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Standard Test Method for Pneumatic Leak Testing of Tubing[1]

This standard is issued under the fixed designation A1047/A1047M; 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 test method provides procedures for the leak testing of tubing using pneumatic pressure. This test method involves measuring the change in pressure inside the tubing over time. There are three procedures that may be used, all of which are intended to be equivalent. It is a qualitative not a quantitative test method. Any of the three procedures are intended to be capable of leak detection and, as such, are intended to be equivalent for that purpose.

1.2 The procedures will produce consistent results upon which acceptance standards can be based. This test may be performed in accordance with the Pressure Differential (Procedure A), the Pressure Decay (Procedure B), or the Vacuum Decay (Procedure C) method.

1.3 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.3.1 Within the text, the SI units are shown in brackets.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

A1016/A1016M Specification for General Requirements for Ferritic Alloy Steel, Austenitic Alloy Steel, and Stainless Steel Tubes

3. Terminology

3.1 *Definitions*—The definitions in Specification A1016/A1016M are applicable to this test method.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *actual starting pressure (P_0 actual)*—the actual starting pressure at time zero on each test cycle.

3.2.2 *calibration hole*—a device (such as a crimped capillary, or a tube containing a hole produced by laser drilling) certified to be of the specified diameter.

3.2.3 *control volume*—fixed volume that is pressurized to compare against an identical pressure contained in one tube under test.

3.2.4 *electronic control device (ECD)*—an electronic system to accumulate input from limit switches and transmitters providing corresponding outputs to solenoid valves, acoustic alarm devices, and visual displays

3.2.5 *pressure change (ΔP)*—the smallest pressure change in a tube, reliably detected by a pressure sensitive transmitter.

3.2.6 *pressure sensitive transmitters*—pressure measuring and signaling devices that detect extremely small changes in pressure, either between two tubes, a tube and a control volume, or a tube and the ambient atmosphere.

3.2.7 *reference standard*—a tube or container containing a calibration hole. The calibration hole may either be in a full length tube, or in a short device attached to the tube or container.

3.2.8 *starting pressure (P_0)*—the test starting pressure set in the test apparatus ECD.

3.2.9 *theoretical hole*—a hole that will pass air at a theoretical rate as defined by the equations given in Appendix X1.2.

3.2.10 *threshold pressure (P_T)*—test ending pressure limit after the allowed test time; the pressure value that must be

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[1] This test method is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel and Related Alloys and is the direct responsibility of Subcommittee A01.10 on Stainless and Alloy Steel Tubular Products.

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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.

crossed to determine reject status. $P_T = P_0$ *actual* – ΔP for pressure decay, and $P_T = P_0$ *actual* + ΔP for vacuum decay.

4. Summary of Test Method

4.1 *Procedure A, Pressure Differential,* measures the drop in pressure over time as a result of air escaping from inside one tube when compared to another tube at an identical pressure, or one tube against a control volume at identical pressure. (See Refs (**1**) and (**2**).)[3]

4.2 *Procedure B, Pressure Decay,* measures the drop in pressure over time as a result of air escaping from the tube.

4.3 *Procedure C, Vacuum Decay,* involves evacuating the tubing to suitably low pressure and measuring the increase in pressure caused by gas entering the tubing.

5. Significance and Use

5.1 When permitted by a specification or the order, this test method may be used for detecting leaks in tubing in lieu of the air underwater pressure test.

6. Apparatus

6.1 An electronic control device (ECD) controls all operations of the test method by accepting inputs from limit switches and transmitters, and by providing corresponding pass/fail outputs to solenoid valves, acoustic alarm devices, and visual displays. The pass/fail determination is achieved by a comparison of the data input from pressure transducers with a standard accept/reject criterion measured over the set test time.

6.2 The test apparatus may have the capability for single- or multi-tube testing. It shall be designed to detect a small predetermined pressure change during the testing cycle. It is intended that the apparatus be fully automated and equipped with suitable instrumentation for the purpose of the test. This instrumentation may include, but is not limited to the following:

6.2.1 Internal transducers for calibration tests,

6.2.2 Differential pressure and leak rate diagnosis,

6.2.3 Control panel display for reporting digital or analog outputs,

6.2.4 Absolute or differential pressure transducers, or both,

6.2.5 Internal timing device,

6.2.6 Failure lamps, and

6.2.7 Automatic shutdown capability.

7. Hazards

7.1 **Warning—**In addition to other precautions, high pressure air is employed during the testing process.

