Standard Practice for Pressure Decay Leak Test Method[1]

This standard is issued under the fixed designation E2930; 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.

1. Scope

1.1 This practice describes a method for determining the leakage rate of a vessel subject to a positive pressure difference. The technique is based upon evaluation of the change of mass within the test object based on a pressure decay measurement. The pressure decay measurement uses the ideal gas equation of state and the measured pressures, temperatures, and time to determine the mass loss from the vessel. This method does not apply to deformable vessels.

1.2 *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]

E479 Guide for Preparation of a Leak Testing Specification (Withdrawn 2014)[3]

E543 Specification for Agencies Performing Nondestructive Testing

E1316 Terminology for Nondestructive Examinations

2.2 *ANSI/ASNT Standards:*[4]

ANSI/ASNT-CP-189 Standard for Qualification and Certification of Nondestructive Testing Personnel

SNT-TC-1A Recommended Practice for Nondestructive Testing Personnel Qualification and Certification

2.3 *AIA Document:*[5]

NAS-410 Certification and Qualification of Nondestructive Testing Personnel

2.4 *ASME Standards:*[6]

ASME Boiler and Pressure Vessel Code Section V Article 10 (paragraph T-1044)

2.5 *ISO Standards:*[7]

ISO/IEC Guide 98–3 Uncertainty of Measurement — Part 3

3. Terminology

3.1 *Definitions:*

3.1.1 *pressure decay test resolution*—the resolution of the test that can be derived from the test equipment specifications and the volume of the test vessel. The test resolution is determined by evaluation of the individual resolutions of the pressure measurement, temperature measurement, and time measurement for a known vessel volume. The method for determining the test resolution is give in Annex A1.

3.1.2 *pressure decay test accuracy*—the test accuracy is the estimated accuracy of the test based on a combination of the measurement accuracies of contributing variables. The method for determining the test accuracy is given in Annex A2.

4. Summary of Test Method

4.1 This practice requires a known volume and the use of the pressure rate of decay technique for quantitative measurement of leakage rates. The practice is written to be usable over a wide range of pressures and system volumes. This method is only applicable to the test of non-deformable volumes or devices. Test devices which may have significant changes in volume due to pressurization should not be tested with this method. The method requires the measurement of the system pressure and temperature as a function of time and as such requires that these measurements be made with calibrated instrumentation. The range of the measurement technique can vary significantly but is generally applicable in the range greater than 1×10^{-8} mol/s (2.2×10^{-4} std cc/s)

5. Significance and Use

5.1 The equipment, test duration, and technique should be determined before commencement of the test based on the

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[1] This practice is under the jurisdiction of ASTM Committee E07 on Nondestructive Testing and is the direct responsibility of Subcommittee E07.08 on Leak Testing Method.

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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.

[3] The last approved version of this historical standard is referenced on www.astm.org.

[4] Available from American Society for Nondestructive Testing (ASNT), P.O. Box 28518, 1711 Arlingate Ln., Columbus, OH 43228-0518, http://www.asnt.org.

[5] Available from Aerospace Industries Association of America, Inc. (AIA), 1000 Wilson Blvd., Suite 1700, Arlington, VA 22209-3928, http://www.aia-aerospace.org.

[6] Available from American Society of Mechanical Engineers (ASME), ASME International Headquarters, Three Park Ave., New York, NY 10016-5990, http://www.asme.org.

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

required test sensitivity or accuracy (see Annex A1 and Annex A2). If the test is used to certify that the vessel has a minimum specified leakage rate, then the test equipment and test duration should be chosen to have a resolution ten times less than the specification and an accuracy which is four times less than the specification. The test should be designed so that the total pressure change is less than 10 % of the starting pressure. Leak test specifications should specify the vessel test pressure or differential pressure. If the test specification does not specify a test pressure, then a safe test pressure should be used that complies with the applicable safety standards[8].

6. Basis of Application

6.1 The following items are subject to contractual agreement between parties using or referencing this practice.

6.2 *Personnel Qualification:*

6.2.1 If specified in the contractual agreement, personnel performing examinations to this practice shall be qualified in accordance with a national or internationally recognized NDT personnel qualification practice or standard such as ANSI/ASNT-CP-189, SNT-TC-1A, NAS-410, or a similar document and certified by the employer or certifying agency, as applicable. The practice or standard used and its applicable revision shall be identified in the contractual agreement between the using parties.

