Designation: ~~D4177 – 95 (Reapproved 2010)~~ D4177 – 15

Manual of 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~~ Scope*

1.1 This practice ~~covers information for the design, installation, testing, and operation of automated equipment for the extraction of representative samples of~~ describes general procedures and equipment for automatically obtaining samples of liquid petroleum and petroleum ~~products from a flowing stream and storing them in a sample receiver.~~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,~~ mixing and handling, refer to Practice D5854 (API

[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.

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

MPMS Chapter 8.3). ~~Petroleum products covered in this practice are considered to be a single phase and exhibit Newtonian characteristics at the point of sampling.~~This practice does not cover sampling of electrical insulating oils and hydraulic fluids.

~~1.2 *Applicable Fluids*—This practice is applicable to petroleum and petroleum products with vapor pressures at sampling and storage temperatures less than or equal to 101 kPa (14.7 psi). Refer to D5842 (API *MPMS* Chapter 8.4) when sampling for Reid vapor pressure (RVP) determination.~~

1.3 *Non-applicable Fluids*—Petroleum products whose vapor pressure at sampling and sample storage conditions are above 101 kPa (14.7 psi) and liquified gases (that is, LNG, LPG etc.) are not covered by this practice.

1.3.1 While the procedures covered by this practice will produce a representative sample of the flowing liquid into the sample receiver, specialized sample handling may be necessary to maintain sample integrity of more volatile materials at high temperatures or extended residence time in the receiver. Such handling requirements are not within the scope of this practice. Procedures for sampling these fluids are described in Practice D1265, Test Method D1145, and GPA 2166.

1.2 *Table of Contents:* Annex A2

contains theoretical calculations for selecting the sampler probe location. Annex A3 lists acceptance methodologies for sampling systems and components. Annex A4 gives performance criteria for permanent installations, while Annex A5 has the criteria for portable sampling units. Annex A6 provides sampler acceptance test data. Appendix X1 is a design data sheet for automatic sampling systems. Appendix X2 compares the percent sediment and water to unloading time period.

1.3 *Units*—The values stated in either SI units or US Customary (USC) units are to be regarded separately as standard. The values given in parentheses are for information only.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]

D923D4007 Practices for Sampling Electrical Insulating LiquidsTest Method for Water and Sediment in Crude Oil by the Centrifuge Method (Laboratory Procedure)

D1145D4840 Test Method for Sampling Natural GasGuide for Sample Chain-of-Custody Procedures (Withdrawn 1986)

D1265 Practice for Sampling Liquefied Petroleum (LP) Gases, Manual Method

D4057 Practice for Manual Sampling of Petroleum and Petroleum Products

[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.

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]
~~*API*~~*MPMS* ~~Manual~~Chapter 3 ~~of Petroleum Measurement Standards, Chapters 3, 4, 5, 6, and 10~~Tank Gauging
MPMS Chapter ~~8.1~~4 ~~Practice for Manual Sampling of Petroleum and Petroleum Products (ASTM Practice~~ Proving Systems~~D4057)~~
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 ~~10.9~~10 ~~Test Method for Water in Crude Oils by Coulometric Karl Fischer Titration (ASTM Test Method~~ Sediment and Water~~D4928)~~
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 *Gas Processors Association Standard:*[5]~~
~~GPA 2166 Obtaining Natural Gas Samples for Analysis by Gas Chromatography~~
2.3 ~~*Institute of Petroleum Standard:*~~*ISO Standards:*[4]
~~IP Petroleum Measurement Manual, Part IV, Sampling Section 2,~~ISO 1998 ~~Guide to Automatic Sampling of Liquids from Pipelines, Appendix B, 34th Ed~~Petroleum Industry – Terminology – Part 6: Measurement

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

~~2.5 *Government Standard:*[7]~~
~~CFR 29, Part 1910.1000 Toxic and Hazardous Substances~~

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] The last approved version of this historical standard is referenced on www.astm.org.~~
[3] Available from American Petroleum Institute (API), 1220 L. St., NW, Washington, DC 20005-4070, http://www.api.org.
[4] Available from ~~Gas Processors Association (GPA), 6526 E. 60th St., Tulsa, OK 74145, http://www.gasprocessors.com.~~American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.
~~[6] Available from Energy Institute, 61 New Cavendish St., London, WIG 7AR, U.K., http://www.energyinst.org.uk.~~

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.

