products[1]

This standard is issued under the fixed designation D4177; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the U.S. Department of Defense.

INTRODUCTION

The previous version of the automatic sampling practice described the design, installation, testing, and operation of automated equipment for the extraction of representative samples from the flowing stream and storing mainly for crude oil.

This practice is a performance-based standard. It still includes the design, installation, testing, and operation of automated equipment for extraction of representative samples. It also includes the testing and proving of a sampling system in the field under actual operating conditions to ensure that the equipment, installation, and operating procedures produce representative samples. The acceptance criteria for custody transfer are covered in this practice. This practice does not address how to sample crude at temperatures below the freezing point of water. Extensive revisions have been made to the prior version of D4177 (API *MPMS* Chapter 8.2).

This practice also provides guidance for periodic verification of the sampling system.

This practice is separated into three parts:

General—Sections 5 – 17 (Part I) are currently applicable to crude oil and refined products. Review this section before designing or installing any automatic sampling system.

Crude Oil Sampling—Section 18 (Part II) contains additional information required to complete the design, testing, and monitoring of a crude oil sampling system.

Refined Product Sampling—Section 19 (Part III) contains additional information required to complete the design of a refined product sampling system.

A representative sample is "A portion extracted from the total volume that contains the constituents in the same proportions that are present in that total volume." Representative samples are required for the determination of chemical and physical properties that are used to establish standard volumes, prices, and compliance with commercial and regulatory specifications.

The process of obtaining a representative sample consists of the following: the physical equipment, the correct matching of that equipment to the application, the adherence to procedures by the operator(s) of that equipment, and the proper handling and analysis.

1. Scope*

1.1 This practice describes general procedures and equipment for automatically obtaining samples of liquid petroleum and petroleum products, crude oils, and intermediate products from the sample point into the primary container. This practice also provides additional specific information about sample container selection, preparation, and sample handling. If sampling is for the precise determination of volatility, use Practice D5842 (API *MPMS* Chapter 8.4) in conjunction with this practice. For sample mixing and handling, refer to Practice D5854 (API *MPMS* Chapter 8.3). This practice does not cover sampling of electrical insulating oils and hydraulic fluids.

[1] This practice is under the jurisdiction of ASTM Committee D02 on Petroleum Products, Liquid Fuels, and Lubricants and the API Committee on Petroleum Measurement, and is the direct responsibility of Subcommittee D02.02 /COMQ the joint ASTM-API Committee on Hydrocarbon Measurement for Custody Transfer (Joint ASTM-API). This practice has been approved by the sponsoring committees and accepted by the Cooperating Societies in accordance with established procedures. This practice was issued as a joint ASTM-API standard in 1982.

Current edition approved May 15, 2015. Published August 2015. Originally approved in 1982. Last previous edition approved in 2010 as D4177 – 95 (2010). DOI: 10.1520/D4177-15.

***A Summary of Changes section appears at the end of this standard**

1.2 *Table of Contents:*

1.3 *Units*—The values stated in either SI units or US Customary (USC) units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard. Except where there is no direct SI equivalent, such as for National Pipe Threads/diameters, or tubing.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D4007 Test Method for Water and Sediment in Crude Oil by the Centrifuge Method (Laboratory Procedure)

D4840 Guide for Sample Chain-of-Custody Procedures

D4928 Test Method for Water in Crude Oils by Coulometric Karl Fischer Titration

D5842 Practice for Sampling and Handling of Fuels for Volatility Measurement

D5854 Practice for Mixing and Handling of Liquid Samples of Petroleum and Petroleum Products

2.2 *API Standards:*[3]

MPMS Chapter 3 Tank Gauging

MPMS Chapter 4 Proving Systems

MPMS Chapter 5 Metering

MPMS Chapter 8.3 Practice for Mixing and Handling of Liquid Samples of Petroleum and Petroleum Products (ASTM Practice D5854)

MPMS Chapter 8.4 Practice for Manual Sampling and Handling of Fuels for Volatility Measurement (ASTM Practice D5842)

MPMS Chapter 10 Sediment and Water

MPMS Chapter 13 Statistical Aspects of Measuring and Sampling

MPMS Chapter 20 Production Allocation Measurement for High Water Content Crude Oil Sampling

MPMS Chapter 21 Flow Measurement Using Electronic Metering Systems

2.3 *ISO Standards:*[4]

ISO 1998 Petroleum Industry – Terminology – Part 6: Measurement

NOTE 1—See the Bibliography at the end of this standard for important historical references.

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *automatic sampling system, n*—fluid sampling system that consists of: *(a)* flowing fluid stream conditioning, if required; *(b)* a means of automatically extracting a representative sample; *(c)* pacing of the sample extraction in a flow or time proportional manner; and *(d)* delivering of each extracted sample to a sample container or an analyzer.

3.1.1.1 *Discussion*—The system consists of a sample extractor with an associated controller and flow-measuring or timing device, collectively referred to as an automatic sampler or auto-sampler. In addition, the system may include a flow conditioner, slipstream, sample probe, and sample conditioning.

3.1.1.2 *Discussion*—Systems may deliver the sample directly to an analytical device or may accumulate a composite sample for offline analysis, in which case, the system includes sample mixing and handling and a primary sample container.

3.1.1.3 *Discussion*—Automatic sampling systems may be used for liquids.

3.1.2 *batch, n*—discrete shipment of commodity defined by a specified quantity, a time interval, or quality.

3.1.3 *component testing, n*—process of individually testing the components of a system.

3.1.4 *dead volume, n—in sampling*, the volume trapped between the extraction point and the primary sample container.

3.1.4.1 *Discussion*—This represents potential for contamination between batches.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from American Petroleum Institute (API), 1220 L. St., NW, Washington, DC 20005-4070, http://www.api.org.

[4] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

3.1.5 *droplet dispersion, adj*—degree to which a fluid in an immiscible fluid mixture is composed of small droplets distributed evenly throughout the volume of the pipe.

3.1.6 *flow-proportional sample, n*—sample taken from a pipe such that the rate of sampling is proportional throughout the sampling period to the flow rate of the fluid in the pipe.

3.1.7 *free water, n*—water that exists as a separate phase.

3.1.8 *grab, n*—volume of sample extracted from a flowing stream by a single actuation of the sample extractor.

3.1.9 *homogeneous, adj*—quality of being uniform with respect to composition, a specified property or a constituent throughout a defined area or space.

3.1.10 *linefill, n*—volume of fluid contained between two specified points in piping or tubing.

