



Designation: D7278 – 06

Standard Guide for Prediction of Analyzer Sample System Lag Times¹

This standard is issued under the fixed designation D7278; 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

Lag time, as used in this guide, is the time required to transport a representative sample from the process tap to the analyzer. Sample system designs have infinite configurations so this guide gives the user guidance, based on basic design considerations, when calculating the lag time of on-line sample delivery systems. Lag time of the analyzer sample system is a required system characteristic when performing system validation in Practice D3764 or D6122 and in general the proper operation of any on-line analytical system. The guide lists the components of the system that need to be considered when determining lag time plus a means to judge the type of flow and need for multiple flushes before analysis on any sample.

1. Scope

1.1 This guide covers the application of routine calculations to estimate sample system lag time, in seconds, for gas, liquid, and mixed phase systems.

1.2 This guide considers the sources of lag time from the process sample tap, tap conditioning, sample transport, pre-analysis conditioning and analysis.

1.3 Lag times are estimated based on a prediction of flow characteristics, turbulent, nonturbulent, or laminar, and the corresponding purge requirements.

1.4 Mixed phase systems prevent reliable representative sampling so system lag times should not be used to predict sample representation of the stream.

1.5 *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

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

D6122 Practice for Validation of the Performance of Multivariate Process Infrared Spectrophotometer Based Analyzer Systems

3. Terminology

3.1 Definitions:

3.1.1 *continuous analyzer unit cycle time*—the time interval required to replace the volume of the analyzer measurement cell.

3.1.2 *intermittent analyzer unit cycle time*—the time interval between successive updates of the analyzer output.

3.1.3 *purge volume*—the combined volume of the full analyzer sampling and conditioning systems.

3.1.4 *sample system lag time*—the time required to transport a representative sample from the process tap to the analyzer.

3.1.5 *system response time*—the sum of the analyzer unit response time and the analyzer sample system lag time.

3.2 Abbreviations:

3.2.1 *I.D.*—Internal Diameter

3.2.2 *Re*—Reynolds Number

4. Summary

4.1 The lag time of an analyzer sample system is estimated by first determining the flow characteristics. The flow is assigned as turbulent or non-turbulent to assign the number of purges required to change out the sample. Based on the hardware employed in the sample system an estimation of the lag time can be calculated.

5. Significance and Use

5.1 The analyzer sample system lag time estimated by this guide can be used in conjunction with the analyzer output to aid in optimizing control of blender facilities or process units.

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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.

5.2 The lag time can be used in the tuning of control programs to set the proper optimization frequency.

5.3 The application of this guide is not for the design of a sample system but to estimate the performance of existing sample systems. The principles listed in this guide are there to help understand design concepts and allow the application of this guide for its intended scope. Additional detailed information can be found in the references provided in the section entitled Additional Reading Material.

6. Basic Design Considerations

6.1 *Acceptable Lag Time*—As a general rule, a one to two minute sample system lag time should be maintained where possible to give acceptable performance. Flow is a key component in the determination of sample system lag time. In most systems the desired system lag time is impossible to achieve with maximum allowable sample flow rate to the analyzer. To improve lag time a fast loop or bypass can be used to increase sample velocities through the system to a point just upstream of the analyzer. A slipstream is taken from the bypass to feed the analyzer at its optimum flowrate. Excess sample in the slipstream is vented to atmosphere, to flare or to the process stream dependant upon application and regulatory requirements.

6.2 *Physical State of Sample:*

6.2.1 *Liquid Samples*—Pressure drop properties often govern the design of a liquid system. This is due for the most part on the close relationship between pressure drop and system flowrate and the fixed pressure differential available from the process for sample transport. The sizing of the sample components is a tradeoff between pressure drop and sample flowrate. High sample flowrates in small sized component systems cause high-pressure drops and low sample transport times. The same flowrate in a larger tubing system will yield significant improvements in pressure drop through the system, but will also increase the time for sample transport significantly.

6.2.2 *Vapor Samples*—Vapor phase sampling is governed less by pressure drop and more by pressure compression properties of gases when compared to liquids. In compressible gases the higher the pressure in a given volume, the more sample present in that volume. For this reason, and different from liquids, the selection and location of pressure regulating devices in the vapor sample system has a great impact on the overall system design. The optimal location for a high-pressure regulator in a vapor sample is immediately downstream of the sample tap or high-pressure location thereby limiting the volume of the system under high pressure. Since the density of a compressible fluid is a function of the pressure, compressible fluid flow rate calculations are sometimes done over segmental lengths where average properties adequately represent the fluid conditions of the line segment.

