Designation: D 3764 – 92 (Reapproved 1998)

Designation: D 3764 – 01

An American National Standard

Standard Practice for Validation of Process Stream Analyzer Systems[1]

This standard is issued under the fixed designation D 3764; 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.

INTRODUCTION

Operation of a process stream analyzer system typically involves four sequential activities. (*1*) **Analyzer Calibration**–When an analyzer is initially installed, or after major maintenance has been performed, diagnostic testing is performed to demonstrate that the analyzer meets the manufacturer's specifications and historical performance standards. These diagnostic tests may require that the analyzer be adjusted so as to provide predetermined output levels for certain reference materials. (*2*) **Correlation**–Once the diagnostic testing is completed, process stream samples are analyzed using both the analyzer system and the corresponding primary test method. A mathematical function is derived that relates the analyzer output to the primary test method (PTM). The application of this mathematical function to an analyzer output produces a predicted PTM result. (*3*) **Initial Validation**–Once the relationship between the analyzer output and primary test method results has been established, an initial validation is performed to demonstrate that the predicted PTM results agree with those from the primary test method within the tolerances established from the correlation activities and with no statistically observable systemic bias. (*4*) **Continual Validation**–During normal operation of the process analyzer system, quality assurance testing is conducted to demonstrate that the agreement between the analyzer and primary test method results during the initial validation is maintained. This practice deals primarily with the third and fourth of these activities.

[1] This practice is under the jurisdiction of ASTM Committee D-2 D02 on Petroleum Products and Lubricants and is the direct responsibility of Subcommittee D02.25 on Validation of Process Analyzers.

Current edition approved Oct. 15, 1992. Dec. 10, 2001. Published December 1992. April 2002. Originally published as D 3764 – 80. Last previous edition D 3764 – 80 (1985). ε2 D 3764 - 92 (1998).

1. Scope

1.1 This practice serves as a guide describes procedures and recommendations for the validation of a total process stream analyzers analyzer system or its subsystems, or both, used in determining the direct measurement of physical or chemical characteristics of petroleum and petrochemical products.1.2 Procedures for treating data from automatic process stream analyzers are outlined. Definitions, terms, calibration techniques, and applicable statistical tests for initial validation and subsequent continuous quality assurance of system performance are described.

1.3 The implementation

1.2 Validation is achieved by statistical assessment of this process requires that results generated for common materials by the total analyzer b system or its subsystem versus results generated by an ASTM or other established primary test method (PTM).

1.2.1 For analyzers used in compliance with product certification, the principles set forth in *Part II Process Stream Analyzers* of analyzer system precision determined by the "Manual statistical assessment is typically compared to the site precision for the PTM.

1.2.2 For other analyzer applications, analyzer system precision determined by the statistical assessment is compared to prespecified performance criteria based on Installation of Refinery Instruments and Control Systems" APIRP-550 of the American Petroleum Institute intended use.

1.3 Two procedures for validation are described: the line sample procedure and in agreement with the supplier's recommendation. In addition it assumes that validation reference material (VRM) injection procedure.

1.4 Only the analyzer system or subsystem downstream of the VRM injection point or the line sample extraction point is being validated by this practice.

1.5 The line sample procedure is limited to monitor applications where material can be safely withdrawn from the specific quality parameter sampling point of interest and at the analyzer unit without significantly altering the property of v interest.

1.6 Validation information obtained in the analyzer application of this practice is applicable only to the type and property range

of the materials used to perform the validation.

1.7 Procedures for conducting an initial validation are described. These procedures are typically conducted at installation or after major maintenance once the ~~conditions specified by~~ system mechanical fitness-for-use has been established.

1.8 Procedures for the ~~manufacturer.~~

~~1.4 The units~~ continual validation of system performance are des~~u~~cribe ~~u~~d. These procedures are typically applied at a frequency commensurate with the criticality of the application.

1.9 This practice ~~shall be~~ applies if the process stream analyzer system and the primary test method are based on the same measurement principle(s), or, if the process strea~~pp~~m analyzer system uses a direct a~~b~~nd well-understood measurement principle that is similar to the ~~laboratory~~ measurement principle of the primary test method it is intended to predict.

1.10 This practice is not intended for use if the process stream analyzer~~d~~ system utilizes an indirect or mathematically modeled measurement principle such as chemometric or multivariate analysis techniques. Users should refer to Practice D 6122 for detailed validation procedures for these types of analyzer systems.

1.11 This practice does not address procedures for diagnosing causes of validation failure.

1.12 This practice does not address the ~~reference~~ methodology for establishing the correlation equation used to generate predicted PTM results using analyzer outputs, nor the expected prediction error. The former is assumed to have been correctly developed as part of the analyzer appli~~d~~cation development work.

1.5~~1~~3 *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:*

D 1265 Practice for Sampling Liqui~~i~~efied Petroleum (LP) Gases~~—~~ (Manual Method)[2]

D 4057 Practice for Manual Sampling of Petroleum and Petroleum Products[3]

D 4177 Practice for Automatic Sampling of Petroleum and Petroleum Products[3]

D 5842 Practice for Sampling and Handling of Fuels for Volatility Measurements[4]

D 6122 Practice for Validation of Multivariate Process Infrared Spectrophotometers[5]

D 6299 Practice for Applying Statistical Quality Assurance Techniques to Evaluate Analytical Measurement System Performance[5]

E 456 Terminology Relating to Quality and Statistics[6]

F 307 Practice for Sampling Pressurized Gas for Gas Analysis[7]

3. Terminology

3.1 ~~*Definitions of Terms Specific to This Standard:*~~*Definitions:* ~~*Time Units*~~

3.1.1 ~~*Lag Time, n*—The time interval from a step change in the measured variable at various points in the system to the first corresponding change in the analyzer signal readout.~~

~~3.1.1.1 *Discussion*—It~~accepted reference value (ARV), *n*—a value that serves as an agreed-upon reference for comparison, and which is derived as: (*1*) a ~~f~~ theoretical or established value, based on scientific principles, (*2*) an assigned or certified value, based on experimental work of ~~system design (length and diameter of lines, number of fittings, flow restrictions, etc.) and~~ some national or international organization, or (*3*) a consensus or certified value, based on collaborative experimental work under the ~~flow rate~~ auspices of ~~the process~~ a scientific or ~~product stream. (See Fig. 1 and Fig. 2.) It consists of the following elements:~~ engineering group.

3.1.2 ~~*Sample Loop Lag Time, n*—The time required for a step change in process or product stream quality to traverse the distance between the start~~precision, *n*—the closeness of ~~the process or product stream sample loop to the inlet of the sample conditioning unit.~~ agreement between independent test results obtained under stipulated conditions. **E 456**

3.1.3 ~~*Sample Conditioning Unit Lag Time, n*—The time required for a step change~~repeatability conditions, *n*—conditions where independent test results are obtained with the same method on identical test items in the ~~process or product stream quality to pass through~~ same laboratory by the ~~sample conditioning unit from~~ same operator using the ~~junction with the sample loop to the inlet~~ same equipment within short intervals of ~~the analyzer unit.~~ time. **E 456**

3.1.4 ~~*Analyzer Lag Time, n*—A function of~~reproducibility conditions, *n*— conditions where test results are obtained with the same method on identical~~yz~~ test items in differ²ent laboratories with different operators using different equipment. **E 456**

3.1.5 *site precision conditions, n*—conditions under which test results are obtaeined by one or more operators in a single site location practicing the same test method on a single measurement system using test specimens taken at random from the same

[2] *Annual Book of ASTM Standards*, Vol 05.01.

[3] *Annual Book of ASTM Standards*, Vol 05.02.

[4] *Annual Book of ASTM Standards*, Vol ~~10.05.~~ 05.03.

[5] *Annual Book of ASTM Standards*, Vol 05.04.

[6] *Annual Book of ASTM Standards*, Vol14.02.

[7] *Annual Book of ASTM Standards*, Vol 15.03.