6.3 *Qualification of Nondestructive Agencies*—If specified in the contractual agreement, NDT agencies shall be qualified and evaluated as described in Practice E543. The applicable revision of Practice E543 shall be in the contractual agreement.

7. Interferences

7.1 Interferences in the reported leak values could result from desorption of gases from the vessel or adsorption of gases into the vessel. In addition, the effect of permeation of gases out of the test vessel may be significant for very low leak rate measurements. Eq A2.3 of Annex A2 can be modified to incorporate these additional effects if appropriate. This test assumes a nominal isothermal testing environment.

8. Apparatus

8.1 The required test equipment includes a pressure gauge/transducer of the appropriate range, automated or manual timing system for data collection, and a temperature measurement device along with proper fixtures as shown in Fig. 1.

9. Reagents and Materials

9.1 A non-condensable, inert gas is required for pressurization of the test vessel. If air is used, the dew point temperature must be lower than the tested temperature range.

10. Hazards

10.1 In no instance should the test pressure exceed the maximum allowed vessel design limits.

[8] See ASME Boiler and Pressure Vessel Code Section V Article 10 (paragraph T-1044)

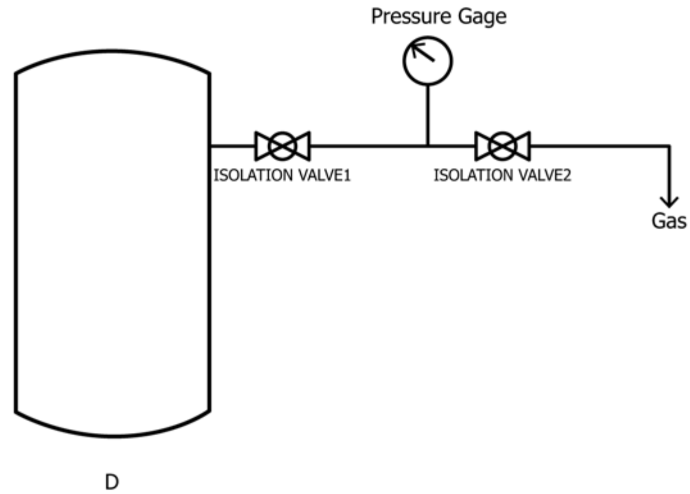

FIG. 1 Test Apparatus

11. Sampling, Test Specimens, and Test Units

11.1 The units for test should be in mol/s or pressure based units of Pa m^3/s or std cc/s with the units referenced to a standard temperature of 0°C or 273.15 K (unless otherwise specified in the test specification). The actual test temperatures can vary over the specified operable ranges of the instrumentation, as long as the temperature is stable enough to meet the test resolution requirements.

12. Preparation of Apparatus

12.1 *Vessel Preparation*—The test vessel should be clean and dry. Hydrostatic, bubble, and liquid penetrant testing should not be performed prior to a pressure decay test. All internal components subject to deformation or failure should be removed. Care should be taken where trapped or poorly accessible volumes may be encountered (double gasket seals) because they can increase the uncertainty of the test.

13. Calibration and Standardization

13.1 The test equipment (pressure measurement, temperature measurement, and time measurement) must be appropriately calibrated and traceable to national or international standards. The accuracy of the method depends on the determination of the test vessel volume as outlined in Annex A3.

13.2 Commercial pressure decay systems often use an internal leak standard to determine the volume of the test system. In this case the manufacturer should specify the accuracy of the determined volume as outlined in Annex A3.

14. Conditioning

14.1 The volume and test equipment should be allowed to thermally equilibrate before commencing the test. The test vessel should not be pressurized beyond the pressure specifications (or design limits).

15. Procedure

15.1 Assemble the test system and determine the system volume (see Annex A3). An isolation valve should be used between the test vessel and test system for isolation purposes.

15.2 Perform a leak test of the test system with the isolation valve closed and ensure that the leakage of the test system is less than 1 % of the target test value for the test vessel.

15.3 Determine the test parameters (initial pressure and test time) and calculate the test resolution and accuracies according to Annex A1 and Annex A2. Ensure that the calculated test resolution is at least ten times less than the target leakage rate. Ensure that the test accuracy is at least four times less than the target leakage rate.