8. Calibration

8.1 Apparatus calibration shall be performed using a reference standard, with adjustments of Starting Pressure (P_0), Pressure Change (ΔP), and test time. Test time is dependent upon starting pressure, allowed pressure change, tube internal volume, hole diameter, and is calculated using the equation in Appendix X1. Actual test time may be longer than the calculated value and shall be adjusted as necessary for the apparatus to cross the threshold pressure and cause the system to automatically shut down.

8.2 Verify that all failure lights are illuminated during the calibration.

8.3 Unless otherwise specified, apparatus calibration shall be made at twelve month intervals maximum.

8.4 Recalibrate the test apparatus prior to use whenever any pressure sensing component is replaced or modified.

8.5 Calibrate the calibration hole at twelve month intervals maximum. It is recommended that the device containing the calibration hole be stored in an inert atmosphere and cleaned with high pressure nitrogen.

8.6 Calibrate all pressure gauges and pressure transducers at twelve month intervals maximum.

8.7 Unless otherwise agreed to by producer and purchaser, the minimum calibration hole size in the reference standard shall be 0.003-in. diameter. Calibration with smaller holes may not be repeatable due to fouling and plugging. (See Ref (**3**).)

9. Procedure

9.1 Perform pneumatic leak testing after all process operations, including cold work, heat treatment, and straightening.

9.2 Clean and dry the tubes before testing. Remove loose scale from the inside and outside surfaces of the tubes.

9.3 Actual test time is calculated in accordance with the parameters of the test using the appropriate equation in X1.2.

9.4 *Test Cycle for Procedure A, Pressure Differential:*

9.4.1 Pressurize the tubes in pairs, or a single tube and a known control volume, to a pressure greater than 33 psia with clean and dry compressed air.

9.4.2 Allow the system to stabilize and measure the actual Starting Pressure (P_0 *actual*). P_0 *actual* must be within 10 % of P_0 for a valid test.

9.4.3 The apparatus is to calculate and set the Threshold Pressure where $P_T = P_0$ *actual* – ΔP.

9.4.4 Isolate the tubes in pairs or a single tube and a known control volume.

9.4.5 Measure the pressure at the end of the test period. The tubes or tube have/has passed the test if the pressure has not crossed the threshold pressure P_T. If the threshold pressure has been crossed, then the tubes or tube have failed. When a failure occurs while testing tubes in pairs, the individual tubes may be tested with other tubes to determine which tube failed.

9.5 *Test Cycle for Procedure B, Pressure Decay:*

9.5.1 Pressurize the tube to a pressure greater than 33 psia with clean and dry compressed air.

9.5.2 Allow the system to stabilize and measure the actual Starting Pressure (P_0 *actual*). P_0 *actual* must be within 10 % of P_0 for a valid test.

9.5.3 The apparatus is to calculate and set the Threshold Pressure where $P_T = P_0$ *actual* – ΔP.

[3] The boldface numbers in parentheses refer to a list of references at the end of this standard.

9.5.4 Measure the pressure at the end of the test cycle. The tube has passed the test if the pressure has not crossed the threshold pressure P_T.

9.6 *Test Cycle for Procedure C, Vacuum Decay:* (See Refs (**4**) and (**5**).)

9.6.1 Draw a vacuum on the tube to a pressure below 6 psia.

9.6.2 Allow the system to stabilize and measure the actual Starting Pressure (P_0 *actual*). P_0 *actual* must be within 10 % of P_0 for a valid test.

9.6.3 The apparatus is to calculate and set the Threshold Pressure where $P_T = P_0$ *actual* $+ \Delta P$.

9.6.4 Measure the pressure at the end of the test cycle. The tube has passed the test if the pressure has not crossed the threshold pressure P_T.

10. Report

10.1 Report the following information:

10.1.1 Tubing identification, and

10.1.2 Procedure used for the satisfactory results of the test.

10.2 Maintain records of the test parameters and results.

11. Precision and Bias

11.1 No information is presented about either the precision or bias of this test method for measuring the leak capability since the test is non-quantative.