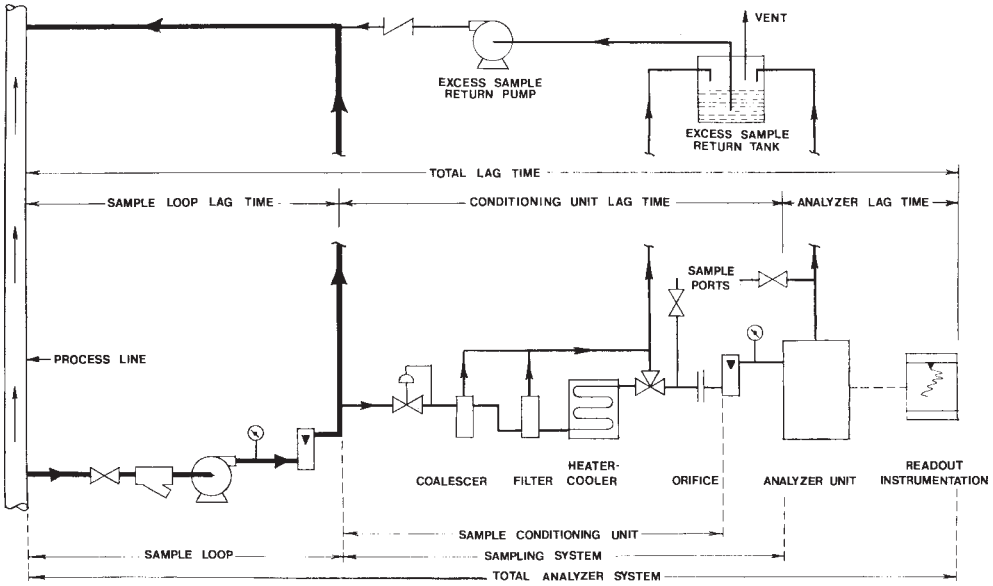

FIG. 1 Total Analyzer System

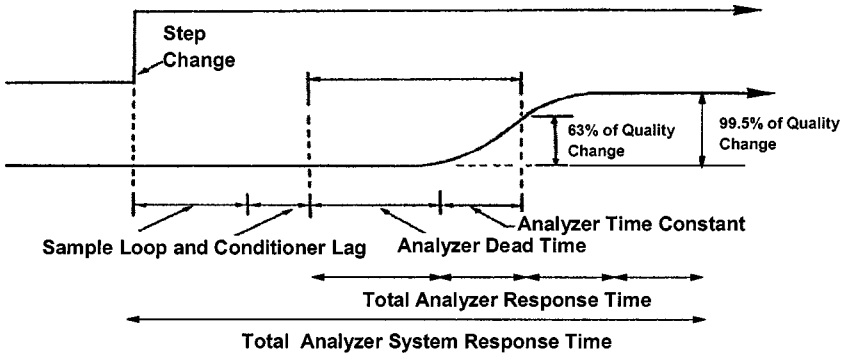

FIG. 2 Analyzer Time Units

sample of material, over an extended period of time spanning at least a 15 day interval. **D 6299**

3.1.45.1 *Discussion*—Where—A measurement system may comprise multiple instrument being used for the analyzer is designed to operate at a specific flow rate, the sum of the elements contributing to the analyzer lag time 3.1.4.2 same test method.

3.1.6 *site precision, (1)* and 3.1.4.3 *(1)* will be a constant value. For *n*—2.77 times the analyzer designed for variable flow rates the analyzer lag time and its elements must be determined for each standard deviation of the flow rates used. These elements are as follows:

3.1.4.2 *(1) Analyzer Dead Time, n*—The time interval between the introduction results obtained under site precision conditions.

D 6299

3.2 *Definitions of a step change in quality at the inlet of the analyzer unit and the initial indication of analyzer response Terms Specific to this change at a specific sample flow rate.*

3.1.4.3 *(1) Analyzer Time Constant This Standard:* (See Fig. 2)—The time interval between the initial response of the analyzer unit and the time required for the analyzer output to reach a value of 63 % of the final output value for a step change in sample quality.

Analyzer Parameters

3.2.1 *Analyzer O System Items*:

3.2.1.1 *analyzer output, n*—A—a signal that is (pneumatic, electrical, or digital), proportional to the quality parameter property being measured and that is suitable for readout or control inpstrumentation external to the analyzer system.

3.2.1.2 *analyzer system result, n*—the measured property reading, in the accepted property measurement units, that is displayed by the analyzer unit readout instrumentation or transmitted to end user of the analyzer system. I

3.2.1.3 *analyzer unit c, n*—the instrumental equipmen bt necessary to automatically measure the physical or chemical property of a pneumatic, process or product stream sample using either an electrical, intermittent or a continuous technique.

3.2.1.4 *analyzer unit repeatability, n*—2.77 times the standard devigation of results obtained from repetitive analysis of the same material directly injected into the analyzer unit under repeatability conditions.

3.2.1.5 *continuous analyzer unit, n*—an analyzer that measures the property value of a process or product stream on a

continuous basis and dynamically displays the instantaneously updated analyzer output.

3.2.1.6 *intermittent analyzer unit, n*—a cyclic type analyzer that performs a measurement sequence on samples from a process or product stream and displays a new analyzer output at the conclusion of each cycle.

3.2.1.7 *total analyzer system, n*—the complete analyzer system inclusive of the sample loop, sample conditioning unit, analyzer unit, readout instrumentation, and excess sample return system (see Fig. 1).

3.2.2 ~~*Analyzer Result, n*—The measured quality parameter displayed by the analyzer readout instrumentation in terms of the accepted quality units.~~ Time Unit Items—General Terms:

3.2.2.1 ~~*Reference Sample Procedure Result,*~~*analyzer unit cycle time, n*~~—The average of the~~—for intermittent~~ or continuous analyzer readings recorded during a specific~~ analyzers, the time interval~~ after~~ between successive updates of the analyzer~~ is at equilibrium.~~ output.

3.2.2.2 ~~*Line Sample Procedure Result,*~~*analyzer unit dead time, n*~~—The average~~—the time interval between the introduction of a step change in property characteristic at the~~ intermittent or continuous~~ inlet of the analyzer~~ readings recorded during~~ unit and the~~ time interval required~~ initial indication of analyzer response to~~ draw one line sample. This time interval starts at one~~ this change.

(1) Discussion—For intermittent analyzers, if the analyzer dead time~~ after sample port valve opening and continues until~~ is less than one analyzer unit cycle time, the analyzer unit dead time~~ after the required sample has been drawn. The line sample must~~ cannot be~~ drawn only when the entire analyzer system is~~ directly measured.

3.2.2.3 *analyzer unit response time, n*—(see Fig. 2) the time interval between the introduction of a step change in property characteristic at the inlet of the analyzer unit and when~~ there is no significant change in~~ the~~ measured property. If~~ analyzer output indicates a~~ quality~~ value corresponding to 99.5 % of the subsequent change~~ occurs during~~ in analyzer results;

(1) Discussion—For continuous and intermittent analyzers with sufficiently short cycle times, the~~ sample collection~~ total analyzer response time~~ interval as defined above,~~ is the analyzer dead time plus three times the analyzer unit time constant. For intermittent analyzers with long cycle times, the analyzer unit response time is effectively equal to the analyzer unit cycle time. For intermittent analyzers with intermediate cycle times, the analyzer unit response time should be defined as~~e~~ the multiple of the analyzer unit cycle time needed to exceed 99.5 % response.

3.2.2.4 *and~~d~~alyzer unit time constant, n*—(see Fig. 2) the time interval between the initial response of the analyzer unit to a~~ new sample collected~~ step change in property characteristic and when the~~ measured property is~~ analyzer output indicates a value corresponding to 63 % of the subsequent change in~~ equilibrium.~~

~~3.1.7 *Sensitivity,*~~ *analyzer results.*

(1) Discussion—For intermittent analyzers, if the analyzer unit time constant is less than one analyzer unit cycle time, the analyzer time constant cannot be directly measured.

3.2.2.5 *lag time, n*~~—The least discernible change~~—the time required for material to travel from Point A to Point B in the~~ quality parameter being measured that~~ total analyzer system (Points A and B are user-defined)

(1) Discussion—Lag time is~~ not masked by background noise~~ a function of an analyzer system design parameters such as~~ displayed by~~ length and diameter of lines, number of fittings, flow restrictions, and the~~ readout instrumentation.~~

~~3.1.8 *Linearity,*~~ *flow rate of the material (process or product stream) through the analyzer system (see Fig. 1 and Fig. 2).*

3.2.2.6 *sample conditioning unit lag time, n*—~~T~~the time required for mategrial to travel from the start of~~ closeness~~ the sample conditioning unit to~~ which a plot~~ the analyzer unit inlet.

3.2.2.7 *sample loop lag time, n*—the time required for material to travel from the process takeoff point of the sample loop to start of the sample conditioning unit.

3.2.2.8 *total analyzer~~ output, over~~ system response time, n*—(see Fig. 2) The time interval between when a step change in property characteristic at the sample loop inlet and when the analyzer~~ operating range approximates~~ output indicates a value *c* corresponding to the 99.5 % of the subsequent change in analyzer results; the total analyzer system response time is the sum of the sample loop lag time, the same conditioning loop lag time, and the total analyzer response time.

3.2.2.9 ~~*Discussion*—It is expressed as the maximum deviation between~~composition-specific VRM, n—a validation reference material consisting of a single, pure compound, or a known, reproducible mixture of compounds for which an~~ average measured output versus~~ accepted reference value or site assigned value can be calculated or measured.

