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Standard Practice for Determining a Flow-Proportioned Average Property Value (FPAPV) for a Collected Batch of Process Stream Material Using Stream Analyzer Data[1]

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INTRODUCTION

The determination of an average property value that is representative of a batch of petroleum product collected and isolated in a tank or vessel has always been a challenge. Historically, the industry practice has been to follow the appropriate procedures prescribed in Practices D4057, D5842, or D4177 to extract one sample (or a limited few, taken from top, middle, and bottom) from the tank or vessel after the content is mixed by any of several means to ensure the material is homogeneous prior to sample extraction. The extracted sample is then sent to a laboratory for analysis. Depending on the property and its criticality, the average property value can also be obtained by independently analyzing each of the top, middle, and bottom samples and the results averaged, or, the three tank samples are mixed and testing for the property is performed on the mixture.

With the introduction of in-line blending and process stream analysis in the 1960s, the potential for real-time delivery to a pipeline, barge, ship, or tank car compartment was envisioned.

To determine the average property value that is representative of a batch of product from a blend or process stream, two approaches have been developed and implemented. One depends on the use of a composite sampler, a vessel into which a sample of the flowing process or blended product stream is introduced at a flow-rate proportional to the flow-rate of the product stream (Practice D4177 or D7453). This sample, collected over the period of time required to generate the batch quantity of product, is then analyzed using a primary test method in the laboratory. Multiple laboratory analyses on one or more aliquots of composite sample can be averaged to provide a more precise estimate of the property value than a single analysis.

A second technique utilizes the results produced by on-line, at-line, or in-line analytical measurement systems that test material from the process or in-line blended stream for the desired property at regular intervals as it flows to a collection tank, pipeline, or shipping compartment. To determine the average property value of all the material collected (or shipped) at any time during the production process, a unique real time flow-proportioned averaging technique evolved. By appropriate selection of a production time period or cycle, the average property value for the collected (or shipped) material at any time in the production or shipment cycle is obtained by recursively calculating a flow-proportion average using all available property values from the analytical measurement system and the measured incremental quantity of product flow associated with each cycle. The determination of this flow-proportioned average property value is the subject of this practice.

[1] This practice is under the jurisdiction of ASTM Committee D02 on Petroleum Products, Liquid Fuels, and Lubricants and is the direct responsibility of Subcommittee D02.25 on Performance Assessment and Validation of Process Stream Analyzer Systems.

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1. Scope*

1.1 This practice covers a technique for calculating a flow-proportioned average property value (FPAPV) for a batch of in-line blended product or process stream material that is collected over time and isolated in a storage tank or vessel, using a combination of on-line or at-line measurements taken at regular intervals of the property and flow rates.

1.2 The FPAPV methodology uses regularly collected on- line or at-line process analyzer measurements, flow, and assessment of other appropriate process measurements or values, to calculate a flow-proportioned average property value in accordance with flow quantity units of material produced.

1.3 When the collecting vessel contains a heel (retained material prior to receipt of the production batch), both the property value and quantity of the heel material can be predetermined and factored into the calculation of the FPAPV for the new batch.

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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.5 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D3764 Practice for Validation of the Performance of Process Stream Analyzer Systems

D4057 Practice for Manual Sampling of Petroleum and Petroleum Products

D4177 Practice for Automatic Sampling of Petroleum and Petroleum Products

D5842 Practice for Sampling and Handling of Fuels for Volatility Measurement

D6122 Practice for Validation of the Performance of Multivariate Online, At-Line, and Laboratory Infrared Spectrophotometer Based Analyzer Systems

D6299 Practice for Applying Statistical Quality Assurance and Control Charting Techniques to Evaluate Analytical Measurement System Performance

D7453 Practice for Sampling of Petroleum Products for Analysis by Process Stream Analyzers and for Process Stream Analyzer System Validation

3. Terminology

3.1 *Definitions:*

3.1.1 *analysis cycle time, n*—period of time required to properly obtain and analyze a representative sample of the process stream material.

3.1.2 *fit-for-use, n*—product, system, or service that is suitable for its intended use.

3.1.3 *flow-proportioned average property value (FPAPV), n*—average property value of the collected material in the tank or vessel, calculated by using the flow-proportioned average technique described in the practice of all measurements performed on aliquots of the material while it is flowing into the tank or vessel.