3.1.11 *sample controller, n*—device used in automatic sampling that governs the operation of a sample extractor.

3.1.12 *sample extractor, n—in sampling*, a mechanical device that provides for the physical measured segregation and extraction of a grabbed sample from the total volume in a pipeline, slip stream, or tank and ejects the sample towards the primary sample container.

3.1.13 *slip stream sample loop, n*—low-volume stream diverted from the main pipeline, intended to be representative of the total flowing stream.

3.1.14 *slip stream take-off probe, n*—device, inserted into the flowing stream, which directs a representative portion of the stream to a slip stream sample loop.

3.1.15 *volume regulator sampler, n*—device that allows pipeline pressure to push a set volume into a chamber that is then trapped and redirected to the sample receiver.

3.2 *Definitions Related to Sample Containers:*

3.2.1 *constant volume sample container, n*—vessel with a fixed volume.

3.2.2 *floating piston container, FPC, n*—high-pressure sample container, with a free floating internal piston that effectively divides the container into two separate compartments.

3.2.3 *portable sample container, n*—vessel that can be manually transported.

3.2.4 *primary sample container, n*—container in which a sample is initially collected, such as a glass or plastic bottle, a can, a core-type thief, a high-pressure cylinder, a floating piston cylinder, or a sample container in an automatic sampling system.

3.2.5 *profile average, n—in sampling*, the average of all point averages.

3.2.6 *profile testing, n*—procedure for simultaneously sampling at several points across the diameter of a pipe to identify the extent of cross-sectional stratification.

3.2.7 *representative sample, n*—portion extracted from a total volume that contains the constituents in the same proportions that are present in that total volume.

3.2.8 *sample, n*—portion extracted from a total volume that may or may not contain the constituents in the same proportions as are present in that total volume.

3.2.9 *sample probe, n*—device extending through the meter tube or piping into the stream to be sampled.

3.2.10 *sampling, n*—all the steps required to obtain a sample that is representative of the contents of any pipe, tank, or other vessel, based on established error and to place that sample into a container from which a representative test specimen can be taken for analysis.

3.2.11 *sampling system, n*—system capable of extracting a representative sample from the fluid flowing in a pipe.

3.2.11.1 *Discussion*—system capable of extracting a representative sample from the fluid flowing in a pipe. **(ISO 1998-6)**

3.2.12 *sampling system verification test, n*—procedure to establish that a sampling system is acceptable for custody transfer.

3.2.13 *secondary sample container, n*—vessel that receives an aliquot of the primary sample container for the purpose of analysis, transport, or retention.

3.2.14 *stationary sample container, n*—vessel that is physically fixed in place.

3.2.15 *stream conditions, n*—state of a fluid stream in terms of distribution and dispersion of the components flowing within the pipeline.

3.2.16 *stream conditioning, n*—mixing of a flowing stream so that a representative sample may be extracted.

3.2.17 *time-proportional sample, n*—sample composed of equal volume grabs taken from a pipeline at uniform time intervals during the entire transfer.

4. Significance and Use

4.1 Representative samples of petroleum and petroleum products are required for the determination of chemical and physical properties, which are used to establish standard volumes, prices, and compliance with commercial terms and regulatory requirements. This practice does not cover sampling of electrical insulating oils and hydraulic fluids. This practice does not address how to sample crude at temperatures below the freezing point of water.

PART I—General

This part is applicable to all petroleum liquid sampling whether it be crude oil or refined products. Review this section before designing or installing any automatic sampling system.

5. Representative Sampling Components

5.1 The potential for error exists in each step of the sampling process. The following describes how sampling system components or design will impact whether the sample is representative. Properly address the following considerations to ensure a representative sample is obtained from a flowing stream.

5.1.1 *Location*—Locate the sampling system close to or at a position where the custody transfer is deemed to have taken place. The quality and quantity of the linefill between the

extractor and the sample container may be significant enough to impact the quality of the sample.

5.1.2 *Conditioning of the Flowing Stream*—Disperse and distribute (homogenize) the sample stream at the sample point so that the stream components (for example oil, water, and sediment) are representative at the point of the slip stream sample loop inlet (if used) or where the sample is to be extracted.

5.1.3 *Sample Extraction*—Take grabs in proportion to flow. However, if the flow rate during the total batch delivery (hours, days, week, month, and so forth) varies less than ±10 % from an average flow rate, and if the sampling stops when the flow stops, a representative sample may be obtained by the time proportional control of the sampling process.

5.1.4 *Sample Containers*—The sample container shall be capable of maintaining the sample's integrity, which includes not altering the sample composition. Minimize the venting of hydrocarbon vapors during filling and storage and protect the sample container from adverse ambient elements. The sample container should also be compatible with the fluid type to avoid degradation of the sample container and possible leakage of the sample.

5.1.5 *Sample Handling and Mixing*—Provide a means to allow the sample to be made homogenous before extraction of aliquots for analysis, retention, or transportation. For more information regarding the handling and mixing of samples, refer to Practice D5854 (API *MPMS* Chapter 8.3).

5.1.6 *System Performance Verification*—Perform test(s) to verify the system is performing in accordance with the criteria set forth within this practice or as otherwise agreed.

5.1.7 *Performance Monitoring*—Provide performance measurement and recording of the sampling system to validate that the system is operating within the original design criteria and compatible with the current operating condition.

6. Design Criteria

6.1 The following items shall be addressed when designing a sampling system:

6.1.1 Volume of sample required for analysis and retention;

6.1.2 Conditions (temperature, pressure, viscosity, density, minimum and maximum flow rates, sediment, water, and contaminants);

6.1.3 Type of fluid (crude oil, gasoline, diesel, kerosine, or aviation fuel);

6.1.4 *Grabs per Batch*—Ensure the sample extractor(s) samples at a high enough frequency to obtain the required number of grabs without exceeding the limits of the equipment or other sampling system constraints. Increasing the number of grabs taken per batch reduces sampling uncertainty as described in Annex A1. For large custody transfer batch quantities, to ensure representativeness of the total volume of extracted sample in the sample receiver, some operators have set an expectation that is equivalent to a margin of error of 0.01 with 95% confidence. Eq A1.6 calculates this to be 9604 grabs per batch. In practice, a rounded up recommended value of 10 000 grabs per batch is often used in industry. Small batch sizes, small capacity of the primary sample container and other sampling system constraints may result in designs with a different design criterion than 9604 grabs per batch;

6.1.5 *Batch Size(s)/Duration*—Ensure the sample extractor(s) samples at a high enough frequency to obtain the required sample volume without exceeding the limits of the equipment;