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 ~~of Terms Specific to This Standard:~~Related to Sample Containers:*

~~3.1.1 *automatic sampler, n*—a device used to extract a representative sample from the liquid flowing in a pipe.~~

~~3.1.1.1 *Discussion*—~~

~~The automatic sampler usually consists of a probe, a sample extractor, an associated controller, a flow measuring device, and a sample receiver.~~

~~3.1.2 *automatic sampling system, n*—a system consisting of stream conditioning, an automatic sampler, and sample mixing and handling.~~

~~3.1.3 *dissolved water, n*—water in solution in petroleum and petroleum products.~~

~~3.1.4 *emulsion, n*—a water in oil mixture, which does not readily separate.~~

~~3.1.5 *entrained water, n*—water suspended in the oil.~~

~~3.1.5.1 *Discussion*—~~

~~Entrained water includes emulsions but does not include dissolved water.~~

~~3.1.6 *flow proportional sample, n*—flow taken such that the rate is proportional throughout the sampling period to the flow rate of liquid in the pipe.~~

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

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

~~3.1.9 *homogeneous, adj*—when liquid composition is the same at all points in the container, tank, or pipeline cross section.~~

3.2.1 ~~*isokinetic sampling,*~~ *constant volume sample container, n*—~~sampling in such a manner that the linear velocity through the opening of the sample probe is equal to the linear velocity in the pipeline at the sampling location and is in the same direction as the bulk of the liquid approaching the sampling probe.~~vessel with a fixed volume.

3.2.2 ~~*Newtonian fluid,*~~ *floating piston container, FPC, n*—~~a liquid whose viscosity is unaffected by the order of magnitude or agitation to which it may be subjected as long as the temperature is constant.~~high-pressure sample container, with a free floating internal piston that effectively divides the container into two separate compartments.

3.2.3 ~~*power mixer,*~~ *portable sample container, n*—~~a device which uses an external source of power to achieve stream conditioning.~~vessel that can be manually transported.

3.2.4 *primary sample ~~receiver/container,~~container, n*—~~a vessel into which all samples are initially collected.~~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 ~~*probe, profile average, n—in sampling,*~~ the ~~portion of the automatic sampler that extends into the pipe and directs a portion of the fluid to the sample extractor.~~average of all point averages.

3.2.6 *profile testing, n*—~~a~~ 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*—~~a~~ portion extracted from a total volume that contains the constituents in the same proportions ~~as~~that are present in ~~the~~that total volume.

3.2.8 *sample, n*—~~a~~ 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 ~~controller,~~probe, n*—~~a~~ device ~~which governs the operation of the sample extractor.~~extending through the meter tube or piping into the stream to be sampled.

~~3.1.19 *sample extractor, n*—a device which removes a sample (grab) from a pipeline, sample loop, or tank.~~

~~3.1.20 *sample handling and mixing, n*—the conditioning, transferring and transporting of a sample.~~

~~3.1.21 *sample loop (fast loop or slip stream), n*—a low volume bypass diverted from the main pipeline.~~

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~~ 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 proving, system,~~ n*—~~a procedure used to validate an automatic sampling system.~~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 ~~*sediment and water (S&W),*~~*sampling system verification test, n*—~~material which coexists with, but is foreign to, a petroleum liquid.~~procedure to establish that a sampling system is acceptable for custody transfer.

~~3.1.24.1 *Discussion—*~~

~~S&W may include dissolved water, free water and sediment, and emulsified and entrained water and sediment.~~

3.2.13 ~~*static mixer,*~~ *secondary sample container, n*—~~a device which utilizes the kinetic energy of the flowing fluid to achieve stream conditioning.~~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 ~~condition,~~conditions, n*—~~the~~ state of a fluid stream in terms of distribution and dispersion of the ~~pipeline contents, upstream of the sampling location.~~components flowing within the pipeline.