12. Keywords

12.1 leak testing; pneumatic testing

APPENDIX

(Nonmandatory Information)

X1. EXAMPLE CALCULATIONS AND APPLICATIONS

X1.1 Nomenclature

X1.1 P_a = absolute atmospheric pressure, in psia = 14.69 psia

P_0 = initial absolute pressure inside the tube, in psia

P_f = final absolute pressure inside the tube, in psia

ΔP = absolute pressure change inside the tube during the test period, in psia

V = tube internal volume, in ft^3 or in.^{3} as noted

A = through wall hole cross section area, in ft^2 or in.^{2} as noted

d = through wall hole diameter, in inches

t = test or decay time, in seconds

T = absolute air temperature inside the tube, in °R = °F + 460; T may be assumed to be 70 °F = 530 °R

M = mass of air contained in a tube, in lbm

ΔM = mass change inside the tube during the test period, in lbm

$\dot{m}$ = mass flow rate of air leaking through a hole, in lbm/sec

ρ_a = density of air at standard conditions = 0.0765 lbm/ft^3

R = gas constant for air = 53.3 ft·lbf/lbm·°R

X1.2 Theoretical Time Equations

X1.2.1 *Pressure Differential and Pressure Decay Time:*

$$t = 1.65 \times 10^{-4} \frac{V}{d^2} \left| \ln \frac{P_0 - \Delta P}{P_0} \right| \tag{X1.1}$$

with units $V = \text{in.}^3$, $d = \text{in.}$,

and assuming $T = 530\,°R$

X1.2.2 *Vacuum Decay Time:*

$$t = 1.65 \times 10^{-4} \frac{V}{d^2} \frac{\Delta P}{P_a} \tag{X1.2}$$

with units $V = \text{in.}^3$, $d = \text{in.}$,

and assuming $T = 530\,°R$

NOTE X1.1—The vacuum equations can be used for the pressure equations by substituting P_0 for P_a with the provision that ΔP is less than 1 psi.

X1.3 Derivation

X1.3.1 *From Fliegner's Formula* (see Ref (**6**), page 85):

$$\frac{\dot{m}\sqrt{T}}{AP} = 0.532 \text{ or } \dot{m} = \frac{0.532AP}{\sqrt{T}} \tag{X1.3}$$

with units $A = \text{ft}^2$, $P = \frac{\text{lbf}}{\text{ft}^2}$

X1.3.1.1 Boundary condition for choked flow (see Ref (**6**), page 84):

$$\frac{P_a}{P_f} < 0.528 \text{ for pressure decay, } \frac{P_f}{P_a} < 0.528 \text{ for vacuum decay} \tag{X1.4}$$

X1.3.2 *Ideal Gas Law:*

$$PV = MRT \text{ or } P = \frac{MRT}{V} \tag{X1.5}$$

X1.3.3 *Pressure Decaying from a Control Volume:*

$$\frac{dP}{dt} = \frac{RT}{V}\frac{dM}{dt} = \frac{RT}{V}\dot{m} \tag{X1.6}$$

X1.3.3.1 Substituting Fliegner's formula:

$$\frac{dP}{dt} = \frac{RT}{V}\frac{0.532AP}{\sqrt{T}} = \frac{28.36AP\sqrt{T}}{V} \tag{X1.7}$$

$$\frac{dP}{P} = \frac{28.36A\sqrt{T}}{V}dt = \tau \cdot dt$$

$$\int \frac{1}{P}dP = \int \tau \cdot dt$$

$$t = \frac{V}{28.36A\sqrt{T}}\left|\ln\frac{P_0 - \Delta P}{P_0}\right|$$

with V in ft^3, A in ft^2, P can be any unit

$$t = 1.65 \times 10^{-4}\frac{V}{d^2}\left|\ln\frac{P_0 - \Delta P}{P_0}\right|$$

with units $V = \text{in.}^3$, $d = \text{in.}$,

and assuming $T = 530\,°R$

X1.3.4 *Vacuum Decay into a Control Volume:*

X1.3.4.1 Because the high pressure source is the atmosphere and is of infinite quantity, pressure in a control volume increases at a linear rate.

$$t = \frac{\Delta M}{\dot{m}} \tag{X1.8}$$

$$\Delta M = V\Delta\rho$$

$$\rho_0 = \frac{P_0}{P_a}\rho_a,\ \rho_f = \frac{P_f}{P_a}\rho_a,\ \Delta\rho = \frac{\Delta P}{P_a}\rho_a = 0.0765\frac{\Delta P}{P_a}$$