(1) Discussion—A composition-specific VRM may be a~~ known input and~~ commercial standard reference material (SRM) having a~~ straight line, where~~ certified accepted reference value.

3.2.2.10 *continual validation, n*—the quality assurance process by which the~~ straight line is drawn through both terminal points of the known input~~ bias and~~ measured output ranges. Linearity of the analyzer over the quality range of interest must~~ precision performance determined during initial validation are shown to be~~ established and the analyzer output, if nonlinear, adjusted manually~~ sustained.

3.2.2.11 *direct measurement, n*—a quantitative measurement result obtained using a principle or~~ automatically so~~ principles that express the characteristic property of interest in its defining units.

3.2.2.12 *indirect measurement, n*—a correl~~y~~z~~a~~ted quantitative measurement result~~ displayed is~~ obtained using a~~ true indication of~~ measurement principle that produces values that do not express the~~ measured quality. See Fig. 3.~~

~~*Precision Parameters*~~

3.1.9 *Precision, n*—The degree desired characteristic property but which can be modified empirically, using mathematical modeling techniques, to estimate the necessary defining units of agreement of reported measurements of the same chemical or physical property of a given material, expressed in terms of dispersion of test results around the arithmetic mean.

3.1.10 *Analyzer Repeatability, interest.*

(1) Discussion—Methods that utilize chemometric or multivariate analysis are indirect measurements for generating correlative characteristic property measurement results.

3.2.2.13 *initial validation, n*—The difference between two successive analyzer results—validation that would be exceeded in the long run in only 1 case in 20 is performed when a single an analyzer system is operated on a flowing sample of uniform quality.

3.1.10.1 *Discussion*—The value is related to the repeatability standard deviation as determined from many sets of successive repeat analyzer results from single analyzers.

3.1.11 *Analyzer Reproducibility, initially installed or after major maintenance, once system mechanical fitness-for-use has been established.*

3.2.2.14 *line sample, n*—The difference between a single result from each of two analyzer systems—process material that would can be exceeded in the long run in only 1 case in 20 when the two systems are operated at different sites, by different operators, but on identical samples.

3.1.11.1 *Discussion*—The value is related to the reproducibility standard deviation as determined from testing the same samples on many analyzer systems.

3.1.12 *Historical Standard Deviation, n*—A test method standard deviation established by averaging the standard deviations of many samples tested by many laboratories.

3.1.13 *Line Sample, n*—A process or product sample safely withdrawn from the a sample port (6.1.3.3) in accordance with Practices D 1265, D 4057, D 4177, and F 307, whichever is applicable during a period when associated facilities located anywhere in the material flowing through the total analyzer is of uniform quality and system without significantly altering the analyzer result displayed (3.1.6) is essentially constant.

3.1.13.1 *Discussion*—The laboratory tests are obtained for each sample property of this material and compared with the analyzer result obtained (3.1.6) at the time of sampling.

3.1.14 *Reference Sample, interest.*

3.2.2.15 *primary test method (PTM), n*—A pure compound—an ASTM or a mixture of compounds of known properties other established standard test method that produces results accepted as the reference measure of a property.

3.2.2.16 *process-derived VRM, n*—a validation reference value for the quality to be measured.

3.1.14.1 *Discussion*—It can also be material derived from an isolated batch of process or product stream material with chemical or physical properties approximating the quality level to be monitored by the analyzer. In this event a characteristics, or both, that is suitable for determination of an accepted reference sample value (3.1.15) or site assigned value for the monitored property must be established through multiple testing by an appropriate ASTM or other standard laboratory test method. Bulk quantities of the reference sample must be stored and handled with care to avoid contamination or degradation of the quality of interest. One or more interest.

3.2.2.17 *site assigned value (SAV)*—a property value of a reference samples encompassing material that is based on multiple results from either the minimum, intermediate, and maximum range of the expected operating range of the analyzer will be required for both the reference sample and line sample procedures.

3.1.15 *Reference Sample Value, n*—The quality value established by appropriate ASTM unit or other standard laboratory a primary test methods on representative pure compounds, mixtures thereof and process method, obtained under site precision conditions.

3.2.2.18 *validation, n*—the statistically quantified judgment that the analyzer system or product samples.

3.1.15.1 *Discussion*—The laboratory apparatus shall be checked carefully before these tests are run to assure compliance with the requirements of the standard subsystem being assessed can produce predicted PTM results with acceptable precision and bias performance when compared to actual results from a primary test procedure. To further assure proper operation it is recommended that method measurement system for common materials.

3.2.2.19 *validation reference material (VRM)*—for validation and quality assurance testing, a previously calibrated material having an accepted reference sample value or an in-house control standard of known quality be tested to validate site assigned value for the operation property of the laboratory equipment. interest.

4. Summary of Practice

4.1 Two procedures have been included; either

4.1 Either line sample or both can be applicable in a given situation.

4.1.1 *Reference Sample Procedure* covers VRM results from the use of a laboratory calibrated reference sample, which is introduced into the analyzer, total analyzer system or its subsystem, and corresponding PTM results for the analyzer result compared with same materials are obtained. Differences between the reference value.

4.1.2 *Line Sample Procedure* covers withdrawal of samples from the analyzer system in accordance with Practices D 1265, D 4057, D 4177, predicted PTM results and F 307, whichever is appropriate. Analyzer actual PTM results are statistically assessed. Precision and bias statistics are generated and assessed against pre-specified performance criteria. The system or subsystem

performance is considered to be validated for materials and property ranges representative of ~~sampling~~ those used in the validation if the performance criteria are ~~compared with laboratory~~ met.

4.2 After initial validation, continued statistical quality control analyses are conducted to ensure on-going performance of the ~~samples using~~ analyzer system meets the ~~applicable ASTM or other test method.~~ levels established from the initial validation.

5. Significance and Use

5.1 This practice can be used to ~~establish~~ quantify the ~~validity~~ performance of a process stream analyzer system or its subsystem in terms of precision and bias relative to those of a primary test method for the property of interest.

5.2 This practice provides developers or manufacturers of process stream analyzer systems with useful procedures for evaluating the capability of newly designed systems for industrial applications that require reliable prediction of measurements of a specific property by a primary test method of a flowing component or product.

5.3 This practice provides purchasers of process stream analyzer systems with some reliable options for specifying acceptance test requirements for process stream analyzer systems at the time of commissioning to ensure the system is capable of making the desired property measurement with the appropriate precision or ~~during routine use,~~ bias specifications, or both.

5.2~~4~~ This practice provides ~~statistically based methodology to quantify~~ the user of a process stream analyzer system ~~variability and any bias relative~~ with useful information for on-going quality assurance testing designed to ~~the applicable test method standard.~~

~~5.3 This practice addresses~~ update or revalidate an analyzer system through the application of statistical quali~~b~~ty control techniques.

5.5 Validation information obtained in the application of this practice is applicable only to the material type and property range of the materials used to perform the validation. Selection of the propes~~r~~ty levels and ~~in accordance with~~ the ~~manufacturer's instructions so that~~ compositional characteristics of the samples must be suitable for the application of the analyzer system. This practice allows the user to write a comprehensive validation statement for the analyzer system including specific limits for the validated range of application. Users are cautioned against extrapolation of validation results beyond the material type and ~~linearity~~ property range used to obtain these results. (**Warning**—Users are cautioned that for measurement systems that show matrix dependencies, bias information determined from pure compounds or simple mixtures of pure compounds may not be representative of that achieved on actual process or product ~~quality change are established and adjusted to produce a meaningful analyzer result.~~ samples.)

6. System Components

6.1 Fig. 1 illustrates a total analyzer system incorporating a selection and arrangement of components that are typical but not specific for any particular analyzer system. A total analyzer system design ~~must consider~~ addresses the chemical and physical properties of the process or product stream ~~in selecting the components required. These must meet the requirements of the analyzer, and provide~~ to be measured, provides a representative sample, and handles it without adversely affecting the value of the specific ~~quality parameter~~ property of ~~interest (1.3).~~

6.1.1 ~~*Total Analyzer System*~~ ~~consists of all~~ interest. Included are a sample loop, piping, hardware, ~~and instrumentation required to automatically perform on-stream analysis of~~ a ~~process or product stream including the analyzer unit, readout instrumentation,~~ sampling port, sample conditioning devices, ~~sample stream, and sampling port.~~

~~6.1.2 *Analyzer Unit*~~ ~~is the instrumental hardware necessary to automatically measure the physical or chemical property of a process or product stream and to provide either~~ an ~~intermittent or a continuous output signal.~~

~~6.1.2.1 *Intermittent Analyzer*~~ ~~is an~~ analyzer ~~that tests the sample~~ unit instrumentation, any data analysis computer hardware and ~~produces the prime output signal at discrete time intervals.~~

~~6.1.2.2 *Continuous Analyzer* is an analyzer that tests the sample~~ software, and ~~produces the prime output signal on an instantaneous or continuously updated basis.~~

~~6.1.3 *Sampling System*~~ ~~is that assembly of valves, lines, containers, regulator, and gages which constitutes the equipment employed to obtain~~ a ~~proper sample from the sample loop or to introduce a reference sample into the analyzer, or both.~~

~~6.1.3.1~~ readout display.