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

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

~~3.1.29 *worst case conditions, n*—the operating conditions for the sampler that represent the most uneven and unstable concentration profile at the sampling location.~~

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 ~~and regulatory specifications.~~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 Criteria~~

~~5.1 The following criteria must be satisfied to obtain a representative sample from a flowing stream.~~

~~5.1.1 For nonhomogeneous mixtures of oil and water, free and entrained water must be uniformly dispersed at the sample point.~~

~~5.1.2 Grabs must be extracted and collected in a flow proportional manner that provides a representative sample of the entire parcel volume.~~

~~5.1.3 Grabs must be a consistent volume.~~

~~5.1.4 The sample must be maintained in the sample receiver without altering the sample composition. Venting of hydrocarbon vapors during receiver filling and storage must be minimized. Samples must be mixed and handled to ensure a representative test specimen is delivered into the analytical apparatus.~~

5. ~~Automatic~~Representative Sampling ~~Systems~~ Components

~~6.1 An automatic sampling system consists of stream conditioning upstream of the sampling location, a device to physically extract a grab from the flowing stream, a flow measurement device for flow proportioning, a means to control the total volume of sample extracted, a sample receiver to collect and store the grabs and, depending on the system, a sample receiver/mixing system. Unique properties of the petroleum or petroleum product(s) being sampled may require the individual components or the entire system be insulated or heated, or both. Appendix X1 references many of the design consideration that should be taken into account.~~

5.1 ~~Grabs must be taken in proportion to flow. However, if the flow rate, during the total parcel delivery (week, month, etc.) varies less than ±10 % from the average flow rate,~~ 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 ~~may be obtained by the time proportional control of the grabs.~~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.

~~6.3 There are two types of automatic sampling systems (see Fig. 1). Both systems can produce representative samples if properly designed and operated. One system locates the extracting device directly in the main line, whereas the other system locates the extracting device in a sample loop.~~

~~6.4 In a sample loop type system, a probe is located in the main pipeline and directs a portion of the fluid flow into the sample loop. This probe may be a 90° elbow or a 45° level facing upstream (see 10.2). The average flow velocity through the sample loop shall be near the maximum average velocity expected in the main pipeline, but not less than 2.5 m/s (8 ft/s).~~

~~6.5 The controller which operates the sample extractor in the sample loop receives its flow proportional signal from the flow meter(s) in the main line. For sample loop installations, a flow indicator must also be installed in the sample loop.~~

~~6.6 If circulation in the sample loop stops and sampling continues, a non-representative sample will result. A low-flow alarm should be installed to alert the operator of a loss of flow. In no case shall a filter be installed in a sample loop, upstream of the sample extractor, as it may alter the representativeness of the sample.~~

6. ~~Sampling Frequency~~ Design Criteria

6.1 ~~Guidelines for sampling frequency can be given in terms of "grab per lineal distance of pipeline volume." For marine and pipeline service this minimum guideline can be related to barrels per grab using the following equation:~~ The following items shall be addressed when designing a sampling system:

~~$$BBL/grab = 0.0001233 \times D^2 \text{ or } 0.079548 \times d^2 \quad (1)$$~~