15.4 Pressurize the vessel to the target pressure and close the isolation valve 2.

15.5 *Stabilization Time (Setting Time)*—After pressurization, the temperature and pressure should be monitored as a function of time over the test duration previously established in 5.1. The pressure should be recorded at a minimum of ten time intervals during the test sequence. The temperature should be recorded at the beginning and end of the test to ensure that the temperature is stable to within the previously assumed limits. Illustrative pressure decay leak test data is shown in Fig. 2. During the charge phase, gas is added to the test system. The pressure in the test system will naturally decay due to a number of factors (pressure equilibrating within the test system, gas temperature equilibrating, and so forth). The settling time will be dependent on the geometry of the test system, the test pressures, filling times, type of gas used, and other environmental factors.

The leak rate should be calculated from the individual measurements with the following equations:

$$N = (\Delta\ PV)/(RT\ (\Delta\ t)), \text{mol/s} \tag{1}$$

$$N = ((\Delta\ PV)/(\Delta\ t))(T_R\ /\ T), \text{Pa m}^3\text{/s, or Std cc/s} \tag{2}$$

where:

V = the vessel volume
R = the universal gas constant 8.3144 J/mol K (8.3144 Pa m^3/(mol K)
T = the vessel temperature, K
T_R = the reference temperature for the units (typically 273.15 K)
ΔP = the change in pressure between successive points
Δt = the change in time in seconds between successive points

Examples are provided in Eq 3 and 4

where:

ΔP = 10000 Pa (0.1 atm)
V = 0.0001 m^3
Δt = 100 sec.
T_R = 273.15
T = 298 K

$$N = \frac{(10000\ \text{Pa}) \cdot 0.0001\text{m}^3 \cdot 273.15\text{K}}{100\text{s} \cdot 293\text{K}} = 9.3 \times 10^{-3}\text{Pa m}^3\text{/s} \tag{3}$$

$$N = \frac{(0.1\ \ \text{atm}) \cdot 100\text{cm}^3 \cdot 273.15\text{K}}{100\text{s} \cdot 293\text{K}} = 9.3 \times 10^{-2}\text{Std cm}^3\text{/s} \tag{4}$$

15.6 Depending upon the test conditions, it may require seconds to hours for the indicated leak rate to stabilize. Stabilization criteria should be based on point to point variations in the measured leak rate with a target of less than three times the calculated test resolution. The test data used in the leak calculation in Section 16 will utilize data collected after stabilization.

15.7 The leak rate calculation can be calculated using one of two methods. Method A is preferred as it also allows for estimation of the precision of the test from the standard deviation of the measurements.

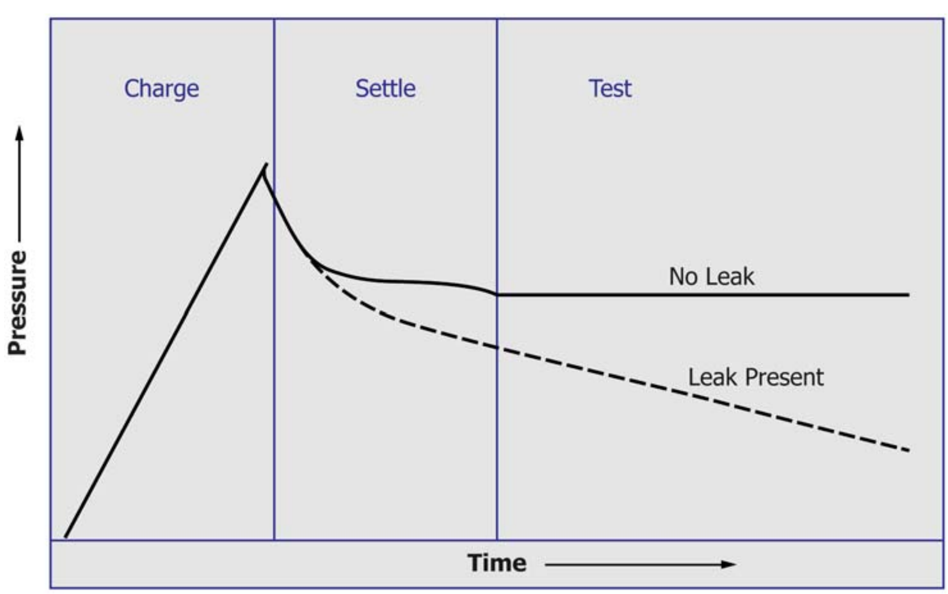

FIG. 2 Illustration of Pressure Decay Test Data

15.7.1 *Method A*—The average of the calculated leak rates determined from successive pressure measurements after stabilization.