6.1.6 *Homogeneity of the Fluid/Stream Conditioning*—Ensure the pipeline content is homogeneous at the point of extraction (sample point) over the entire flow range of all anticipated product types. Give special consideration to viscosity, density, and vapor pressure;

6.1.7 Consider the interface between batches;

6.1.8 Consider incorporating additional analyzers in the sampling system design that would provide for valuable feedback with regards to the stream being sampled;

6.1.9 Consider the failure and maintenance of any devices inserted directly into the process pipeline and their ability to withstand pressure surges. Additionally, consider bending moment and vibrations caused by flow-induced vortices that the devices may encounter;

6.1.10 Consider the interconnection between the sample extractor and the primary sample container to ensure the sample remains representative of the batch;

6.1.11 Provide a flow measurement device or a method to provide a flow signal for flow proportioning the sampling system;

6.1.12 Ensure the tubing from the sample probe or extractor to the sample container slopes continuously downward towards the sample container point of entry;

6.1.13 Provide a control system (which may include an overall supervisory reporting system (Human-machine Interface (HMI)/Supervisory Control and Data Acquisition (SCADA))) to operate the sample system in proportion to flow;

6.1.14 Use performance monitoring equipment to verify that samples are being taken in accordance with the sampling system design and this practice;

6.1.15 Provide environmental protection that may consist of a building, enclosure, or shelter and heating or cooling systems. Heating may impact the electrical certification. It may be necessary to install parts or all of the sampling system in heated (or cooled) or enclosed environments to maintain the integrity of the samples taken, sample handling, or reduce the incidence of mechanical failure, for example, caused by increased viscosity or wax content. Safety protections in regard to static electricity and flammable vapors when sampling shall also be considered;

6.1.16 Consider sample system integrity and security;

6.1.17 Ensure all applicable regulatory requirements are met;

6.1.18 Consider the properties of interest to be analyzed;

6.1.19 Extracting samples in proportion to flow or time;

6.1.20 Locating the opening of the sample probe in the part of the flowing stream where the fluid is representative;

6.1.21 Locating the opening of the sample probe in the direction of the flow;

6.1.22 Ensuring the fluid entering the sample probe tip follows a path that creates no bias;

6.1.23 Ensuring that the fluid from the extractor flows into the primary sample container;

6.1.24 Ensuring all of the samples taken during the batch go into the primary sample container, the sample container contents are properly mixed, and any portion extracted for analysis is representative; and

6.1.25 Ensuring that good sampling and handling procedures are followed to maintain representativeness at each stage of the mixing, distribution, and handling of the sample from point of first receipt into the primary sample container to its analysis.

6.2 *Other Considerations:*

6.2.1 *High Reid Vapor Pressure (RVP) Fluids (Examples are Crude and Condensate)*—Where the crude oil or crude condensate has a RVP greater than 96.53 kPa, the process and practicalities of handling and transporting large pressurized (constant pressure) containers precludes the possibility of taking 9604 grab samples. A practical expectation for handling is normally 1 L to 4 L. Systems and processes that yield samples based on less than 9604 grabs should be established and agreed between all interested parties.

6.2.2 *Representative Sample—Sample Extractor to Container*—Sample grabs are extracted from the flowing pipe by the sample extractor. At the beginning of each batch, the volume retained in the internal mechanism of the sampling device or tubing between the sample extractor and sample container may contaminate the properties of the subsequent batch if not properly displaced. This may be minimal where the sampling process is measuring identical products in sequential batches belonging to a common owner. However, where sequential batches may possess significantly different properties, be different types of refined products or be of differing ownership, the volume between the point of sample extraction and the sample container has the potential to produce non-representative samples. These non-representative samples can impact the integrity of the custody transfer and volumetric reconciliations of each batch transferred and may also result in unwarranted product quality concerns. Consider the evaluation of this interface and minimize the dead volume. Purging with alternate fluids, air, or inert gas has the potential to displace this linefill into the proper sample container, but exercise caution to ensure that other quality properties of the sample are not impacted. A sampling system capable of purging through the sampling container and using multiple containers may also be an alternative.

7. Automatic Sampling Systems

7.1 Automatic sampling systems may be fixed or portable and are divided into two types: in-line or slip stream sample loop. Each system design has a sample extraction mechanism that isolates a sample from the stream. The sample extractor can be within the flowing stream or mounted offset as in the case of a volume regulator (Fig. 3). When a fixed system is not practical, the use of portable designs may be considered, see Figs. 1 and 2.

7.2 *In-line Sampling Systems*—An in-line sampling system places the sampling extraction mechanism or the take-off probe of a volume regulator sampler directly within the flowing stream. See Fig. 1 and Fig. 3.

7.3 *Slip Stream Sample Loop System*—A slip stream sample loop system has a take-off probe located in the main pipeline that directs a portion of the fluid flow into the slip stream sample loop (see Fig. 2) and past a sample extractor or the take-off probe of a volume regulator sampler (see Fig. 3).

7.3.1 Give consideration to the following aspects involving the take-off probe placement and design to prevent stratification or separation of the hydrocarbon stream components or significant lag time:

7.3.1.1 The opening size;

7.3.1.2 Forward facing; and

7.3.1.3 Sufficient velocity through interconnecting piping, sample extractor or analyzers, and slip stream sample loop system.

7.3.2 Avoid blockage in the slip stream sample loop or pressure pulses created by sample extractors. See Fig. 2. For more information on crude oil design characteristics, refer to 18.4.

7.4 *Portable Sampling Systems*—Portable samplers are those that may be moved from one location to another. The requirements for obtaining a representative sample with a portable sampler are the same as those of a fixed sampling system.

7.4.1 In crude oil, fuel oil, or product sampling applications, a typical application of a portable sampling system is on board at the manifold of a marine vessel or barge. There are also occasional applications on shore.

7.4.2 The same design criteria for representative sampling apply to both portable and stationary sampling systems. An example of portable samplers is shown in Fig. 4.

8. Sampling Location

8.1 *System Location*—The optimal location for installation of the sampling system is to be as close as possible to the custody transfer point. Consideration should be given to onshore, offshore, shipboard, tanker, rail car, loading arm installations, and linefill issues that may impact the location, geography, or environmental restrictions, and other possible locations. It may not be practical to place the system close to this optimal position; therefore, minimize the distance from the system to the custody transfer point. See Fig. 5.

8.2 *Linefill Sampling Point Location*—The optimal location for the sampling point or take off to a slip stream sample loop system is in the pipeline after stream conditioning.