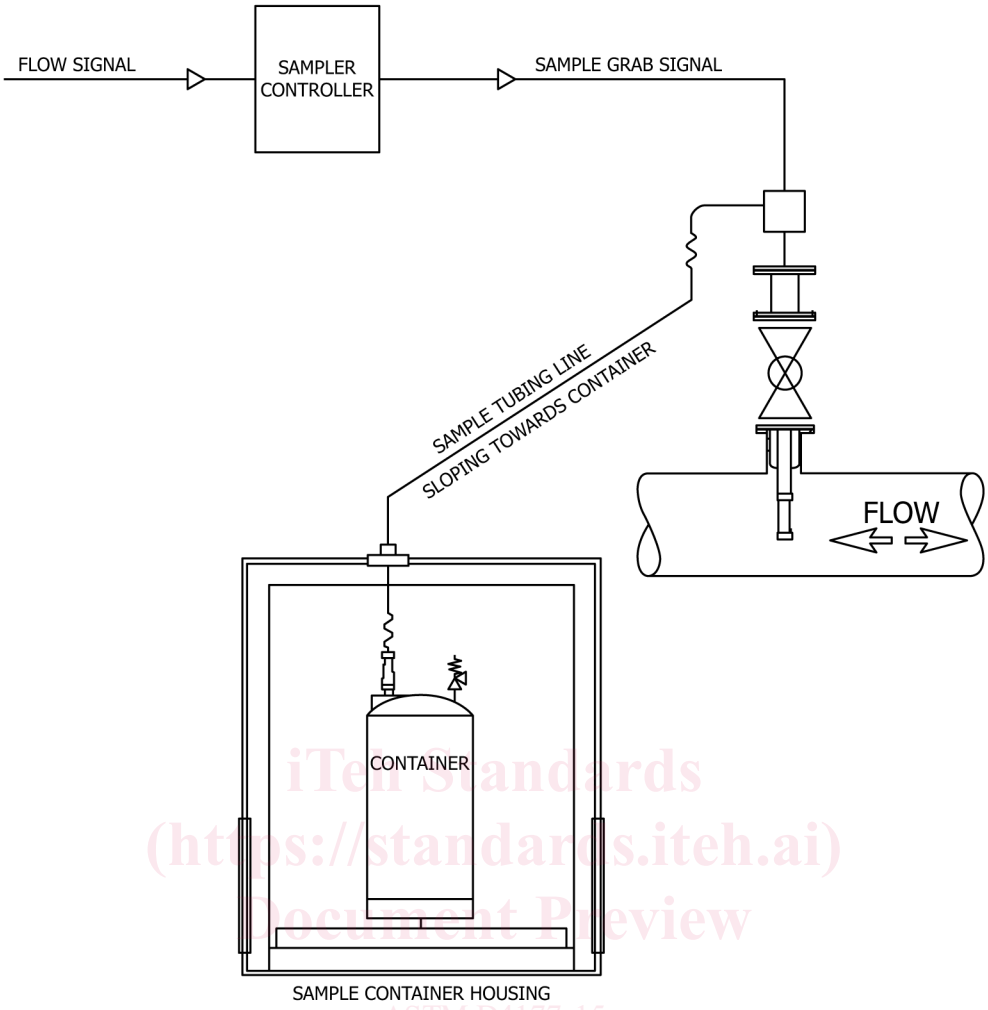

FIG. 1 ~~Typical Automatic~~ In-Line Sampling ~~Systems~~ System

~~where:~~

~~*D* = nominal pipe diameter, mm and~~
~~*d* = nominal pipe diameter, in.~~

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.

~~7.2 This formula equates to one grab for every 25 lineal metres (approximately 80 ft) of pipeline volume.~~

~~7.3 Sampling frequency should be based on maximizing grabs for the available receiver size. Typically, Lease Automatic Custody Transfer (LACT) or Automatic Custody Transfer (ACT) units are paced at one grab per one to ten barrels.~~

6.2 ~~The optimum sampling frequency is the maximum number of grabs which may be obtained from any parcel operating within the grab frequency and grab volume limitations of the equipment. The completed sample should be of sufficient volume to mix and properly analyze while not over filling the sample receiver.~~*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.