6.2.3 *Liquid to Vapor Samples*—A change of phase due to sample vaporization can impact the sample lag time. The volume change from the liquid phase to the vapor phase is substantial. Typical flow rates in gaseous sample lines downstream of the vaporizer can represent very small liquid feed rates to the vaporizer. Deadheaded sample line lengths upstream of the vaporizer can, in turn, represent appreciable lag times.

6.2.4 *Phase Separation*—This guide is not intended to deal with dual phase samples as the volume and flow characteristics are outside the scope.

6.3 *Sample Temperature*—Temperature also impacts sample system lag time but to a lesser degree than pressure. Increased temperature of a sample lowers the sample density thus lowering the amount of sample flow needed to purge a given volume. Temperature impact is generally so minute that it is ignored in rough estimations of sample system lag time.

6.4 *Typical Sources of Lag Time to Consider:*

6.4.1 *Process Sample Tap:*

6.4.1.1 Sample taps can be a significant source of lag time if a sampling probe is not used, need to know the design inside the sample stream. See Fig. X1.1.

6.4.1.2 Sample taps can present a problem for liquid vaporizing systems with high volume and low flow on the liquid side. See Fig. X1.2.

NOTE 1—This refers to the case where the vaporizing regulator is located at the sample tap and one then has a length of liquid filled line from the probe/process interface to the inlet of the vaporizing regulator. This situation can be mitigated by using a sample probe that takes the pressure drop, and subsequent vaporization, at the probe/process interface so that one extracts a gaseous sample only. The sensible heat of the bulk process stream flowing past the tip of the sample probe provides the energy necessary to vaporize the sample that is extracted.

6.4.2 *At-Tap Conditioning:*

6.4.2.1 *Filters and Strainers at Sample Stream*—Depending on design and size these can add large volumes to the sample system that may not be turbulent flow.

NOTE 2—For filters with diameters greater than the sample tubing diameter calculate the internal volume and use the 3 times the volume rule to account for the delay attributable to the filter.

6.4.2.2 *Flow or Pressure Regulators*—Internal volume of the regulator(s) needs to part of the system calculation.

6.4.3 *Vaporizing Regulators*—Internal volume of the regulator needs to part of the system calculation.

6.4.3.1 The volume change from a liquid to a gas is on the order of 300 to 600 volumes of gas per volume of liquid so the lag time of the liquid filled slipstream tubing length from a fast loop to a vaporizing regulator can represent very large lag times. See Fig. X1.3.

6.4.3.2 A system designed on the basis of a good gas volumetric flow rate can represent a very small liquid flow rate.

6.5 Sample delivery tubing all needs to be taken into account and this can sometimes be a significant run length depending on the analyzer location to the process stream.

6.5.1 *Sample Conditioning at Analyzer:*

6.5.1.1 *Filtering*—Depending on design and size filters can add large volumes to the sample system that may not be turbulent flow. See Note 2.

7. Procedure

7.1 *Determination of Flow Characteristics:*

7.1.1 Calculate the Reynolds number, Re , of each section of the sample system using the tubing / pipe internal diameter (I.D.), the flow velocity, density of the sample stream, and viscosity of the sample stream.

$$Re = [(I.D.) \times (Velocity) \times (Density)] / \text{Viscosity} \quad (1)$$

NOTE 3—Various forms of this equation exist for different units.

7.1.2 Use Reynolds number, Re , to determine whether the sample flow is turbulent or non-turbulent in a particular section of the sample system.

7.1.2.1 Assume turbulent flow for sections with a $Re > 4000$.

7.1.2.2 Assume non-turbulent flow for sections with a $Re < 4000$.

Discussion—Traditionally, the break point Re from laminar flow has been 2100. The region of $Re > 2100$ to $Re < 4000$ is a transition region in that in some systems laminar flow could exist while in other systems, at the same Re , eddy formation and turbulent behavior could be observed.

7.1.3 Record the result, turbulent or non-turbulent, for each section of the sample system.

7.2 *Number of Purge Volumes Required:*

7.2.1 Assume a single purge volume is sufficient for system portions with turbulent flow, $Re > 4000$. See **Figs. X1.4 and X1.5**.

7.2.2 Assume three purge volumes are required for adequate sample exchange in systems with non-turbulent flow, $Re < 4000$ (laminar or transition). See **Fig. X1.6**.

NOTE 4—Three purge volumes are probably excessive for some system components but helps compensate for items that are difficult to purge.