6.2 *Sample Loop*~~ is that~~—Piping connected to the main process stream to deliver a portion of the streamp to a locationg close to the analyzer system ~~which takes~~ with minimum lag time and return the ~~sample from the process or product line~~ unused material to the ~~sample conditioning unit~~ main process stream.

6.3 *Sampling System*—Sample probes, valves, lines, containers, pressure regulator, and ~~returns most of~~ gages that constitute the ~~flow back~~ equipment employed to obtain a proper sample from the ~~line of origin~~ sample loop and introduce either it or a validation standard sample to ~~waste.~~

~~6.1.3.2~~ the analyzer.

6.4 *Sample Conditioning Unit*~~ is one or more~~—A collection of devices ~~that~~ to properly ~~prepare~~ treat a portion of the sample from the sample loop so that it meets the requirements for testing by the process ~~analyzer consistent with the requirements of the~~ analyzer. ~~This preparation~~ These components can ~~consist of~~ incorporate temperature or pressure adjustment, change of state (liquid, vapor), or removal of contaminants.

6.5 *Inlet Port*—Appropriate piping with selector valve(s) for placement either at the inlet to ~~assure consistent treatment of~~ the analyzer unit or, when dictated by the measurement specifications, at the inlet to the sample conditioning unit. The purpose of this

inlet port is to ~~testing by~~ allow injection of validation standards or other calibration material into the analyzer system with quick switching between these typically containerized materials and the flowing process stream.

6.5.1 For many analyzer systems the inlet port requires a manifold arrangement for validation or quality assurance studies.~~3~~ Such a manifold, with suitable valving, provides a means to use a containerized supply of standby material when a flowing process stream is not available for the purpose.~~3~~ It also permits quick switching between different validation standards when that is desirable.

6.6 *Sample Port*~~—is that point on the sampling system, located between the sample conditioning unit and the analyzer~~—An appropriate probe or ~~at~~ fitting in the piping to~~u~~ permit collection of ~~the analyzer from which~~ representative samples for laboratory ~~analysis are taken. A sample port location at~~ analyses using a primary test method.

6.7 *Analyzer Unit*—Instrumentation designed to automatically measure the ~~outlet of the analyzer can be used only if the properties of the sample are unchanged as it passes through the analyzer~~ chemical or ~~if the sample is~~ physical property of a ~~slip~~ process or product stream ~~identical to the~~ sample ~~tested. It is important that the sample port is located as close as possible to the inlet~~ and provide either an intermittent or a continuous output signal represent ~~of~~ing the ~~analyzer to minimize lag time.~~

~~6.1.4~~ measurement result.

6.8 *Readout Instrumentation*~~ is any device used to accept~~—If it is not an integral component of the ~~prime signal from the~~ analyzer system, a device to ~~produce and~~ display or record or both, the ~~quality parameter in acceptable quality units.~~ property measurement analyzer result.

7. Preparation of Analyzer System for Validation

7.1 Implementation of this practice requires that the process stream analyzer system operates under conditions specified:

7.1.1 Meets all applicable electrical and safety codes.

7.1.2 Meets the supplier's recommendation.

7.1.3 Complies with operating conditions specified by the manufacturer.

7.1.4 Includes a predicted PTM algorithm, if necessary.

7.2 After installation or major maintenance, conduct such diagnostic tests as recommended by the manufacturer to demonstrate that the analyzer meets the manufacturer's specifications or historical performance levels, or both. If necessary, adjust the analyzer system components so as to obtain recommended analyzer output levels for specified reference materials.

7.3 Inspect the entire analyzer system to ensure it is installed properly, is in operating condition, and is properly adjusted after completion of the initial commissioning procedures.

8. Validation Procedure

8.1 The objective of the validation procedures is to quantify the performance of a process stream analyzer system or its subsystem in terms of precision and bias relative to the precision and bias of the primary test method for ~~Establishing Reference Sample Value~~

~~7.1 A minimum~~ the property of ~~six laboratory determinations are required~~ interest. The user must specify acceptable precision and bias performance criteria before initiating the validation. These criteria will be dependent on ~~each reference sample, preferably~~ the intended use of the analyzer.

8.1.1 For analyzer systems used in ~~several laboratories using different operators~~ product certification, analyzer system precision criteria will typically be based directly to the site precision of the PTM. Bias criteria will be based on regulatory or contractual requirements.

8.1.2 For analyzer systems used in other types of service, precision and bias criteria must be developed based on the intended use of the analyzer results.

8.2 The line sample procedure directly fulfills the validation objective since the validation results for both the process system and the primary test method are obtained on process samples. Depending on circumstances that are described as follows, the validation reference material procedure may or may not fulfill this objective adequately, particularly when the validation reference materials are composition-specific, or not representative of current process samples.

8.2.1 If the process analyzer system is not based on identically the same measurement principle as the primary test method, or if the sample analyzed by the process analyzer system is not identical to ~~minimize laboratory bias.~~

~~7.1.1 When~~ that submitted to the primary test method for analysis (after sample conditioning for both methods are considered), then it is ~~necessary~~ recommended that the line sample procedure be used to validate the pr~~u~~ocess stream analyzer performance.

8.2.2 If the process analyzer system is based on identically the same measurement principle as the primary test method, if the sample analyzed by the process analyzer system (post sample conditioning) is compositionally identical to the material in the process, and, if sample conditioning steps in the PTM do not materially change the sample that was taken from the process and submitted for analysis, then the validation reference material procedure is expected to adequately fulfill the validation objective regardless of the nature of the VRM.

8.2.3 If the process analyzer system is not based on identically the same measurement principle as the primary test method, or if the sample analyzed by the process analyzer system is not identical to that submitted to the primary test method for analysis and the user wishes to use the VRM procedure, then it is recommended that ~~different operators~~ the user conduct validation using both the line sample procedure and ~~a~~ the VRM p~~p~~rocedure for a period of time sufficient to demonstrate that the VRM procedure

adequately reflects process analyzer system performbance.

8.2.3.1 The initial process analyzer system validation should be ~~utilized~~ done using both procedures to demonstrate that both procedures agree on the ~~maximum extent possible.~~

~~7.1.2 When only one testing unit is available, make~~ accuracy of the ~~multiple determinations over~~ analyzer predicted PTM results.

8.2.3.2 The statistical quality control for continual validation should be done using both procedures for a period of time adequate to demonstrate that both procedures provide acceptable agreement on the precision and bias of the predicted PTM results.

NOTE 1—If the process analyzer system is not based on identically the same measurement principle as the primary test method, then the analyzer system may react differently to variations in the sample matrix than does the primary test method. In such case, analyzer results for process samples might be biased relative to primary test method results even when the VRM procedure results shown no such bias. The bias can be minimized by using a process stream (test) sample for which an ARV or SAV was determined as the VRM. The test sample used in this fashion should be representative of the current process stream.

NOTE 2—If, due to differences in sample pretreatment, the sample analyzed by the process stream analyzer and the sample analyzed by the primary test method are not identically the same, then the use of the VRM procedure may not accurately reflect agreement between the process analyzer and the primary test method. The VRM may not be affected in the same manner as process samples by the different sample pretreatments. Again, this effect can be minimized by using current process stream (test) samples as VRMs.

8.3 *Line Sample Procedure*:

8.3.1 *General*—This procedure is applicable for analyzer systems that are equipped with sample ports anywhere within the system that can facilitate the safe co~~u~~llection of material intended for analysis by the analyzer unit without significantly altering the property of interest. The subsystem downstream of the sample port is considered to be validated for current process stream samples if validation results are in statistical control, and the predicted PTM results are in agreement with actual PTM results within satisfactory precision and bias limits.

8.3.2 *Line Sample Procedure Requirements:*

8.3.2.1 Select point of line sample withdrawal.

8.3.2.2 Determine the total lag time of the system or subsystem downstream of the sample withdrawal point (see Figs. 1 and 2 for guidance).

8.3.3 *Initial Validation*—Collect analyzer unit results from at least 15 implementations of the line sample procedure under site precision conditions, with nominally 8 to 12 h between each implementation, as follows:

8.3.3.1 Observe the analyzer unit output until the change between readings over at least three subsystem lag times does not exceed the known repeatability of the analyzer unit (that is, the manufacturing process is at steady state). If steady state conditions cannot be achieved, the line sample validation procedure should not be executed at this time. If the analyzer system repeatability is unknown, the repeatability of the primary test method can be used as the reference for data ~~have~~ comparison.