15.7.2 *Method B*—The leak rate is calculated from a single pressure reading obtained after stabilization and the pressure at the end of the test.

15.8 Once the stabilization time has been determined for a particular test system, it is not required to perform multiple pressure measurements when utilizing Method A. The initial pressure after stabilization and the final pressure are sufficient.

16. Calculation or Interpretation of Results

16.1 The leak rates should be calculated with equation 4 in 15.5. The significance of the measured leak rates should be interpreted from the computed test resolution and test accuracy. Measured leak rates which are less than or equal to either the test accuracy or test resolution are not significant.

16.2 *Method A*—The leak rate should be calculated using Eq 1 and 2 in 15.5 with the pressure change, ΔP, calculated as the difference between the pressure after stabilization from the pressure at the end of the test. The change in time, Δt, is the difference in elapsed time between the pressure measurements. The temperature, T, should be the average of the beginning and ending temperature of the test system.

16.3 *Method B*—The leak rate should be calculated using Eq 1 and 2 in 15.5 with the pressure change, ΔP, calculated as the difference between the successive pressure readings after stabilization. The change in time, Δt, is the difference in elapsed time between successive pressure measurements. The temperature, T, should be the average of the beginning and ending temperature of the test system. If the temperature is recorded with each pressure measurement, the average temperature between successive pressure measurements may be used. The reported leak rate should be the average of the computed leak rates.

16.4 It is important to perform multiple tests if possible to understand the stability of the measurements. Leak rate measurements can be affected by environmental variables and these effects can be significant; particularly when testing large volumes (greater than 100 L).

17. Report

17.1 *Report of Test*—The report of the test should have the following information:

17.1.1 Test Date
17.1.2 Test Time
17.1.3 Test Technician
17.1.4 Test Accuracy
17.1.5 Beginning vessel test pressure
17.1.6 Ending vessel test pressure
17.1.7 Average reference test pressure (pressure outside of vessel)
17.1.8 Average test temperature
17.1.9 Duration of test
17.1.10 Test gas
17.1.11 Average test leak rate in standard units

18. Precision and Bias

18.1 *Precision and Bias*—The bias should be calculated using Eq A2.4 in Annex A2. The precision may be calculated with either of two methods.

18.1.1 *Single Test*—If only one test is performed, the standard deviation of the calculated flows should be used to estimate the test precision (assumes Method B is used).

18.1.2 *Multiple Tests*—If five or more tests are performed, the average and the standard deviation of the five tests should be computed. The standard deviation can be used to estimate the test precision.

19. Keywords

19.1 leak; leakage; mass flow; pressure; pressure change; pressure decay; rate of change; vessel

ANNEXES

(Mandatory Information)

A1. TEST RESOLUTION FOR THE PRESSURE DECAY METHOD

A1.1 The test resolution for the pressure decay method is given by Eq A1.1 in SI units or equations Eq A1.2-A1.4 in custmoarty units of measure.

A1.1.1 Minimum of

$$\left(\frac{V}{RT}\right)\frac{DP}{\Delta t},\left(\frac{PV}{RT^2}\right)\frac{DT}{\Delta t},\left(\frac{PV}{RT}\right)\frac{Dt}{\Delta t^2},\text{units(mol/s)} \quad (A1.1)$$

$$\left(\frac{V}{T}\right)\frac{DP}{\Delta t}\left(\frac{T_s}{1}\right),\text{units(Pa}\quad \text{m}^3/\text{s or Std cc/s)} \quad (A1.2)$$

$$\left(\frac{PV}{T^2}\right)\frac{DT}{\Delta t}\left(\frac{T_s}{1}\right),\text{units(Pa}\quad \text{m}^3/\text{s or Std cc/s)} \quad (A1.3)$$

$$\left(\frac{PV}{T}\right)\frac{Dt}{\Delta t^2}\left(\frac{T_s}{1}\right),\text{units(Pa}\quad \text{m}^3/\text{s or Std cc/s)} \quad (A1.4)$$

where:

P = the maximum pressure
T = the average temperature, K
T_s = the reference temperature for the leak rate units, typically 273.15 K
Δt = the leak rate calculation interval, s
R = the universal gas constant, J/(mol K)
Dt = the time resolution (time), s