7.2.3 Using the results from 7.1.3 record for each section the number of purge volumes required.

7.3 *Calculating Sample System Lag Time:*

7.3.1 Calculate the internal volume of each section of the sample system.

7.3.2 Calculate the lag time of each section with the volume, number of purge volumes and flow through the section.

$$\text{Sample system lag time} = \frac{\text{internal volume} \times \text{number of required purge volumes}}{\text{flow}} \quad (2)$$

7.3.3 Sum all the section lag times to determine the lag time for the full analyzer sample system.

NOTE 5—Lag time calculation is different for gases and liquids due to the compressive nature of gaseous samples. Basically the amount of gaseous sample present in a given volume equals the number of atmospheres of pressure applied to the system times the volume of the system (at a fixed temperature). A guide for this is to take the system volume and multiply it by the pressure in Bar to give the volume present in the system. This has to be factored into the calculation to determine the time and flow required to obtain one purge volume.

APPENDIX

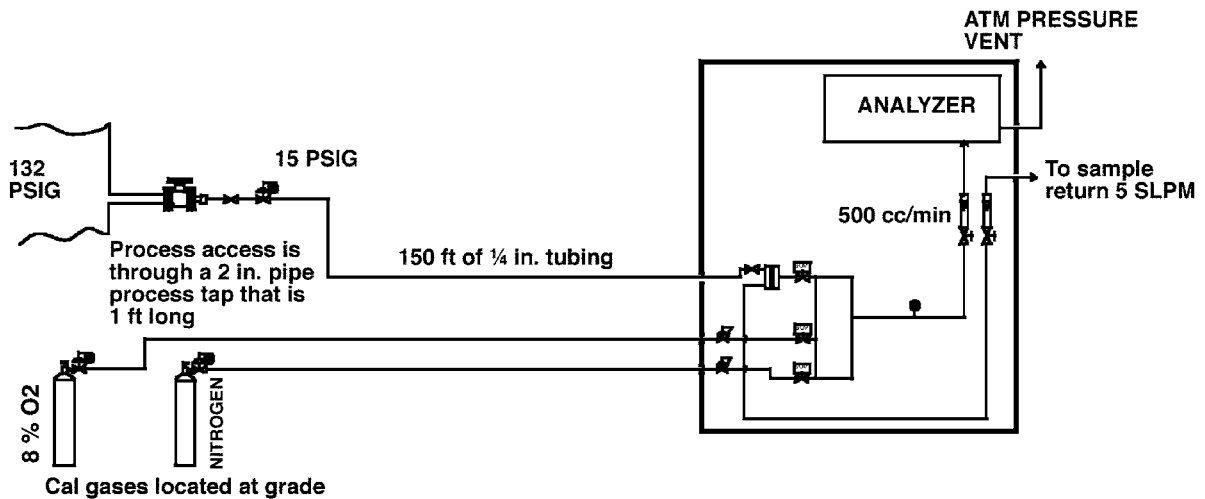
(Nonmandatory Information)

X1. EXAMPLE LAG TIME CALCULATIONS

iTeh Standards
(<https://standards.itih.ai>)
Document Preview

[ASTM D7278-06](#)

<https://standards.itih.ai/catalog/standards/sist/38af6d50-589b-4b57-acf8-a6d32b25314b/astm-d7278-06>



	Process Tap	Tap Sam Cond	Sample Transport	Analyzer Sam Sys	Lagtimes	
Molecular weight of sample gas	30	30	30	30	seconds	
Temperature of sample gas, °C	25	25	25	25		
Approximate gas density (lbs/cf)	0.7637	0.7637	0.1546	0.1546		
Viscosity of sample gas (cP)	0.0171	0.0171	0.0171	0.0171		
Reynolds Number	165	NA	1829	NA		
Pressure (PSIG)	132	132	15	15	89.71	1 Purge 75%R
L (feet)	1	NA	150	NA	179.42	2 Purge >93%R
ID (inches)	2.0000	NA	0.1800	NA	269.12	3 Purge >97%R
Flow (SLPM)	5.5000	5.5000	5.5000	0.5000	358.83	4 Purge >98%R
Volume (litres)	0.6175	0.0100	0.7502	0.0200		
Pressure corrected purge volume	6.1620	0.0998	1.5157	0.0404		
Single Purge Time (seconds)	67.2223	1.0887	16.5354	4.8490		
Average Velocity (FPS)	0.0149	NA	9.0714	NA		
Flow Type (w/o Transition)	Non Turbulent	Non Turbulent	Non Turbulent	Non Turbulent		
Non-Turb Components (Sec)	67.2223	1.1000	16.5354	4.8500	89.71	
Turbulent Components (Sec)	0.0000	0.0000	0.0000	0.0000	0.00	

FIG. X1.1 Gas Sample Without Tap Probe

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<https://standards.iteh.ai/catalog/standards/sist/38af6d50-589b-4b57-acf8-a6d32b25314b/astm-d7278-06>