X1.3.4.2 Again using Fliegner's formula:

$$\dot{m} = \frac{0.532AP_a}{\sqrt{T}} \tag{X1.9}$$

with units $A = \text{ft}^2$, $P_a = \frac{\text{lbf}}{\text{ft}^2}$

$$t = \frac{\Delta M}{\dot{m}} = \frac{0.0765V\frac{\Delta P}{P_a}}{\frac{0.532AP_a}{\sqrt{T}}} = 0.1438\frac{V\sqrt{T}}{AP_a}\frac{\Delta P}{P_a}$$

Using $P_a = 2115$ psfa (14.69 psia)

$$t = 6.8 \times 10^{-5}\frac{V\sqrt{T}}{A}\frac{\Delta P}{P_a}$$

with units $V = \text{ft}^3$, $A = \text{ft}^2$, $T = °R$,

and P can be any unit

$$t = 1.65 \times 10^{-4}\frac{V}{d^2}\frac{\Delta P}{P_a}$$

with units $V = \text{in.}^3$, $d = \text{in.}$,

and assuming $T = 530\,°R$

X1.4 Application Example

X1.4.1 For *Procedure A, Pressure Differential*, determine the pressure decay time of a 1 in. OD by 0.050 in. wall by 60 ft long tube with a 0.003 in. diameter hole; the test apparatus initial pressure is 110 psig with 0.031 psig allowed pressure drop.

X1.4.1.1 Using the equation given in X1.2.1:

$$t = 1.65 \times 10^{-4}\frac{V}{d^2}\left|\ln\frac{P_0 - \Delta P}{P_0}\right| \tag{X1.10}$$

$$V = 458\ \text{in.}^3$$

$$d = 0.003\ \text{in.}$$

$$P_0 = 110 + 14.69 = 124.69\ \text{psia}$$

$$\Delta P = 0.031\ \text{psia}$$

$$t = 1.65 \times 10^{-4}\frac{458}{0.003^2}\left|\ln\frac{124.69 - 0.031}{124.69}\right|$$

$$= \frac{1.65 \times 10^{-4} \times 458 \times 2 \times 10^{-4}}{9 \times 10^{-6}} = 1.7\text{sec}$$

X1.5 Graph

X1.5.1 The graph in Fig. X1.1 displays decay time as a function of tube internal volume assuming a 0.003 in. hole diameter, 110 psig initial pressure, and 0.031 psig allowed pressure drop.

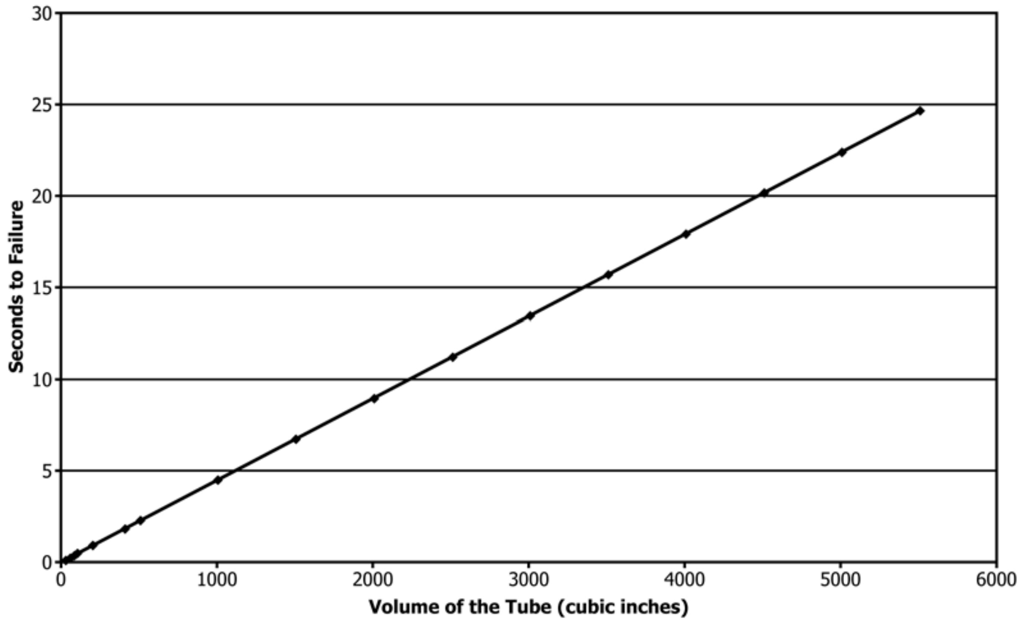

FIG. X1.1 Pressure Differential Standardization 110 psig @ 0.031 Threshold 0.003 in. Leak Diameter

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