DP = the pressure resolution
DT = the temperature measurement resolution, K

A1.1.2 For example, if a vessel of 1 m^3, P = 100 000 Pa, T = 273 K, Δt = 10 s, R = 8.3144 J/mole K, Dt = 0.1 s, DP = 100 Pa, DT = 0.1 C, the minimum would be:

From Eq A1.2

$$\left(\frac{1\,m^3}{(298\ K)}\right)\frac{100Pa}{10s}\left(\frac{(273.15\ K)}{1}\right) = 9.2Pa\ m^3/s \qquad (A1.5)$$

From Eq A1.3

$$\left(\frac{100000Pa\cdot 1\,m^3}{(298\ K)^2}\right)\frac{0.1K}{10s}\left(\frac{(273.15\ K)}{1}\right) = 3.1\ Pa\ \ m^3/s \quad (A1.6)$$

From Eq A1.4

$$\left(\frac{100000Pa\cdot 1\,m^3}{(298\ \ K)}\right)\frac{0.1s}{(10\ s)^2}\left(\frac{(273.15\ K)}{1}\right) = 92\ Pam^3/s \quad (A1.7)$$

A1.1.3 The above example illustrates the calculation of the resolution based on the test parameters. Eq A1.2-A1.4 also give insight in the most appropriate way to increase the test resolution. For the particular example, either increasing the test interval or increasing the time resolution will improve the test resolution.

A2. TEST ACCURACY (BIAS)

A2.1 The test accuracy can be derived by evaluation of the individual equipment specifications and test conditions.

A2.1.1

$$\delta n = (V/\,RT\,t)(\delta\ \Delta\ P) + (P/\,RT\,t)(\delta\ V) \qquad (A2.1)$$

$$-(\Delta\ PV/\ R\ T^2\ \Delta\ t)(\delta\ T) - (\Delta\ PV/\ RT\ \Delta\ t^2)(\delta\ \Delta\ t)$$

where:

$\delta\Delta P$ = the uncertainty in the differential pressure measurement
δV = the uncertainty in the volume
δT = the uncertainty in the measured temperature
$\delta\Delta t$ = the uncertainty in the measured time

which can be expressed in fractional form as:

$$\delta n/n = (\delta\ \Delta\ P\,/\,\Delta\ P) + (\delta\ V/\ V) - (\delta\ T/\ T) - (\delta\ \Delta\ t/\ \Delta\ t) \qquad (A2.2)$$

using the ISO recommended method[9] the uncertainties are combined in quadrature to give the total uncertainty in the measured leak rate.

[9] ISO/IEC Guide 98-3.

$$\delta n/n = ((\delta\ \Delta\ P\,/\,\Delta\ P)^2 + (\delta\ V/\ V)^2 + (\delta\ T/\ T)^2 + (\delta\ \Delta\ t/\ \Delta\ t)^2)^{\frac{1}{2}} \qquad (A2.3)$$

For example if the parameters in the below table are used for the test.

	Pressure change, Pa	Volume, m^3	Temperature, K	Time, s
Value	1000	1	298	60
Uncertainty	6	0.02	1	0.1

In conjunction with Eq A2.3 yields,

$$\left[\left(\frac{6}{1000}\right)^2 + \left(\frac{0.02}{1}\right)^2 + \left(\frac{1}{298}\right)^2 + \left(\frac{0.1}{60}\right)^2\right]^{\frac{1}{2}} = 2.1\% \qquad (A2.4)$$

A3. VOLUME DETERMINATION

A3.1 The volume of the test vessel can be determined in a number of ways. Two methods will be described in this practice.

A3.1.1 *Method A*—Volume determined using a flow standard

A3.1.1.1 The most straightforward method for volume determination is to connect a mass flow measurement device to the vessel, as depicted in Fig. A3.1, and measure the amount of gas input into the vessel while monitoring the vessel pressure and temperature. The volume can be calculated by Eq A2.4 and A3.2.

$$V = ((\text{total mass flow})R\ T)/\Delta P, \qquad mol/s \qquad (A3.1)$$

$$V = ((\text{total mass flow})R\ T)/(T_R\ \Delta\ P), Pa\ m^3/s \text{ or Std cc/s} \qquad (A3.2)$$

where:

R = the universal gas constant
T = the absolute temperature
T_R = the flow unit reference temperature (typically 273.15 K)
ΔP = the pressure change that occurred as a result of the gas introduction

To ensure that the volume determination is not significantly skewed by the vessel leakage, the amount of flow required to maintain a constant vessel pressure (at the maximum test pressure) should be less than 1 % of the test mass flow rate. The mass flow rate may be increased if this rule is violated.