~~8. Stream Conditioning~~

~~8.1 The sampler probe must be located at a point in the pipe where the flowing stream is properly conditioned. This conditioning may be accomplished with adequate flow velocity through the piping system or mixing elements may be added to supplement mixing provided by the basic piping. Petroleum that contains free or entrained sediment and water (S&W) requires adequate mixing energy to create a homogeneous mixture at the sample point.~~

~~8.2 Petroleum products are generally homogeneous and usually require no special stream conditioning. Exceptions to this may occur if free water is present or if a product is exiting a blending system.~~

~~8.3 *Velocities and Mixing Elements:*~~

~~8.3.1 Fig. 2, based on tests, provides a guideline for minimum velocities versus mixing elements for pipes 50 mm (2 in.) in diameter and larger. Stream conditioning can be accomplished with pressure reducing valves, metering manifolds, lengths of reduced diameter piping, or piping elements (valves, elbows, tees, piping, or expansion loops).~~

~~8.3.2 Where the flow velocity at the automatic sampler probe location falls below the minimum levels detailed in Fig. 2, additional means will be required to provide adequate stream conditioning such as power mixers or static mixers. The effect of viscosity, density, water content, as well as the relative position of the mixing element(s) and sample probe should also be considered.~~

~~8.3.3 Specific calculation procedures for estimating the acceptability of a proposed or existing sampling location are detailed in Annex A2.~~

~~8.3.4 Again it should be remembered that petroleum products are assumed to be homogeneous at the point of sampling and require no additional stream conditioning unless specifically sampling for water content, or where the sampler is downstream of a blending manifold.~~

7. ~~Special Considerations for Marine Applications~~ 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*—~~When pumping from a shore tank or from a vessel, a significant amount of free water may be transferred during a short period of time (see~~ A slip stream sample loop system has a take-off probe located in ~~Appendix X2). This may occur when the pumping rate is low and the oil/water mixture is stratified. The stream conditioning may not~~the main pipeline that directs a portion of the fluid flow into the slip stream sample loop (see Fig. 2~~be adequate to provide a representative sample. To help minimize this condition, a tank that does not~~) and past a sample extractor or the take-off probe of a volume regulator sampler (see Fig. 3~~contain free water should be utilized first. Tanks containing free water can be discharged when the pumping rate is normal.~~).

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*—~~If the sampler is located some distance from the point of load/discharge, operating procedures should account for the line fill between those two points.~~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. ~~Probes~~ 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 ~~*Probe Location and Installation:*~~ *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