8.3 *Sample Take-Off Probe Location*—For sample extractor probes or sample take-off probes, to prevent the sample from being misrepresentative of the flowing line, insert the sample probe in the center half of the flowing stream. Verify that the probe is installed correctly, the probe opening is facing in the desired appropriate direction for the application, and the external body of the probe is marked with the direction of flow. See Fig. 6 (probe design).

8.3.1 The sample probe shall be located in a zone in which sufficient mixing results in adequate stream conditioning (see 19.2).

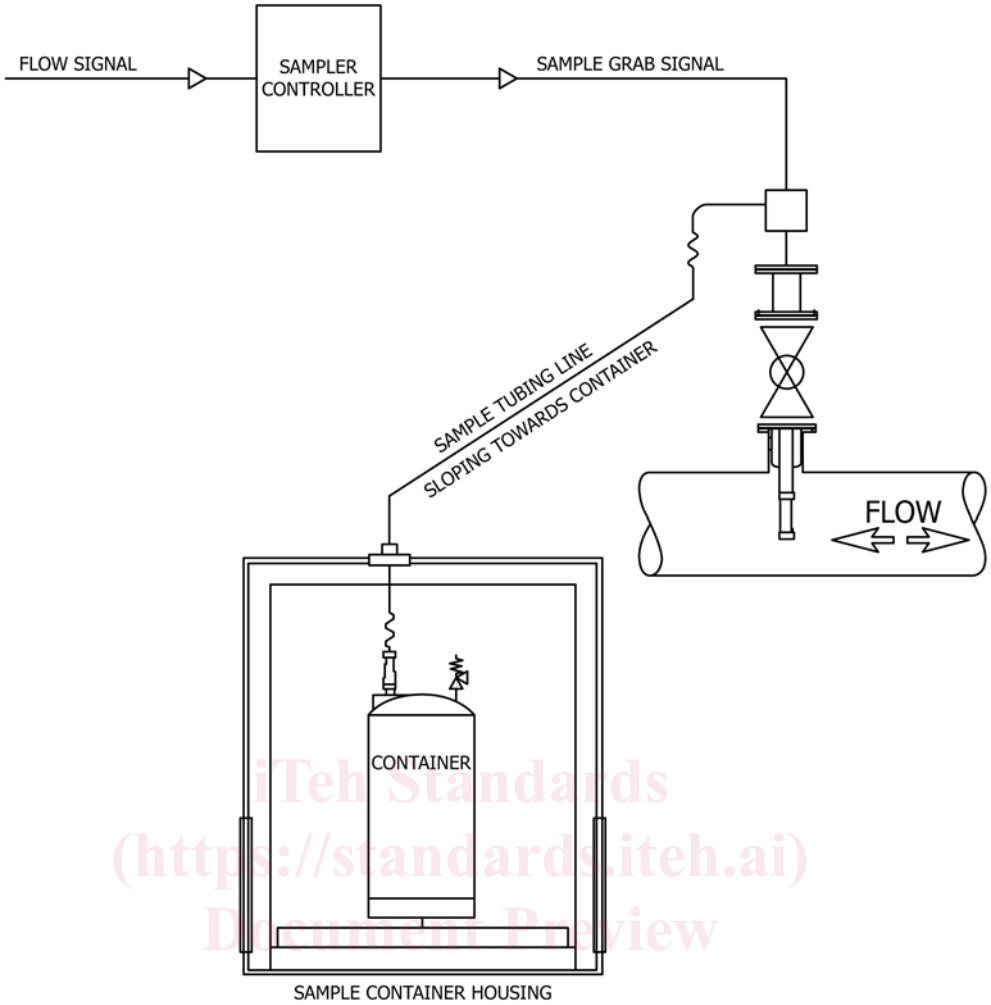

FIG. 1 In-Line Sampling System

8.3.2 The recommended sampling area is approximately the center half of the flowing stream as shown in Fig. 7.

8.3.3 When a main line mixing device is used, the manufacturer shall be consulted for the sample probe's optimum location with regard to downstream distance and piping.

8.3.4 When possible, the preferred orientation of the extractor probe is horizontal.

8.3.5 Use a sample take-off probe of sufficient strength to resist the bending moments and vortices that may be created across the full process range.

8.4 *Sample Extractor Location*—The position and design of the extractor within the piping cross section may be influenced by the basic properties of the product being sampled. Design and install the extractor in the pipeline in a position so that it minimizes any change to the properties of the sample as it is withdrawn.

8.4.1 Install the probe in a position on the cross section considered as representative. Insertion of the probe within the center half of the flowing stream see Fig. 7 meets the criteria.

8.4.2 If stream conditioning has been used to improve the homogeneity at the sample position, install the sample extractor in the optimal position downstream. The recommended distance downstream will be supplied by the stream conditioner manufacturer.

8.4.3 Use an extractor probe of sufficient strength to resist the bending moments and vortices that may be created across the full process range.

8.5 *Linefill Considerations*—When the transfer happens, when the receipt point and sample point are a substantial distance apart such as in excess of a mile away from the meters and sampling system, the linefill between the receipt point and the sampling system will not be sampled until the next movement occurs. Account for the linefill at a later date when the volume is displaced. See Fig. 5 (linefill).

8.5.1 *Linefill*—The linefill portion of a parcel may be handled in a variety of ways. Some line fills are pushed the final distance using water or inert gas. This clears the pipeline of the batch and samples the last few cubic metres (bbl) of the parcel into the same sample container.

8.5.2 Linefill is a known or estimated volume and requires special consideration as part of cargo transfer calculations and procedures. The simplest example is one ship or tank and one