8.3.3.2 After steady state has been verified, begin collecting the~~d~~ process line sample from the sample port. Refer to Practices D 1265, D 4057, D 4177, D 5842, or F 307 for procedures for sample collection. Record the time, t_s, corresponding to the start of sample collection. Record the analyzer system result $A_0(t_s)$ observed at t_s. Collect the volume of sample required for PTM analysis. Record the time, t_e, when sample collection ends.

8.3.3.3 If the sample collection interval $t_e - t_s$ is less than the total subsystem lag time, record the analyzer result $A_1(t_s)$ at a time one subsystem lag time interval after t_s. If $A_1(t_s)$ and $A_0(t_s)$ agree to within known analyzer system repeatability, assign $A_1(t_s)$ as the predicted PTM result (A) for the collected line sample. Otherwise, the line sample and results are discarded. Wait until steady state is re-established before beginning the line sample procedure again.

8.3.3.4 If the sample collection interval $t_e - t_s$ is longer than the subsystem lag time, then record analyzer results $A_1(t_s)$ and $A_1(t_e)$ at times corresponding to one total analyzer response interval after t_s and t_e respectively. If $A_1(t_s)$ and $A_1(t_e)$ agree to within the known repeatability of the analyzer system, assign either $A_1(t_s)$ or $A_1(t_e)$, or the average of these ~~ci~~ two results, as the predicted PTM value (A) for the collected line sample. Otherwise, the line sample an~~e~~d results are discarded. Wait until steady state is re-established before beginning the line sample procedure again.

8.3.3.5 Obtain a PTM result (P) for the line sample collected.

8.3.3.6 For each line sample collected, calculate the difference (Δ) between the analyzer system predicted PTM value (A) and the actual PTM value.

8.3.3.7 Follow the instructions in Practice D 6299 (section on Procedure for Pretreatment, Assessment, and Interpretation of Test Results) and assess all the Δ results following the quality control (QC) sample results protocol. Interpret the control chart generated and determine if the system that generated these Δ results is in statistical control.

NOTE 3—The system that generated the Δ results comprises the analyzer subsystem being validated, the PTM, and the process of obtaining the line samples.

8.3.3.8 If the system that generated the Δ results is in statistical control, proceed with calculation of system precision and bias statistics. Otherwise, investigate the out-of-control points and take appropriate corrective actions to address the root cause(s). Replace the out-of-control points by repeating the line sampling procedure.

8.3.3.9 Assess the standard deviation of the Δ results against the appropriate site standard deviation of the PTM (site precision standard deviation). For certification applications, the standard deviation of the Δ results is typically expected to meet or better 1.4

times the site standard deviation of the PTM. For other applications, the standard deviation of the Δ should meet the specifications for the intended use.

8.3.3.10 Assess the bias by performing a one-sample *t*-test using all the Δ results in accordance with Practice D 6299. If the bias is statistically significant, assess the bias magnitude against the application requirement for practical significance.

8.3.3.11 If both the precision and bias meet the application requirements, the subsystem is considered to have met the initial validation requirements for materials representative of ~~different qualified operators be~~ the line samples used in the assessment.

8.3.3.12 Prepare a validation statement and control charts for the Δ results. Establish control limits based on the results from initial validation.

8.3.3.13 *Continual Validation*—Deploy the control chart constructed for the Δ results into operation. Continue to validate the information from the initial validation by populating the control chart with new Δ results at a frequency commensurate with the criticality of the analyzer application. A recommended frequency is at least once a week. Frequency can be reduced if the subsystem stability and precision is monitored by way of other QC material in accordance with Practice D 6299.

8.4 *VRM Injection Procedure*:

8.4.1 *General*—This procedure requires analyzer system to be equipped with storage and injection facilities designed for the delivery of a VRM into the analyzer unit. The subsystem downstream of the VRM injection point is considered to be validated if validation results are in statistical control, and the predicted PTM results are in agreement with actual PTM results within satisfactory precision and bias limits. The validation applies only for analyses of materials of the same type as the VRM.

8.4.2 Injection procedure requirements.

8.4.2.1 Select the point of injection.

8.4.2.2 Determine the total lag time of the subsystem downstream of the injection point (use Fig. 1 for guidance).

8.4.3 *Initial Validation*—Collect analyzer unit results from at least 15 implementations of the VRM injection procedure for each selected VRM under site precision conditions, with nominally 8 to 12 h between each implementation, as follows:

8.4.3.1 Isolate the subsystem to be validated from the regular process stream sample flow.

8.4.3.2 Commence injection of the VRM.

8.4.3.3 Observe the analyzer unit output until the change between readings over at least three subsystem lag times does not exceed the known repeatability of the analyzer unit (that is, steady state has been reached). If the analyzer system repeatability is unknown, the repeatability of the primary test method can be used as the reference for data comparison.

8.4.3.4 Record the steady state analyzer unit output as the result for one implementation of VRM injection procedure.

8.4.3.5 Pre-treat and assess the collected data in accordance with Practice D 6299, including the construction of the I/MR control charts, using the protocol for a single check standard. Use the SAV instead of the ARV for VRMs that do not have ARVs.

8.4.3.6 If the data exhibits in statistical control behavior, follow the procedure in Practice D 6299 to ~~reduce~~ estimate the ~~influence~~ site precision and bias of ~~possible operator~~ the analyzer subsystem for the specific VRM. For the bias test use the protocol for a single check standard.

8.4.3.7 Assess the standard deviation of results for each VRM against the appropriate site standard deviation of the PTM. For product certification applications, the subsystem is expected to meet or better the site precision of the PTM. For other applications, the standard deviation of the results should exceed the pre-specified precision criteria for the intended use.

8.4.3.8 If the one-sample *t*-test for bias is statistically significant, assess the bias magnitude against the application requirement for practical significance.

8.4.3.9 If both the precision and bias meet the application requirements, the subsystem is considered to have met the initial validation requirements for materials of the same type and property range as the VRMs used in the ~~test results.~~

~~7.2 More than~~ assessment.

8.4.3.10 Prepare a validation statement and control charts for each VRM. Establish control limits based on results from initial validation.

8.4.4 *Continual Validation*—Deploy the control charts constructed for each VRM. Obtain additional results using the VRM injection procedure at a frequency commensurate with the criticality of ~~six test~~ the analyzer application (typically at least once a week). Plot results on control charts. Assess control chart status in accordance with procedures in Practice D 6299. The frequency of VRM injection can be reduced if the subsystem stability and precision is monitored by way of other QC material in accordance with Practice D 6299.

8.5 *Validation of Total Process Analyzer System*:

8.5.1 The complete analyzer system, inclusive of the sample loop, can be validated by a ~~reference~~ combination of line sample and VRM procedure where:

8.5.1.1 The Line sample procedure is deployed to validate the entire system using current production material by sampling from a location located in close proximity to the process takeoff point of the sample loop.

8.5.1.2 The VRM procedure is deployed to validate the analyzer unit for material that is not currently available from the process.

ANNEX

(Mandatory Information)

A1. PROCEDURE FOR DEVELOPING A VALIDATION REFERENCE MATERIAL

A1.1 Determine the number of validation standards and the quantity of each that is appropriate for the proposed validation and quality assurance testing uses for the specific analyzer system application.

A1.1.1 If the analyzer system is known or suspected to produce nonlinear results, at least three validation standards having different accepted reference values can be required.

A1.1.2 The desired quantity of each validation standard shall be sufficient to sustain necessary analyzer system operation long enough to determine the data for initial validation of the system. In addition, it is recommended that enough material be included in a given lot, to permit on-going statistical quality control (SQC) testing after the validated system is placed in service. The quantity of validation standard selected for such SQC testing will depend on the stability of the material, available storage capacity, and so forth.

A1.1.3 Obtain the validation reference material(s) and store them under conditions that will ensure essentially no degradation of the critical property accepted reference value once it is established.

A1.1.4 Commercial standard reference materials are often available for use as a designated validation reference material. The property and the accepted reference value are available from the supplier.

A1.2 When commercial standard reference material is not available, the validation standard may be prepared from on-site process or product material meeting the desired specifications. Utilization of this type of material requires testing by a primary test method, preferably under reproducibility conditions, to establish the accepted reference value of the selected property.

A1.2.1 Collect and store the appropriate quantity of an on-site process or product material for use as a validation standard. Prepare and fill the necessary number of individual containers of validation standard for primary test method analyses to determine the ARV or SAV of the desired property.

A1.2.2 For each validation standard, obtain a minimum of ten primary test method results.