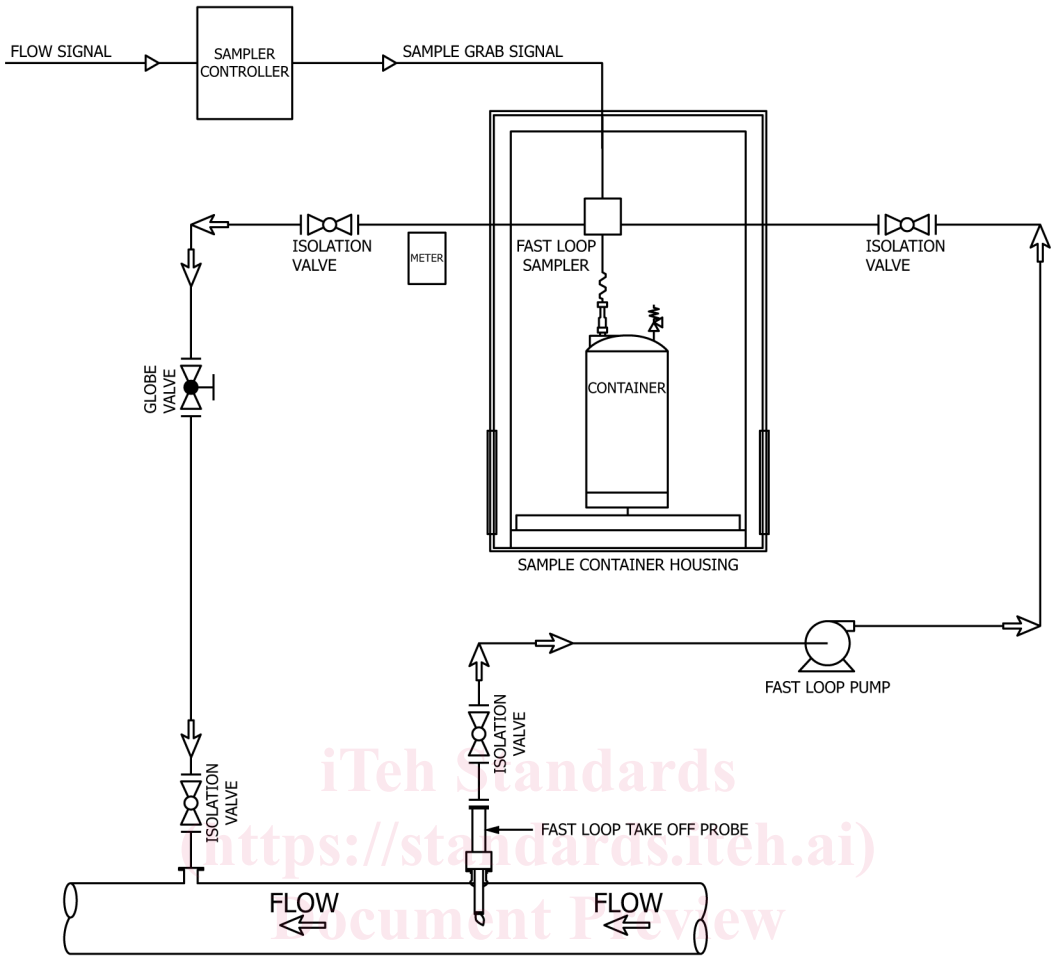

FIG. 2 ~~General Guidelines for Minimum Velocities Versus Mixing Elements~~Slip Stream Sample Loop Sampling System

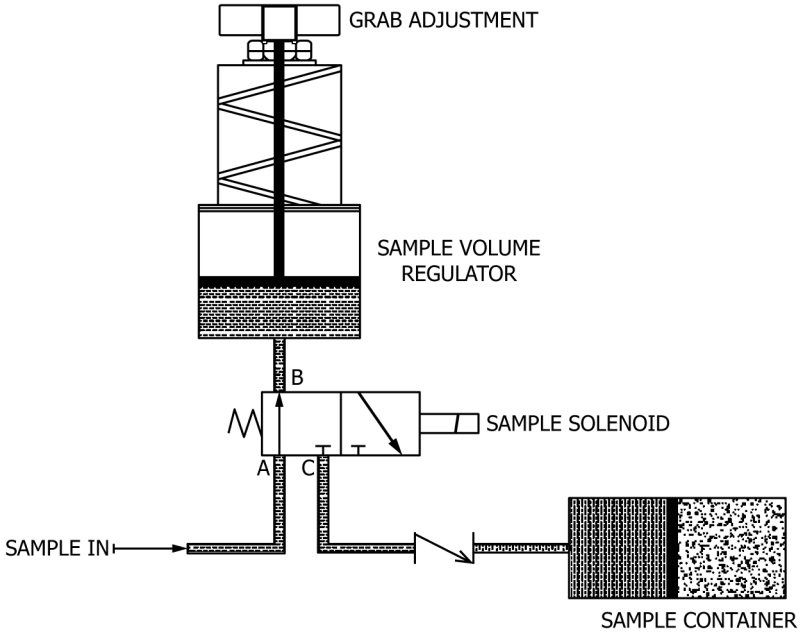

FIG. 3 ~~Recommended Sampling Area~~Sample Volume Regulator

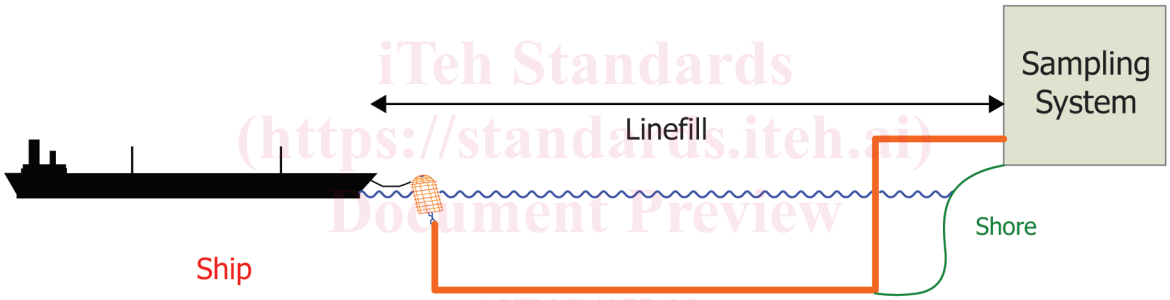

FIG. 5 ~~Probe Designs~~Linefill

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).