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

3.1.3.1 *Discussion—*

The term *property* as used in this practice can be the physical, chemical, or performance property measurements as provided by on-line or at-line analyzer systems.

3.1.3.2 *Discussion—*

The FPAPV can include a property value contributed by material (commonly referred to as a tank heel) present in the collection tank or vessel before the start of delivery of the current process stream material. This property value can be determined using the on or at-line measurement system, or a different measurement system that is suitably bias-corrected to provide statistically indistinguishable results from the on or at-line measurement system.

~~3.1.3 *fit-for-use, n*—product, system, or service that is suitable for its intended use.~~

3.1.4 *linearly mixable, adj*—property is deemed to be linearly mixable in a mass or volume measurement unit if the property of the mixed material can be calculated from the quantities and properties of the materials used to produce the mixture.

3.1.4.1 *Discussion—*

The general equations describing this linearly mixable attribute are as follows:

$$P_{MIXED} = \frac{A_1 \cdot P_1 + A_2 \cdot P_2 + A_3 \cdot P_3 + A_4 \cdot P_4 + \ldots + A_N \cdot P_N}{A_1 + A_2 + A_3 + A_4 + \ldots + A_N} \quad (1)$$

$$A_{MIXED} = A_1 + A_2 + A_3 + A_4 + \ldots + A_N \quad (2)$$

where:

A_N = quantity of material N,
P_N = property of material N,
P_{MIXED} = property of mixed material, and
A_{MIXED} = quantity of mixed material.

3.1.4.2 *Discussion—*

The material being mixed can be from the same process stream over time.

3.1.5 *total analyzer system response time, n*—time interval between when a step change in property characteristic at the sample loop inlet and when the analyzer 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. **D3764**

4. Significance and Use

4.1 Contractual or local regulation, or both, permitting, the FPAPV calculated according to this practice can be used to represent the average property of the quantity of material collected.

4.2 Due to the averaging and appropriate weighting of analysis results, the FPAPV estimate of the property for the collected material is expected to be more representative and more precise than an estimate based on a small number of analyses on a few samples.

NOTE 1—For applications where the on-line analyzer system result is being used in direct feedback control in a contiguous manner, the true property distribution for a large population of batches with essentially identical FPAPV's is expected to be Gaussian, centered at the FPAPV value, with a standard deviation that is no less than the long term site precision standard deviation of the analyzer system.

4.3 If the measured property value is used to predict another property value through the use of an appropriate correlation equation, the FPAPV can also be used as a suitable prediction of that property.

4.4 The most recently updated FPAPV can be used to represent the property of the material currently accumulated in the tank or vessel for process control or material disposition decisions, or both.

5. General Requirements

5.1 The analytical and flow measurement instrumentation systems ~~shall~~should be installed in compliance with the principles set forth in API ~~TP-550.~~RP-555.[3]

5.2 The property being measured shall be linearly mixable within the range of the property measurements used to calculate FPAPV, and with respect to the quantity units (volume or mass).

5.3 The integrity of the design, physical components and assemblies of both the analytical measurement system (inclusive of the sampling subsystem), and the instrumentation for flow quantity measurement shall be determined and documented at the time of commissioning and at regular intervals thereafter. Factors to be addressed shall include, but not be limited to, the following:

5.3.1 The sampling system design and operation shall ensure a sample representative of the process stream is delivered to the applicable process stream analyzer.

5.3.2 The process stream shall have dynamics such that there is no substantial change in the property over the time period required to produce the analytical measurement system result used for each FPAPV update calculation.

5.3.3 Analyzer functions shall be in proper condition to produce accurate property measurement results.

5.3.4 During the calculation of FPAPV, inferential or other validation strategies shall be in place to ensure the analytical measurement system results are representative of the material in the process stream. The effectiveness of these strategies shall be supported by data.

NOTE 2—Examples of these strategies can include, but are not limited to, the following: monitoring of appropriate system parameters to ensure each

[3] Part II Process Stream Analyzers, *Manual on Installation of Refinery Instruments and Control Systems*, available from American Petroleum Institute, 1220 L St. NW, Washington, DC 20005–8197.