A3.1.2 *Method B*—Volume determined using a gas expansion technique

A3.1.2.1 This method utilizes a standard volume, V_{S1}, and test apparatus as shown in Fig. A3.2. In this case, the gas (at the desired test pressure) is introduced into the volumes with valves V1 and V2 open. Valve V1 is then closed to isolate the test volume D. The pressure P_D is recorded. The pressure in S1, P_{S1}, is now set at base conditions and recorded (typically vented to atmosphere by opening V2). Valve V2 is closed and valve V1 is opened. The final system pressure, P_F , is recorded after stabilization. The sample volume, V_D, is then calculated as:

$$V_D = V_{S1}\left(\frac{P_{s1} - P_F}{P_F - P_D}\right) \quad (A3.3)$$

where:
V_D = the test volume

Often due to the nature of connecting a known volume to a test volume some test systems will have a connection volume that will be referred to as a "stray" volume. In this case, shown in Fig. A3.3, the determination of the volume is modified to account for the "stray" volume. The known volume should first be filled to a measured pressure, P_{S1}. The stray volume and the test volume should be adjusted to a pressure, P_D, lower than the standard volume by closing V2 and adjusting the pressure via the gas inlet (V1 and V3 open). The valve connecting the standard volume to the stray volume, V2, should be opened (V1 closed and V3 closed) and the system allowed to equilibrate after which the pressure, P_{SC1} should be recorded. The valve connecting the stray volume to the test volume, V1, should be opened and the system allowed to equilibrate (V3 closed, V2 open). The pressure P_F should be recorded.

$$V_D = \left(\frac{V_{S1}}{P_F - P_D}\right)\left((P_{S1} - P_F) + (P_D - P_F)\left(\frac{P_{S1} - P_{SC1}}{P_{SC1} - P_D}\right)\right) \quad (A3.4)$$