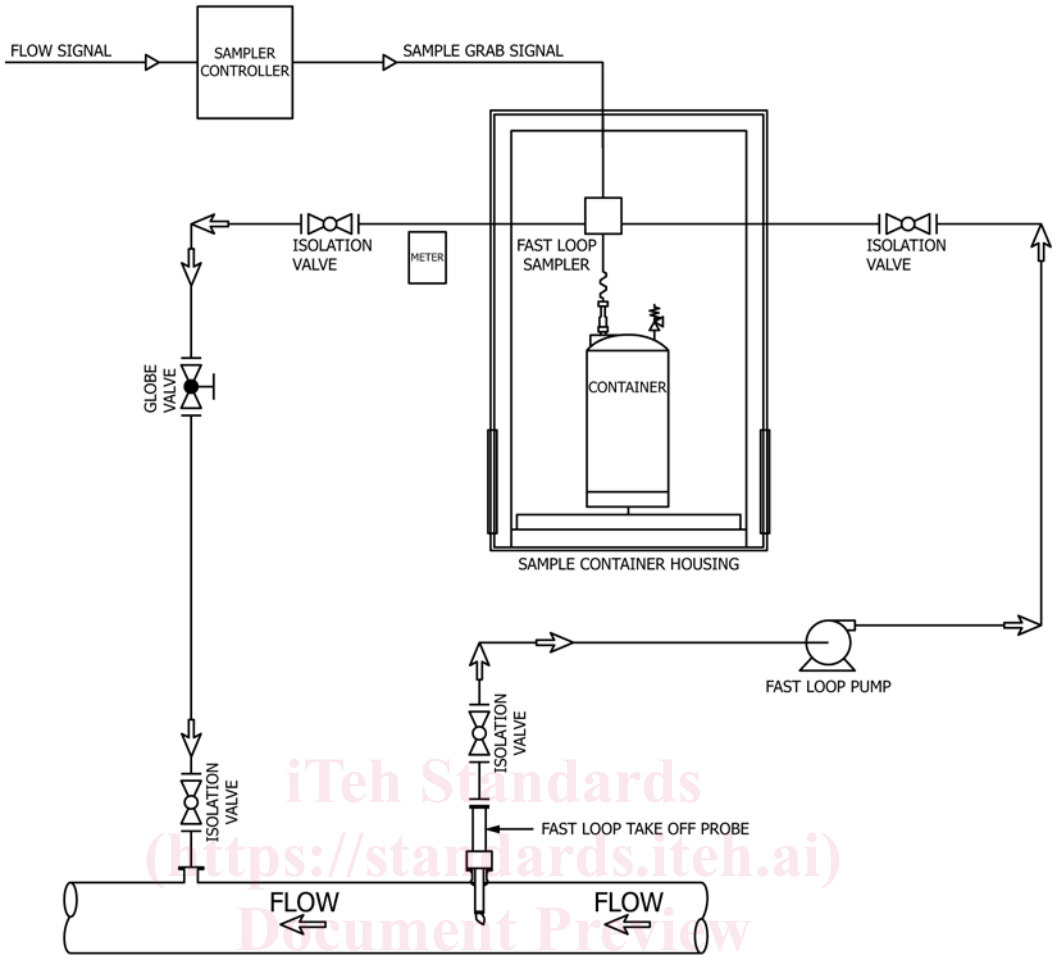

FIG. 2 Slip Stream Sample Loop Sampling System

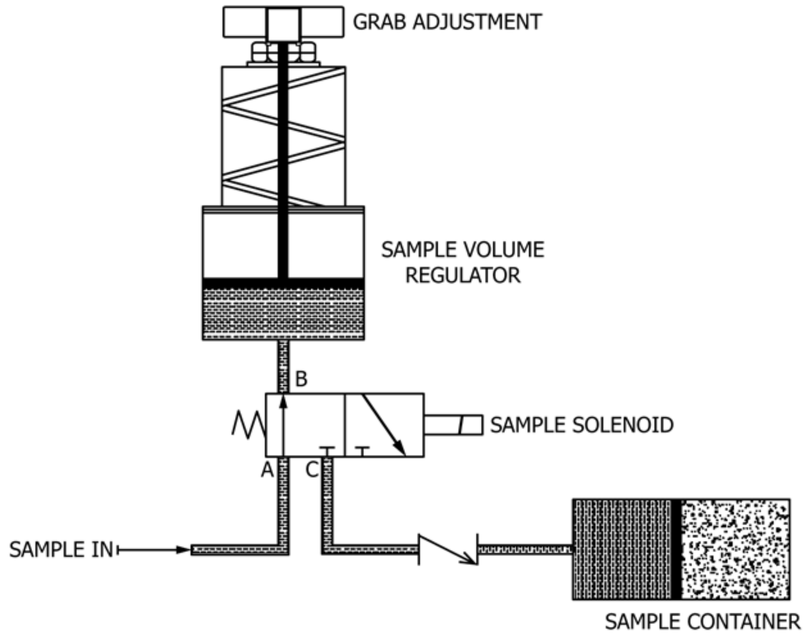

FIG. 3 Sample Volume Regulator

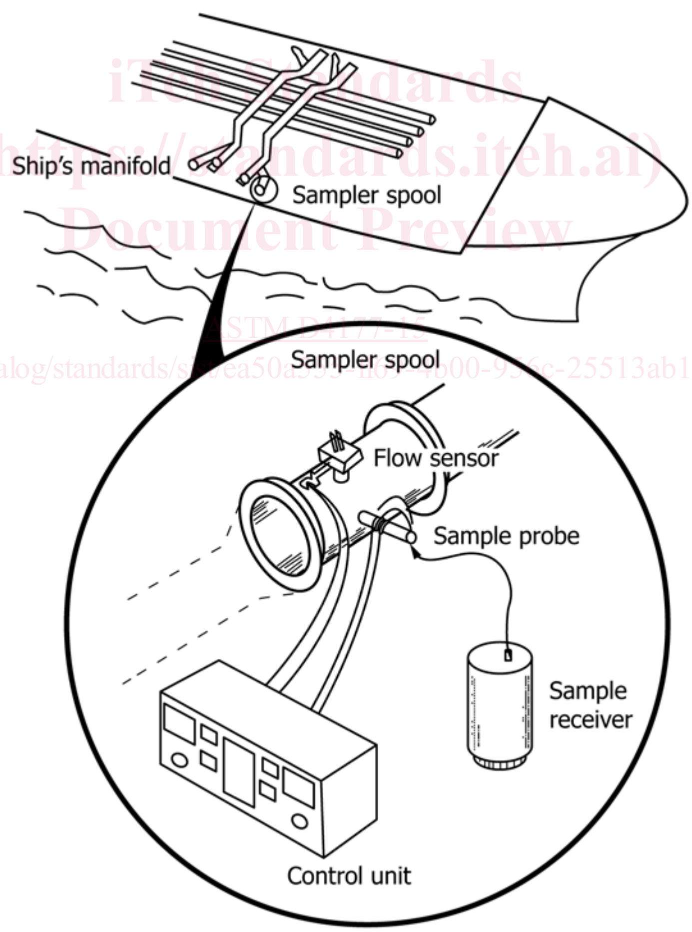

FIG. 4 Typical Portable Installation

pipeline. Consider the volume of the batch to be sampled between the take-off point and the transfer position, which is known as linefill. The influence of the properties of interest in