A1.2.2.1 More than ten primary test method results can be necessary to provide an average value ~~with~~ having acceptable confidence limits. This ~~will~~ can vary significantly for different ~~laboratory procedures~~ primary test methods and ~~reference sample properties. This applies to the laboratory determination as well as to the analyzer results.~~

~~7.2.1 Controlling~~ validation standard properties.

A1.2.2.2 The controlling factors in defining the number of ~~tests obtained~~ test results required are: degree of precision desired, testing costs, precision of the ~~laboratory~~ primary test method, and the criticality of the analyzer system accuracy and precision.

~~7~~A1.2.~~2~~3 For guidance in determining the number of primary test method results required to establish ~~a~~ desired confidence limits for the ~~reference sample value,~~ ARV or SAV of the validation standard, refer to ~~Fig. X1.1 and the~~ instructions ~~for use given~~ provided in ~~X1.2.~~

~~7.3 Tabulate~~ A1.4.

A1.2.4 To establish an ARV, it is necessary that the primary test method results be obtained under reproducibility conditions, to minimize effects of inter-laboratory bias and test variability.

A1.3 To establish an SAV, it is recommended that different operators and apparatus combinations be utilized to the maximum extent possible so the data are representative of site precision conditions.

A1.3.1 If it is considered necessary to obtain the multiple determinations in a single laboratory that has only one piece of apparatus available, make the multiple determinations over an extended period of time using multiple operators and testing other samples between the validation standard measurements. This approach will provide data obtained in a manner that is closest to site precision conditions.

A1.3.2 If the validation standard primary test method results are determined in a single laboratory, it is recommended that the laboratory maintain records verifying their bias status, based on participation in an industry-wide round-robin exchange sample testing program.

A1.4 *Calculating the Accepted Reference Value (ARV) or Site Assigned Value (SAV) for the Validation Reference Material*:

A1.4.1 Tabulate the primary test method results for the validation standard and ~~check~~ visually screen for extreme values or outliers, or both, by an accepted statistically based rejection criterion. ~~As an example,~~[8] Remove the ~~details for application~~ outliers to further analyze the data. No more than 10 % of ~~Dixon's Rejection Criterion are included in Appendix X1, Typical Statistical Procedures.~~

[8] Supporting data are available from ASTM International Headquarters. Request RR: D02–1481.

~~7.4 Determine~~ the data points should be removed through this process.

A1.4.2 Determine the arithmetic average ~~value~~ (~~$\bar{X}$~~ $\bar{X}_r$) *and the variance* (S_r^2) *of the* ~~*reference sample test*~~ *acceptable validation standard data.*

~~7~~A1.4.2.1 Calculate the arithmetic average ~~by~~ value using the following equation:

$$\bar{X}_r = \frac{\Sigma X_r}{N_r} = \text{arithmetic average test result} \quad \text{(A1.1)}$$

$$\bar{X}_r = \frac{\Sigma X_r}{N_r} \quad \text{(A1.1)}$$

where:

X_r = individual test results on the ~~reference sample,~~ validation standard, and

N_r = number of test results.

~~7~~A1.4.2.2 Calculate the variance by either of the following equations:

$$S_r^2 = \frac{\Sigma X_r^2 - \frac{(\Sigma X_r)^2}{N_r}}{(N_{r-1})} \quad \text{(A1.2)}$$

$$S_r^2 = \frac{\Sigma X_r^2 - \frac{(\Sigma X_1)^2}{N_r}}{(N_{r-1})} \quad \text{(A1.2)}$$

$$S_r^2 = \frac{\Sigma(X_r - \bar{X}_r)^2}{(N_r - 1)} \quad \text{(A1.3)}$$

$$S_r^2 = \frac{\Sigma(X_r - \bar{X}_r)^2}{(N_r - 1)} \quad \text{(A1.3)}$$

~~7~~A1.~~5~~4.3 Compare the ~~variance of the reference sample~~ calculated validation standard data variance to that used to establish the reproducibility precision statement of the applicable primary test method. The statistical criteria for this judgment is the *F*-Test, which ~~is based on~~ requires determination of the ratio of the variances as follows:

$$F = \frac{S_r^2}{\sigma_t^2} \quad \text{(A1.4)}$$

where:

S_r^2 = variance of ~~reference sample data, and~~ validation standard data,

σ_t = historical reproducibility standard deviation of the ~~laboratory~~ primary test ~~method as utilized to define the reproducibility of the~~ method. ~~When the precision statement is in the form of a reproducibility limit, divide the limit value by 2.772 to obtain the standard deviation.~~

~~7~~A1.~~5~~4.3.1 This standard deviation can be obtained by dividing the reproducibility (*R*) given in the precision statement of the primary test method by 2.772.

A1.4.4 Determine the limiting *F* value from the statistical *F* Distribution (5 % ~~Significance Level)~~ error level) tables for ($N_r - 1$), ($N_r - 1$) degrees of freedom in the numerator and ~~infinite~~ 30 degrees of freedom ~~for~~ in the denominator. (See Table ~~X1.2 in Appendix X1~~ A1.1 for a condensed portion of the ~~aforementioned~~ *F* Distribution ~~T~~ table~~)~~.

~~7~~A1.~~6~~4.5 Compare the calculated *F* value to the limiting *F* ~~value.~~

~~7.6.1 If~~ value obtained from the ~~calculated~~ *F* Distribution table and interpret as follows:

A1.4.5.1 If the calculated *F* value is equal to or less than the limiting *F* value, the variance of the ~~reference sample~~ validation standard data is ~~as good or better~~ not significantly worse than that of the expected primary test method ~~predicts,~~ precision and the ~~qualification is complete. Proceed to 7.7.~~

~~7.6.2 If~~ validation standard data are qualified and acceptable.

A1.4.5.2 If the calculated *F* value is larger than the limiting *F* value, the variance of the ~~reference sample~~ validation standard data is not as good as the expected primary test method ~~predicts~~ precision and the difference is statistically significant.

~~7.6.3 When~~

A1.4.6 When a significant difference ~~in variance exists,~~ between the variances occurs, the reason(s) for the substandard validation standard primary test ~~precision shall be determined, appropriate corrections made~~ method data requires investigation. Make any needed changes to the procedure or apparatus, or both, and ~~the complete reference sample procedure qualification repeated until acceptable laboratory test precision is obtained.~~

~~7.7 When a satisfactory reference sample value is achieved, the arithmetic average result shall be the assigned value for the reference sample.~~

~~7.8 Reference samples shall be stored under conditions that will not cause changes in the critical characteristics. Because storage conditions and the factors that affect sample stability can change with time, confirm the reference sample value at periodic~~

TABLE A1.1 F-Distribution
Degrees of freedom for numerator

	1	2	3	4	5	6	7	8	9	10	12	15	20
1	161	200	216	225	230	234	237	239	241	242	244	246	248
2	18.5	19.0	19.2	19.2	19.3	19.3	19.4	19.4	19.4	19.4	19.4	19.4	19.4
3	10.1	9.55	9.28	9.12	9.01	8.94	8.87	8.85	8.81	8.79	8.74	8.70	8.66
4	7.71	6.94	6.59	6.39	6.26	6.16	6.09	6.04	6.00	5.96	5.91	5.86	5.80
5	6.61	5.79	5.41	5.19	5.05	4.95	4.88	4.81	4.77	4.74	4.68	4.62	4.56
6	5.99	5.14	4.76	4.53	4.39	4.28	4.21	4.15	4.10	4.06	4.00	3.94	3.87
7	5.59	4.74	4.35	4.12	3.97	3.87	3.79	3.73	3.68	3.64	3.57	3.51	3.44
8	5.32	4.46	4.07	3.84	3.69	3.58	3.50	3.44	3.39	3.35	3.28	3.22	3.15
9	5.12	4.26	3.86	3.63	3.48	3.37	3.29	3.23	3.18	3.14	3.07	3.01	2.94
10	4.96	4.10	3.70	3.48	3.33	3.22	3.14	3.07	3.02	2.98	2.91	2.85	2.77
11	4.84	3.98	3.59	3.36	3.20	3.09	3.01	2.95	2.90	2.85	2.79	2.72	2.65
12	4.75	3.89	3.49	3.26	3.11	3.00	2.91	2.85	2.80	2.75	2.69	2.62	2.54
13	4.67	3.81	3.41	3.18	3.03	2.92	2.83	2.77	2.71	2.67	2.60	2.53	2.46
14	4.60	3.74	3.34	3.11	2.96	2.85	2.76	2.70	2.65	2.60	2.53	2.46	2.39
15	4.54	3.68	3.29	3.06	2.90	2.79	2.71	2.64	2.59	2.54	2.48	2.40	2.33
16	4.49	3.63	3.24	3.01	2.85	2.74	2.66	2.59	2.54	2.49	2.42	2.35	2.28
17	4.45	3.59	3.20	2.96	2.81	2.70	2.61	2.55	2.49	2.45	2.38	2.31	2.23
18	4.41	3.55	3.16	2.93	2.77	2.66	2.58	2.51	2.46	2.41	2.34	2.27	2.19
19	4.38	3.52	3.13	2.90	2.74	2.63	2.54	2.48	2.42	2.38	2.31	2.23	2.16
20	4.35	3.49	3.10	2.87	2.71	2.60	2.51	2.45	2.39	2.35	2.28	2.20	2.12
∞	3.84	3.00	2.60	2.37	2.21	2.10	2.01	1.94	1.88	1.83	1.75	1.67	1.57

intervals. The frequency of confirmation can best be determined by the user of the analyzer.