where:
V_D = the sample volume

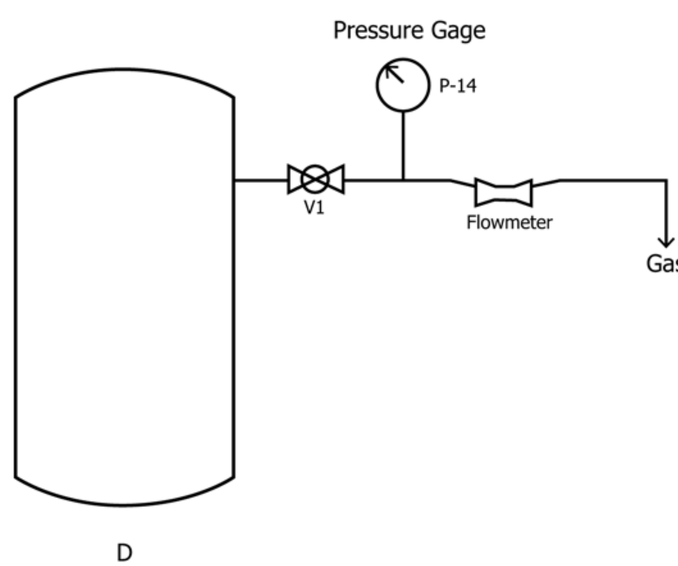

FIG. A3.1 Test Apparatus

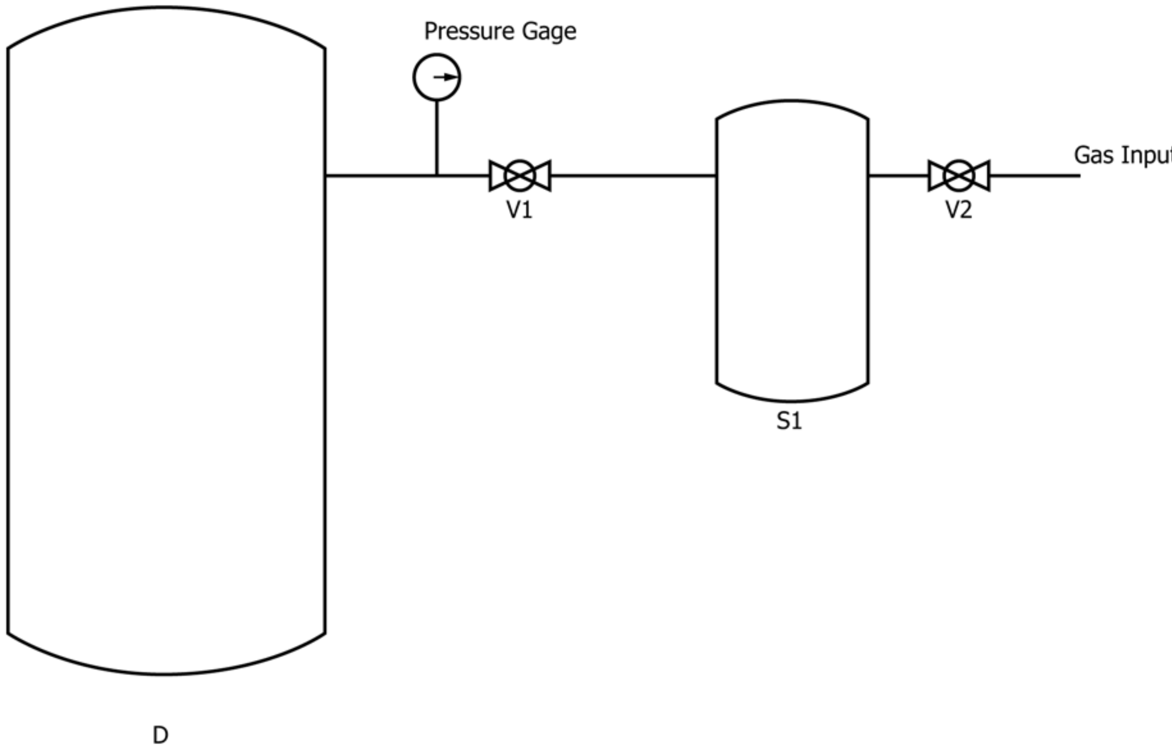

FIG. A3.2 Test System for Volume Determination

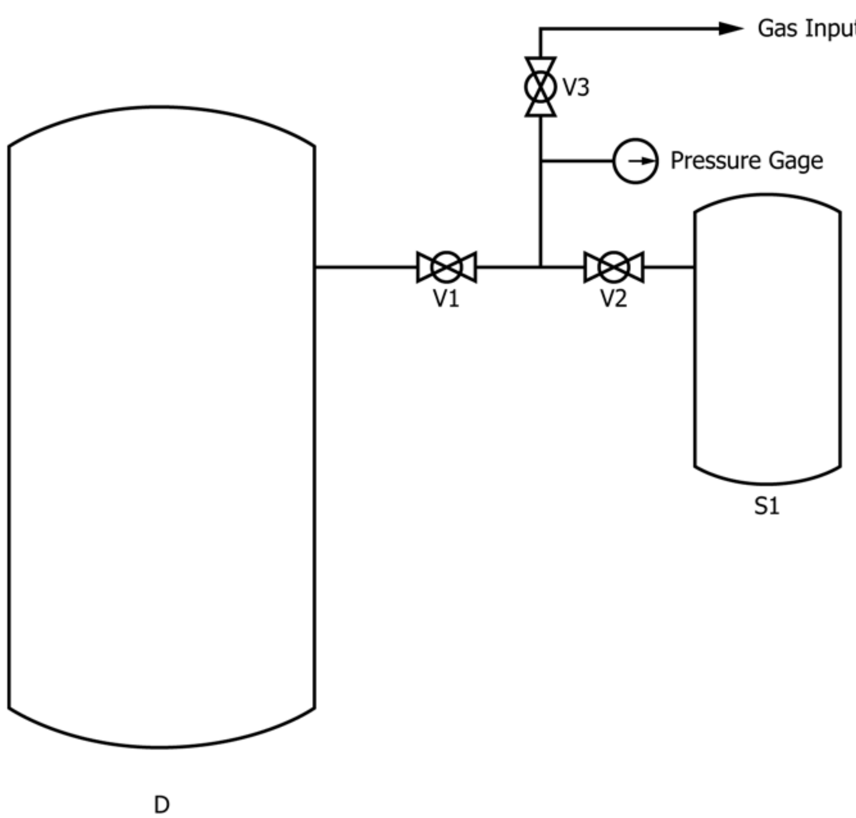

FIG. A3.3 Test System for Volume Determination with Stray Volume