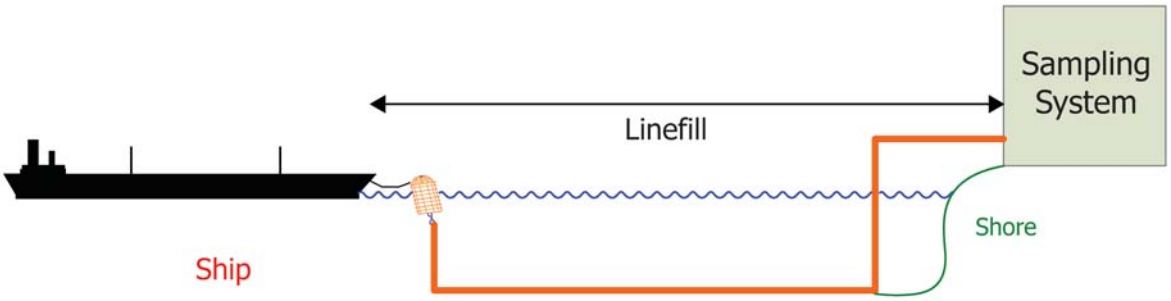

FIG. 5 Linefill

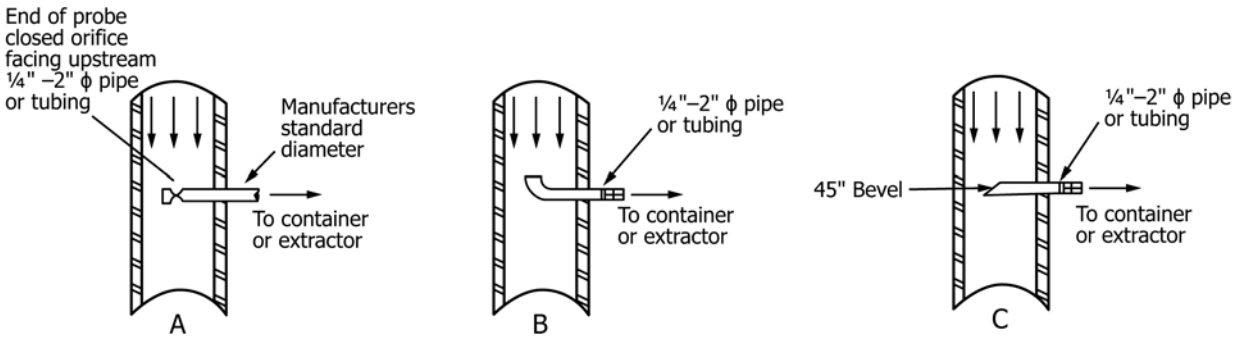

FIG. 6 Probe Design

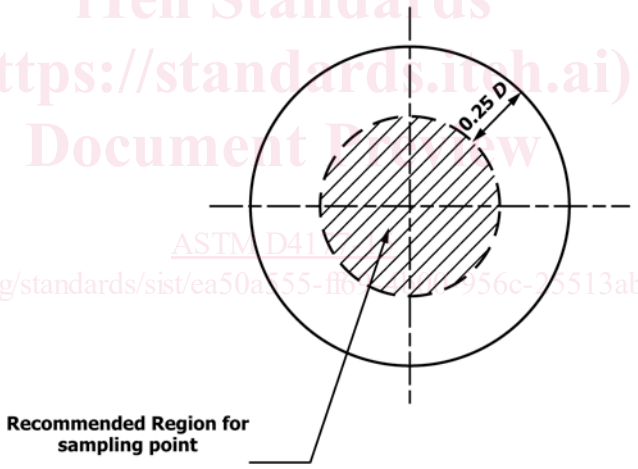

FIG. 7 Sample Probe and Slip Stream Take-Off Probe Location for Vertical or Horizontal Pipe

relation to the overall batch volume may be significant enough to alter the composite sample.

9. Mixing of the Flowing Stream

9.1 *Stream Conditioning:*

9.1.1 Stream conditioning increases the level of turbulence by using additional energy. Ensure that, at the point of sampling the fluid is homogenous so that, when the fluid is tested, the test result is representative of the entire stream. When there is not adequate turbulence, additional efforts are required to condition the stream so that it will be representative at the point of sampling.

9.1.2 Hydrocarbon fluids containing a denser phase product (that is, water, sediment, or both) will require energy to disperse the contaminants within the flowing stream. Refined petroleum products and non-crude feed stocks, such as naphtha, are generally homogeneous and usually require no special stream conditioning. Exceptions include when free water, sediment, or unique contaminants are present or if a nonhomogeneous product is being sampled.

9.1.3 Stream conditioning is impacted by upstream piping elements such as elbows and valves. These elements can promote mixing but may also skew the flow profile. Piping elements can be installed that are specifically designed to

develop a homogenous stream. Other elements can be installed to add energy to the stream, increasing turbulence.

9.2 *Stream Conditions:*

9.2.1 When assessing whether stream conditions require that additional measures be taken to ensure adequate mixing, consider the following, in each case considering the worst-case conditions:

9.2.1.1 *Velocity of the Flowing Stream*—It is most difficult to ensure representative sampling at low-stream velocities. If an in-line mixing element is installed, pressure drops will increase as the stream velocity increases potentially resulting in unacceptable pressure drops across the mixing element. For streams at or near their bubble point, pressure drops across the mixing element may lead to phase separation.

9.2.1.2 *Water Content*—It is more difficult to sample streams with higher water contents because water droplets in the emulsion tend to be larger and slugging of the water can occur.

9.3 *Methods of Stream Conditioning:*

9.3.1 *Base Case Stream Properties*—Some streams are sufficiently homogenized because of the fluid properties and velocity so that additional stream conditioning is not required.

9.3.2 *Upstream Piping Elements*—Thoughtful selection of the location of the sampling point can improve the chances of a well-mixed stream. Harnessing the impact of upstream elements such as valves, tees, elbows, flow meters, reducers, air eliminators, or pumps can enhance mixing of the flowing stream. To be effective, the sample point needs to be located in close proximity to selected upstream elements. The effectiveness of this approach in generating a homogenous stream is not assured in any case and may not be adequate for all stream conditions.

9.3.3 *Static Mixer*—A device that uses the kinetic energy of the moving fluid to achieve stream conditioning by placing a series of internal obstructions in the pipe designed to mix and evenly distribute all stream components throughout the pipe cross section.

9.3.4 *Power Mixer*—Power mixing systems use an external energy source; typically, an electric motor or pump to increase fluid velocity and turbulence.