8.3.2 The recommended sampling area is approximately the center ~~one-third~~half of the ~~pipeline cross-section area~~ flowing stream as shown in Fig. ~~3~~7.

~~10.1.2 The probe opening must face upstream and the external body of the probe should be marked with the direction of flow to verify that the probe is installed correctly.~~

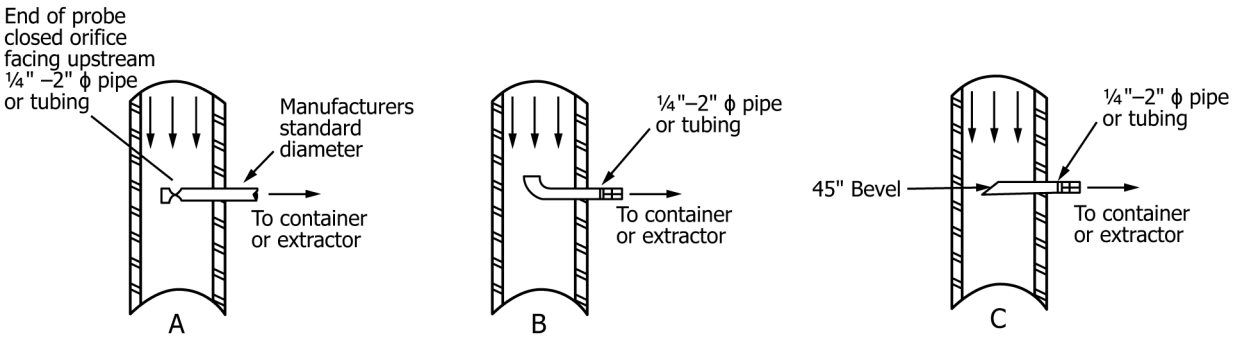

FIG. 6 ~~Receiver(s) Installation~~Probe Design

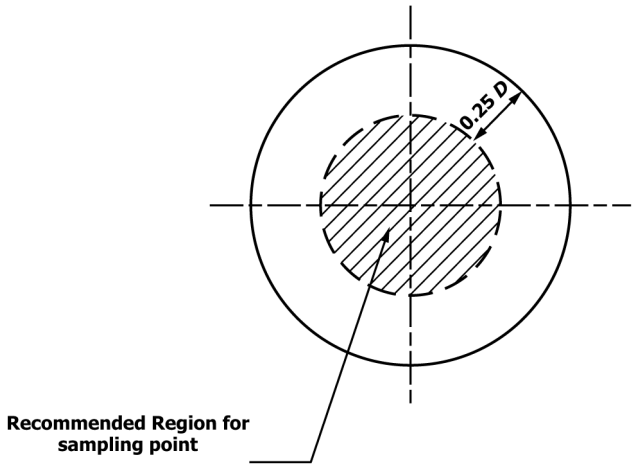

FIG. 7 Sample Probe and Slip Stream Take-Off Probe Location for Vertical or Horizontal Pipe

8.3.3 ~~The probe must be located in a zone where sufficient mixing results in adequate stream conditioning. This zone is generally from 3 to 10 diameters downstream of piping elements, 0.5 to 4 diameters from static mixers, and 3 to 10 diameters from power mixers. When static or power mixers are~~ When a main line mixing device is used, the manufacturer ~~of the device should~~ shall be consulted for the ~~probe's optimum location.~~sample probe's optimum location with regard to downstream distance and piping.