8. Preliminary Analyzer Adjustments

8.1 Check the entire system to assure that the analyzer is installed, operating, and adjusted properly.

8.2 Check linearity 3.1.8 over the quality range of expected operation through the use of one or more qualified reference samples to cover the minimum intermediate and maximum quality ranges.

8.2.1 Plot the analyzer results obtained and draw a line through the points as illustrated in Fig. 3 (see Fig. A1.3).

8.3 Adjust the analyzer to then obtain the linearity specified by the manufacturer or to establish linearity over the specific range of interest.

8.4 Adjust the analyzer to obtain the optimum required sensitivity.

9. Reference Sample Procedure

9.1 *Procedure*:

9.1.1 Select the applicable qualified reference sample(s) in sufficient quantity to permit operation of the analyzer system for a time period adequate to collect the required new set of validation standard primary test method data for validation.

9.1.2 Provide suitable means for introducing the reference sample into the inlet comparison of the analyzer or, where required, variances once again. Repeat the sample conditioning system. The flow rate, temperature, and pressure used in introducing the reference sample shall be consistent with the analyzer requirements.

9.1.3 Operate the analyzer system on the reference sample and observe the analyzer results. Do not record results process until a period of time equivalent to at least one analyzer lag time has elapsed after equilibrium is reached.

9.2 *Data Collection*:

9.2.1 For an intermittent analyzer, record a minimum of seven analyzer results and discard the first as illustrated in Fig. 4.

9.2.2 For a continuous analyzer, obtain a minimum precision of seven averaged analyzer results allowing at least one analyzer time constant interval for each analyzer result. Discard the primary test method data obtained during is acceptable.

A1.4.7 Assign the first analyzer time constant interval. See Fig. 5.

9.3 *Data Analysis for Analyzer Validation*:

9.3.1 Tabulate the selected analyzer results obtained on the accepted reference sample value (ARV) and check appropriate confidence limits for extreme values or outliers by an accepted statistically based rejection criterion. (See Appendix X1.)

9.3.2 Determine the arithmetic average value ($\bar{X}_a$) and the variance (S_a^2) property of the accepted analyzer results.

9.3.2.1 Calculate validation standard material tested as follows:

A1.4.7.1 Use the arithmetic average by the following equation:

$$\bar{X}_a = \text{arithmetic average analyzer result} = \frac{\Sigma X_a}{N_a} \quad (5)$$

where:

$\bar{X}_a$ = individual analyzer results, and

N_a = number result of analyzer results obtained.

9.3.2.2 Calculate the variance by either of the following equations:

Analyzer result variance = S_a^2 (6)

$$S_a^2 = \frac{\Sigma X_a^2 - \frac{(\Sigma X_a)^2}{N_a}}{(N_a - 1)}$$

$$S_a^2 = \frac{\Sigma (X_a - \bar{X}_a)^2}{(N_a - 1)} \quad (7)$$

9.3.3 Apply the statistical *F* validation standard primary test to determine whether or not method data as the variance of property ARV.

A1.4.7.2 Calculate the analyzer results (S_a^2) and 95 % confidence interval limits for the laboratory reference sample results (S_r^2) are from ARV based on the same population with validation standard test data using the same (but unknown) variance.

9.3.3.1 Establish the calculated *F* ratio by the following equation:

F value = *L*/*M* (8)

$$95\ \%\ \text{confidence limits} = X_r \pm t \frac{S_r}{\sqrt{N_r}} \quad \text{(A1.5)}$$

where:

L = larger variance (S_a^2 or S_r^2), and
M = smaller variance.

9.3.3.2 Determine the limiting *F* value from a 95 % Probability, *F* Distribution Table. (See Table X1.2 in Appendix X1 for a condensed portion of the *F* Table.)

9.3.3.3 Compare the calculated *F* value to the limiting *F* value and follow the instructions given in either 9.3.4 or 9.3.5, whichever applies.

9.3.4 If the calculated *F* value is equal to or less than the limiting *F* value, the variances are essentially the same. Proceed to apply Student's

Where: *t* test to determine if there is a statistically significant difference between the average analyzer result and the average laboratory reference sample result.

9.3.4.1 The appropriate equations to establish the calculated = students *t* value for this set of variance conditions are as follows:

$$t \text{ value} = \frac{(\bar{X}_a - \bar{X}_r)}{S_d} \quad (9)$$

$$S_d = \sqrt{\frac{(N_a - 1)S_a^2 + (N_r - 1)S_r^2}{N_a + N_r - 2}\left(\frac{1}{N_a} + \frac{1}{N_r}\right)} \quad (10)$$

where:

S_d = pooled standard deviation of the difference,
$\bar{X}_a$ = arithmetic average analyzer result,
95^{th}
$\bar{X}_r$ = arithmetic average laboratory reference sample result,
N_a = number of analyzer results,
N_r = number of laboratory reference sample results,
S_a^2 = variance of analyzer results (Eq 6 or Eq 7), and
S_r^2 = variance of laboratory reference sample results (Eq 2 or Eq 3).

9.3.4.2 Determine the critical *t* value percentile from a Table of *t* at 5 % Probability Level using ($N_a + N_r - 2$) standard t-tables for n-1 degrees of freedom. (See Table X1.3 in Appendix X1 A1.2 for a condensed portion of the *t* Table.)

9.3.4.3 If t-table).

A1.4.7.3 If the calculated *t* value is equal to or less than the critical *t* value, the analyzer can be expected to give essentially the same average results as the reference sample test method at the quality level tested. Proceed to 9.4, *Case A.*

9.3.4.4 If the calculated *t* value exceeds the critical *t* value, there is a statistically significant bias (at the 5 % level) confidence interval width (magnitude between the two analyzer techniques. Further investigation of the analyzer functions upper and operation should be made to deal with the probable bias that lower confidence limits) is indicated. Proceed too far apart to 9.4, *Case B.*

9.3.5 If the calculated *F* value of 9.3.3.1 is greater than the limiting *F* value, the variances are indicated to be significantly different. Proceed to apply Student's *t* test to determine if there is a statistically significant difference between the average analyzer result and the average laboratory reference sample result.

9.3.5.1 The appropriate equation to establish the calculated *t* for this set of variance conditions is as follows:

TABLE A1.2 Table of *t* at 5 % Probability Level

Degrees of Freedom (*N*-1)	*t*
1	12.706
2	4.303
3	3.182
4	2.776
5	2.571
6	2.447
7	2.365
8	2.306
9	2.262
10	2.228
11	2.201
12	2.179
13	2.160
14	2.145
15	2.131
16	2.120
17	2.110
18	2.101
19	2.093
20	2.086

$$t = \frac{(\bar{X}_a - \bar{X}_r)}{\sqrt{\frac{S_a^2}{N_a} + \frac{S_r^2}{N_r}}} \tag{11}$$

9.3.5.2 Calculate the degrees of freedom for the *t* test by the following equation:

$$\text{degrees of freedom} = \frac{\left(\frac{S_a^2}{N_a} + \frac{S_r^2}{N_r}\right)^2}{\frac{\left(\frac{S_a^2}{N_a}\right)^2}{N_a + 1} + \frac{\left(\frac{S_r^2}{N_r}\right)^2}{N_r + 1}} - 2 \tag{12}$$

Round the calculated degrees of freedom value to the nearest whole number.

9.3.5.3 Determine the critical *t* value from a Table of *t* at 5 % Probability Level using the calculated degrees of freedom. (See Table X1.3.)

9.3.5.4 If the calculated *t* value is equal to or less than the critical *t* value, the analyzer can be expected to give essentially the same average results as the reference sample test method at the quality level tested. Proceed to 9.4, *Case C*.

9.3.5.5 If the calculated *t* value exceeds the critical *t* value, there is a greater than 5 % probability that the average analyzer results are not the same as the average laboratory reference sample results. Proceed to 9.4, *Case D*.

9.4 *Interpretation of Analyzed Data*:

9.4.1 *Case A*—Analyzer results and laboratory reference sample results have essentially the same variances, and no bias in level. The analyzer can be considered satisfactory and validated.