9.4 *Location of Automatic Sampling System:*

9.4.1 *General*—An automatic sampling system should be located in a position that best guarantees access to a homogeneous stream. Consideration should be given to using any mixing benefits of upstream elements and avoiding partially filled pipes, dead legs, or headers.

9.4.2 *Multiple Run Metering Systems and Headers*—When a sampling system is used in conjunction with a multiple-run metering system, the sample point should not be located on an individual meter run, inlet, or outlet header. For example, a horizontal pipeline carrying crude oil and water will, at low flow rate, have the potential for stratification resulting in free water, which is likely to be divided unevenly between the metering streams. Additionally, flow patterns within headers are unpredictable and impacted by the number and order of streams in service. The sampling system may be located upstream or downstream of the metering system. If the velocity of the product in the pipe at the sample point does not provide adequate homogeneity for sampling (under worst-case flow and product conditions), the system requires additional stream conditioning. (For water-in-oil sampling, see *C1/C2* calculations in Annex A2 for further guidance around mixing.)

9.4.3 *Stream Blending*—Ensure automatic sampling systems are sufficiently downstream of points where different streams are blended to enable thorough mixing to occur.

10. Proportionality

10.1 An automatic sampling system controller paces a sampling device to extract representative samples throughout a batch or period. The proportionality of the samples being extracted can be defined by the following categories:

10.1.1 *Flow-Proportional Sampling:*

10.1.1.1 *Custody Transfer Meters*—Use custody transfer meters to pace the sampler where available. When using a single sampling point and measuring flow by multiple meters, pace the sampler by the combined total flow signal. In some circumstances, install a separate sampling system in each meter run. In this case, pace the sampler by the meter it is supporting (API *MPMS* Chapter 5).

10.1.1.2 *Special Flow Rate Indicators*—Automatic tank-gauging system for custody transfer may pace the sampling system in proportion to flow API *MPMS* Chapter 3.

10.1.1.3 An add-on flow metering device such as a clamp-on meter may be able to pace the sampling in proportion to flow.

10.1.2 *Time-Proportional Sampling*—Sampling in a time-proportional mode is acceptable if the flow rate variation is less than ±10 % of the average rate over the entire batch and if the sampling stops when the flow stops.

10.2 Care shall be taken not to sample faster than either the sample extractor or the sample control system is capable of operating. Operating a sampling system in this manner will result in a non-representative sample.

11. Sample Extractor Grab Volume

11.1 Sample extractors extract a wide variety of volumes per sample grab. When designing the sample system, consider the extractor grab volume. The extraction of larger volumes per grab may require a larger container to provide the necessary resolution of the desired 9604 grabs per batch. (See Annex A1 on how to calculate the error when the grabs per batch are reduced.)

11.2 Larger grab volumes may also be required to fill a container to an acceptable level per Practice D5854 (API *MPMS* Chapter 8.3) during small-volume batches delivered at high flow rates. For the same overall volume collected, larger sample grab volumes will reduce the sample frequency and also the resolution of the sample.

11.3 Sample grab volumes should be repeatable within ±5.0 %. The nominal grab volume (as determined by the sample probe manufacturer) is not necessarily the same as the actual grab volume. For purposes of establishing the sampling frequency for a batch, only the actual volume should be used.

11.4 The actual grab volume may be determined as an average by measuring 100 grabs into a suitably sized graduated cylinder. The volume contained in the cylinder at the end of test shall be divided by 100 (or the number of grabs taken) to establish the actual grab volume.

11.4.1 For example, if a sampler grabs 100 samples with the nominal grab size of 1.0 mL and an actual grab size of 1.2 mL, the end result would be 120 mL. In that situation, the person taking the sample could expect to observe anywhere from a low of 114 mL to a high of 126 mL during future verifications of the grab size.

12. Containers

12.1 *Sample Containers:*

12.1.1 A sample container is required to hold and maintain the composition of the sample in liquid form. This includes both stationary and portable containers, either of which may be of variable or fixed volume design. If the loss of vapors will significantly affect the analysis of the sample, a variable volume type container should be considered. Materials of construction should be compatible with the petroleum or petroleum product sampled. In general, one sample container should be used for each batch. Sampling a single batch into two receivers should be avoided since this will increase the potential for error.

12.1.2 Fixed primary sample containers require local mixing. Perform flushing, cleaning, and inspection of the internal mixing system after each batch. Clean, flush, and inspect transportable primary containers either on location or at the laboratory.

12.1.3 The containers types will generally be either variable volume (constant pressure) or fixed volume (constant volume). Sample containers may be stationary or portable and shall allow for cleaning and inspection. When designed for off-site analysis, both in-line and slip stream sample loop-type sampling systems will have primary sample containers. Use a sample container designed to hold and maintain the composition of the sample in liquid form. Stationary systems typically require local product mixing for any potentially nonhomogeneous product. Stationary sample containers remain permanently attached to the sampling system and are not intended to be removed while portable sample containers are removed from the sampling system and transported to the laboratory for mixing and analysis.

12.1.4 Both the design and materials of a sample container shall be tailored for the application. Container components including gaskets and O-rings, couplings, closures, seals, and relief valves should be assessed when reviewing the compatibility of container materials. The materials used in the construction of the sample container shall be compatible with the fluids to be collected and retained, as well as not compromising the properties of interest to be tested. Some contaminants may be adsorbed or absorbed by typical container materials. Special coatings or surface preparations may be required to avoid such effects.

12.1.5 The design of the sample container shall facilitate mixing of the sample to obtain a representative sample. The sample container may require special construction details to obtain an aliquot or test specimen for the purpose of performing an analysis and sample retention. Some analyses require that the sample not be exposed to air which will impact the method of sealing the container as well as other design considerations.

NOTE 2—If an aliquot or test specimen is to be drawn directly into the testing device, the primary sample container may need to have the capability of being homogenized.

12.1.6 Sample containers that are exposed to ambient environmental conditions (that is, sunlight, rain, heat, cold, ice, and other weather conditions) may impact the ability to mix and remove aliquots (for example, viscous or waxy products at low-temperature extremes) or sample integrity (for example, high-temperature loss of light ends of high RVP products).

12.1.7 A sampling system will typically be comprised of one or more sample containers (see Fig. 8). Multiple containers may be required on systems moving multiple batches, to take samples of linefill, or even to provide a safety backup. Consider the number of containers to be used, how these will be monitored, and whether the sample trapped in the interconnecting tubing will influence the representivity of the sample. Use methods to provide purging from the extraction point to the container. Failure to purge into another empty container or drain system will compromise the integrity of the next sample. The purge volumes are variable and in a multi-product system, purge volumes required are often a multiplier of the actual volume to sweep clingage away. Consult with manufacturer for guidance with system purging requirements.