8.3.4 ~~The line from the outlet~~ When possible, the preferred orientation of the extractor ~~to the sample receiver must continuously slope downward from the extractor to the receiver and contain no dead space.~~probe is horizontal.

~~10.1.5 The preferred installation of a combined probe-extractor is in the horizontal plane.~~

8.3.5 ~~If a vertical piping loop is used for stream conditioning, locate the probe in the downflow section of the loop to obtain the benefit of the additional stream conditioning provided by the three 90° elbows. Locate the probe a minimum of three pipe diameters downstream of the top 90° elbow and not closer than one-half pipe diameter upstream of the final exiting elbow (see~~ 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.~~Fig. 4).~~

~~10.1.7 According to tests sponsored by the American Petroleum Institute (API), locating a sample probe downstream of a single 90° bend is not recommended because of inadequate stream conditioning.~~

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 ~~*Probe Design:*~~ *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 ~~mechanical design of the probe should be compatible with the operating conditions of the pipeline and the fluid being sampled. There are three basic designs shown in~~ 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) ~~Fig. 5. Probe openings should be in the center third of the cross sectional area of the pipe.~~of the parcel into the same sample container.

8.5.2 ~~Probe designs commonly used are described as follows:~~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 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 relation to the overall batch volume may be significant enough to alter the composite sample.

~~10.2.2.1 A closed end probe equipped with an open orifice (see Fig. 5A).~~

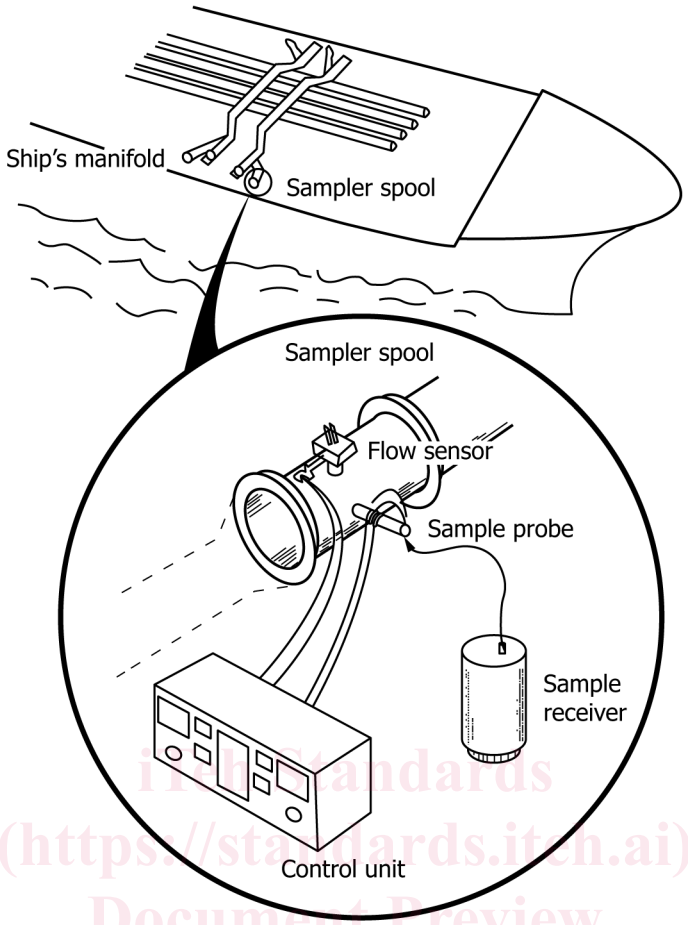

FIG. 4 ~~General Vertical Piping Loop Configuration~~Typical Portable Installation

~~10.2.2.2 A short-radius elbow or pipe bend facing upstream. The end of the probe should be chamfered on the inside diameter to give a sharp entrance (see Fig. 5B).~~

~~10.2.2.3 A tube cut at a 45° angle with the angle facing upstream (see Fig. 5C).~~

9. ~~Automatic Sampling Components~~ 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.