9.4.2 *Case B*—Analyzer results and laboratory reference sample results have essentially the same variances, but there is a bias in level. The analyzer procedure should be repeated. If the bias is confirmed, investigation of the analyzer function and operation should be made to eliminate the probable bias indicated.

9.4.3 *Case C*—Analyzer results and laboratory reference sample results have significantly different variances, and there is no bias in level.

9.4.3.1 If the analyzer results have the smaller variance, the analyzer can be considered very satisfactory and validated.

9.4.3.2 If the analyzer results have the larger variance, the analyzer procedure should be repeated, and if the larger variance condition is confirmed, the analyzer system should be thoroughly evaluated to improve the variability condition.

9.4.4 *Case D*—Analyzer results and laboratory reference sample results have significantly different variances, and there is a bias in level.

9.4.4.1 If the analyzer results have the smaller variance, the analyzer has considerable merit, but investigation of the analyzer function and operation should be made to eliminate the probable bias indicated.

9.4.4.2 If the analyzer results have the larger variance, the system should be completely reevaluated.

10. Line Sample Procedure

10.1 *Application Information*:

10.1.1 The line sample procedure is primarily for use as an operational check on an analyzer system that has been previously validated and is in service on a process or product stream. The line sample procedure therefore is not applicable for predelivery validation of an analyzer system or calibration before start-up and is not generally considered a viable alternative to the reference sample procedure.

10.1.2 For analyzer systems applications or process and product stream conditions, or both that negate the practical use of the reference sample procedure for predelivery or regular validation, the line sample procedure may have to be substituted for calibration purposes. It shall, in such cases, be applied at appropriate times when the process or product stream correspond to low, midscale, and high quality characteristics within the range of the analyzer.

10.2 *Procedure*:

10.2.1 Operate the analyzer at a time when the line sample meets the desired quality level at which validation is required. It is important that the quality measure of the line sample is as constant as possible and that the system is operating at equilibrium.

10.2.2 Provide a suitable sampling tap at a point as close as possible to the analyzer inlet so that the samples to be drawn represent the material passing through the analyzer.

10.2.3 Provide a sufficient number of clean sample containers for conducting the test and condition these containers to meet the requirements of the laboratory test method to be utilized. For example, the containers may need to be chilled.

10.2.4 Confirm the analyzer dead time at the specific sample flow rate in use to establish the times for sampling in relation to those during which the analyzer output signal is to be recorded.

10.2.5 Operate the analyzer system and observe that the analyzer results are at equilibrium.

10.2.6 *Sample Collection and Data Recording Sequences* *useful, mathematically increase* —For both intermittent and continuous analyzers, the procedure requires synchronization of the collection of samples with the recording of the analyzer output signal.

10.2.6.1 Start collection of the sample and a suitable timer so that the period required for obtaining the required volume of sample is established. This period of time will be used as the time of recording of the analyzer output signal. Note, however, that signal recording is not to start until a delay from start of sampling equal to the analyzer dead time. Some practice may be required to properly coordinate these steps. (See Fig. 6 and Fig. 7.)

10.3 *Line Sampling and Analyzer Signal Recording*:

10.3.1 Obtain a minimum of seven laboratory line samples and record the analyzer output signal representative of each sample. During this sequence, observe that the quality measure remains essentially constant. If an upset occurs, the entire sequence must be repeated at a time when line sample quality is steady.

10.3.2 Identify each sample by a code number so that the laboratory test data for it can be properly associated with the related analyzer output signal recording.

10.4 *Line Sample Testing*—Determine the laboratory test value for each sample withdrawn using the appropriate ASTM or other standard test method for the quality measure of interest.

10.5 *Data Analysis for Analyzer Validation*:

10.5.1 Tabulate the analyzer and line sample laboratory results so that the differences (d_i) between the individual analyzer results (A_i) and the corresponding line sample results (L_i) can be listed.

$$d_i = A_i - L_i \tag{13}$$

10.5.2 Discard the first difference and check the remaining differences for extreme values or outliers by an accepted statistically based rejection criterion. (See Appendix X1.)

10.5.3 Calculate the average difference ($\bar{d}$) and the standard deviation (S_d) of the individual differences ($\bar{d}$) by the following equations:

$$\bar{d} = \frac{\Sigma d}{N} \tag{14}$$

$$S_d = \sqrt{\frac{\Sigma(d_i - \bar{d}_i)^2}{N-1}} \tag{15}$$

$$\text{or } S_d = \sqrt{\frac{\Sigma d_i^2 - \frac{(\Sigma d_i)^2}{N}}{(N-1)}} \tag{16}$$

where:

N = number of differences.

10.5.4 Apply the statistical Student's t test to determine whether there is a systematic difference or bias between the analyzer results and the laboratory line sample results.

10.5.4.1 Calculate the t value for the difference data by the following equation:

$$t = \frac{\bar{d}_i\sqrt{N}}{S_a} \tag{17}$$

10.5.4.2 Determine the critical t value from a Table of t at 5 % Probability Level using (N − 1) degrees of freedom. (See Table X1.3.)

10.5.4.3 If and recalculate until the calculated t value desired confidence interval width is equal to or less than obtained. Proceed and collect the critical t value, the analyzer can be expected to give essentially the same average additional results as the laboratory

line sample test method at the quality level tested.

10.5.4.4 If the calculated *t* value exceeds the critical *t* value, there is a greater than 5 % probability that the analyzer results are not the same as the average laboratory line sample results. Further investigation of laboratory and process stream analyzer functions and operation should be made to deal with meet the probable bias indicated.

11. Keywords

11.1 analyzer; process stream analyzer; validation

APPENDIX

(Nonmandatory Information)

X1. TYPICAL STATISTICAL PROCEDURES

X1.1 Dixon's Test Functions for Rejection of Outliers

X1.1.1 This test provides a simple and highly efficient method for determining whether all data obtained came from the same population (with unknown mean and standard deviation) and if one or more of the data points are suspect and should be rejected (Fig. X1.1).

X1.1.2 In applying this test the number of determinations (increased *N*) are tabulated in increasing order of magnitude and designated as $X_1, X_2, X_3, \ldots X_n$.

X1.1.3 The values at requirement.

A1.4.8 Confirm the extremes of the tabulation X_1 and X_n are tested in turn in accordance with the number of values in the tabulation.

X1.1.4 Select the proper expression shown below in accordance with the number (*N*) of the values in the tabulation and the upper or lower limit to be tested.

Outliers Under Test For *N* =	X_1	X_n
3 to 7	$r = \frac{(X_2 - X_1)}{(X_n - X_1)}$	$r = \frac{(X_n - X_{(n-1)})}{(X_n - X_1)}$
3 to 10	$r = \frac{(X_2 - X_1)}{(X_{(n-1)} - X_1)}$	$r = \frac{(X_n - X_{(n-1)})}{(X_n - X_2)}$
11 to 13	$r = \frac{(X_3 - X_1)}{(X_{(n-1)} - X_1)}$	$r = \frac{(X_n - X_{(n-2)})}{(X_n - X_2)}$
14 to 30	$r = \frac{(X_3 - X_1)}{(X_{(n-2)} - X_1)}$	$r = \frac{(X_n - X_{(n-2)})}{(X_n - X_3)}$

X1.1.5 Substitute the appropriate values in the equation selected, calculate *r* and compare the value obtained to the *r* value in Table X1.1 for the appropriate sample size (*N*).

X1.1.6 Reject the value if the calculated *r* is greater than the tabulated value.

X1.2 *Confidence Limit Nomograph Instructions:*

X1.2.1 The nomograph is based on the use of a test method historical validation standard deviation (Table X1.2).

X1.2.2 If the historical standard deviation is unknown, the sample standard deviation can be substituted for it in using the nomograph accepted reference value at periodic intervals because storage conditions and then multiplying the value found on the 95 % CL (Table X1.3) scale by the factor given below for the number of results in the average to obtain reliable 95 % confidence limits.

No. of Results	3	4	5	6	7
Factor	2.20	1.62	1.42	1.31	1.25
No. of Results	8	10	15	25	35
Factor	1.21	1.15	1.09	1.05	1.04

X1.2.3 *To Find the Number of Determinations Needed in an Average to Give Specific Confidence Limits*—Lay a straight edge across the nomograph so factors that its edge passes through affect the point on the right scale corresponding to the standard deviation for the test and through the desired point on the confidence limit scale. Read the number stability of determinations required from the left scale.

X1.2.4 *To Find material can change with time. The analyzer system user best determines the Confidence Limits frequency of an Average*

Using the number of determinations in the average, lay a straight edge from this point on the left scale through the point on the

~~right scale corresponding to the standard deviation. Read the confidence limits from the intermediate scale.~~ confirmation.