12.1.8 Any containers used for the collection and handling of samples shall:

12.1.8.1 Meet the local health, safety, and environmental requirements, including spill and overflow containment;

12.1.8.2 Provide for relief valves that can be set and maintain a pressure that does not exceed the design pressure of the container;

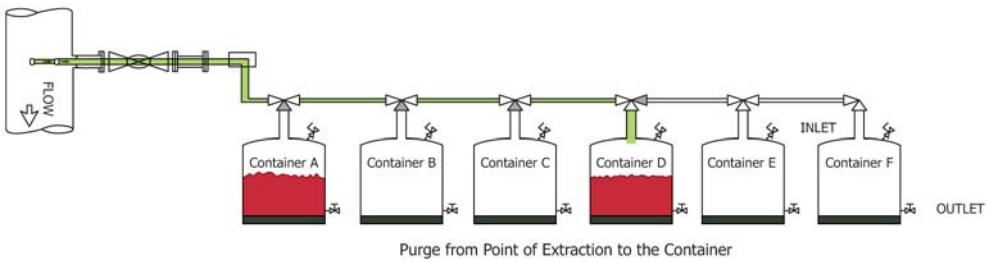

FIG. 8 Sample Probe with Multiple Containers

12.1.8.3 Be designed so as to allow adequate mixing of the sample;

12.1.8.4 Use a design and materials that prevent retention of any of the components within the sample (such as water, metals, and long-term buildup/encrustation) and that do not react with the sample over the period in which it is likely to be in contact with the container material;

12.1.8.5 Facilitate complete withdrawal of the sample. When using mixing systems, they shall be capable of being fully drained;

12.1.8.6 Ensure internal pockets or dead spots are cleaned or mixed during a normal cycle. This includes any attachments such as glass level gauges;

12.1.8.7 Include a vacuum breaker if required for the removal of the sample or draining of the sample;

12.1.8.8 Be equipped with a pressure gauge;

12.1.8.9 Provide facilities for security sealing to prevent tampering with the sample;

12.1.8.10 Require closures on containers of sufficient size to facilitate easy inspection and cleaning;

12.1.8.11 Unless included in an auxiliary monitoring system, provide a means to monitor filling of the container; and

12.1.8.12 Unless included in an auxiliary monitoring system, provide a high-level alarm.

13. Sample Handling and Mixing

13.1 Maintain the properties and composition of the product in the container to ensure its contents are not compromised. Transfer of samples from the primary sample container to another container or the analytical glassware in which they will be analyzed requires special care to maintain their representative nature. Adequately mix the sample in the container to ensure a homogenous sample. For more information on the handling of the sample, refer to Practice D5854 (API *MPMS* 8.3) for detailed procedures.

14. Control Systems

14.1 The control system for automatic samplers is now generally microprocessor-based. The control system shall have adequate speed to ensure that the required number of samples is taken proportionally across the entire batch. However, the sampler control may at times be integrated as part of an overall process and, therefore, it is a requirement that the timing of the sample extractor signal (output) is within an acceptable tolerance for the system. While sample pacing is important, other aspects of the control system may include, but are not limited to:

14.1.1 Power failure signal,

14.1.2 Flushing of lines between batches,

14.1.3 Filling progress,

14.1.4 Sample verification,

14.1.5 Low-flow or no-flow alarm,

14.1.6 Over-fill warning,

14.1.7 Sample counter,

14.1.8 Sample container switching,

14.1.9 Batch calculations, and

14.1.10 Manual test fire button.

14.2 Do not change the sampling frequency (that is, units in volume per grab) during the sampling of a batch as it will render the resulting composite sample not representative.

14.3 Considering all the provisions of the sample control system shown in 14.1, the sampling frequency can also be manually calculated using the following guidelines shown as an example below. Variables used in the calculations are shown in Table 1.

14.3.1 Calculate the volume of sample to fill the container to expected percent of fill – SV_e (mL):

$$SV_e = SV_{cap} \times SV_{max\%} \tag{1}$$

where:

SV_{cap} = 22 712 mL,
$SV_{max\%}$ = 75 %, and
SV_e = 22 712 mL · (75/100) = 17 034 mL.

14.3.2 Calculate total grabs necessary (N_e) to achieve the SV_{cap} for the batch.

Where:

$$N_e = SV_e/b$$
$$N_e = 17\ 034\ \text{mL}/1.2\ \text{mL} = 14\ 195\ \text{grabs} \tag{2}$$

14.3.3 Calculate the frequency of sampling (B) based on the parcel volume expected PV_e.

Where:

$$B = PV_e/n$$
$$PV_e = 125\ 000\ \text{bbl}$$
$$N_e = 14\ 195\ \text{grabs} \tag{3}$$
$$B = 125\ 000/14\ 195\ \text{grabs} = 8.805\ \text{bbl/grab}$$

14.3.3.1 If B is rounded to 8.8 bbl/grab, then N_e is recalculated to N_e = 125 000 /8.8 =14 204 grabs and SV_e is recalculated to 14.204 · 1.2 mL = 17 004 mL.

14.3.3.2 If B is rounded to 9.0 bbl/grab, then N_e recalculated to N_e = 125 000 /9.0 = 13 888 grabs and SV_e is recalculated to 13 888 · 1.2 mL = 16 665 mL.

14.4 As shown in the example below, consider that the frequency of sampling is achievable based on the equipment being used and the flow rate at which the batch is being delivered. The calculated frequency of samples shall be within the performance capabilities of the sampling equipment.

14.4.1 Assume the cycle time design limitation of the sample probe is 4s/grab and the flow rate is 5 000 bbl/h, which is equivalent to 1.4 bbl/s.

14.4.2 For example 4 s/grab · 1.4 bbl/s = 5.6 bbl/grab is the highest frequency of sampling that can be achieved. Therefore, the required sampling frequency of 8.8 bbl/grab can be achieved because the frequency at 8.8 bbls/grab is less frequent than the sampling frequency at the 5.6 bbl/grab.

TABLE 1 Sample Frequency Variables

SV_{cap}	Sample container volume (total capacity	expressed in mL
$SV_{max\%}$	Sample container volume (maximum fill %/API *MPMS* 8.3)	expressed in % fill
PV_e	Parcel (batch) volume expected	expressed in m^3 (bbl)
b	Expected extractor grab size as determined by prior testing	expressed in mL