Designation: E3278 – 21

Standard Test Method for Bubble Point Pressure of Woven Wire Filter Cloth[1]

This standard is issued under the fixed designation E3278; 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 is based on a capillary flow test that measures the pressure required to force an air bubble through a flat specimen of industrial woven wire filter cloth wetted under a test liquid of known surface tension. An established physical phenomenon, the pressure is inversely proportional to the pore size. This test method details the methodology to determine the bubble point pressure, and the applicable variables to calculate a standardized pressure. The test is recommended for filter cloth with a minimum test pressure of 1.0 inches of water.

1.2 A means for determining a pore size calculation factor (CF) is provided to allow the calculation of a pore size from the resultant pressure (see 15.2).

1.3 This test method uses mixed unit of measures. The values stated in inch-pound units shall be considered standard with regard to the bubble point pressure, test fixture, and procedures. The values stated in SI units shall be considered standard for the test fluid properties and pore size.

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]

E1638 Terminology Relating to Sieves, Sieving Methods, and Screening Media

E2814 Specification for Industrial Woven Wire Filter Cloth

2.2 *SAE Standards:*[3]

ARP901 Bubble-Point Test Method

3. Terminology

3.1 *Definitions:*

3.1.1 For definitions of related terms, refer to Terminology E1638.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *absolute filtration rating, n*—largest pore size found in the test specimen.

3.2.2 *hydraulic diameter, n*—the diameter equal to four times the pore throat area divided by the pore throat perimeter.

3.2.2.1 *Discussion*—This diameter can be generated using the PoroDict module in the software GeoDict[4,5] (see 4.2.2)..

3.2.3 *hydraulic diameter bubble point pressure, n*—a pressure calculated using the hydraulic diameter.

3.2.3.1 *Discussion*—This pressure can be generated using the PoroDict module in the software GeoDict (see 4.2.2), and is based on a statistically fitted bubble contact angle of 40 degrees and the hydraulic diameter.

3.2.4 *percolation path fitting particle diameter, n*—the maximum pore diameter based on the percolation path geometric pore size analysis.

3.2.4.1 *Discussion*—This diameter can be generated using the PoroDict module in the software GeoDict (see 4.2.2), and which results have been shown to correspond to the results of glass bead testing (see Specification E2814, Table 1).

3.2.5 *pore size, n*—the maximum equivalent spherical diameter of an opening in the filter cloth.

[1] This test method is under the jurisdiction of ASTM Committee E29 on Particle and Spray Characterization and is the direct responsibility of Subcommittee E29.01 on Sieves, Sieving Methods, and Screening Media.

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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] Available from SAE International (SAE), 400 Commonwealth Dr., Warrendale, PA 15096, http://www.sae.org.

[4] GeoDict is a trademark of Math2Market GmbH, Kaiserslautern, Germany.

[5] The sole source of supply of this simulation program known to the committee at this time is GeoDict by Math2Market GmbH, Kaiserslautern, Germany. If you are aware of alternative suppliers, please provide this information to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee,[1] which you may attend.

3.2.6 *pore size calculation factor (CF), n*— a factor calculated using the hydraulic diameter bubble point pressure and the percolation path fitting particle diameter.

FILTECH 2016[6]

3.2.6.1 *Discussion*—This factor can be generated using the PoroDict module in the software GeoDict (see 4.2.2), and is used to calculate the pore size from the bubble point pressure.

3.2.7 *tortuosity factor, n*—the ratio of the length of the path a particle must follow through the filter cloth to the actual filter cloth thickness.

3.2.7.1 *Discussion*—The fluid flow path through filter cloth is a distance somewhat longer than the mere thickness of the cloth due to its complex geometry; the tortuosity factor of the filter cloth specification is used to correct the pore size equation (see 4.2.1), and in general the greater the porosity of the filter cloth the lower the tortuosity factor.

4. Summary of Test Method

4.1 A bubble point test, a type of liquid-gas capillary flow porometry, is conducted by mounting the filter cloth specimen in a special test fixture, immersed in a test liquid, and gas pressure is slowly applied to the wetted specimen. A manometer is used to determine the pressure when the first gas bubble stream is observed on the surface of the specimen. This pressure indicates the absolute filtration rating of the specimen. The procedure to correct for specific test conditions is presented in order to standardize the test result pressure.

4.2 As background information,[7] the bubble point test characterization technique is based on displacing a wetting liquid from a pore by applying a gas pressure, with the physical phenomena that smaller pores are emptied at higher pressures. The pore diameter is calculated using the measured pressure based on the Young-Laplace equation for the equilibrium of the gas pressure and surface tension forces:

$$D = 4\gamma \cos\theta / p \quad (1)$$

where:

D = pore size diameter (µm),
p = measured pressure (kPa),
γ = surface tension of the wetting liquid (dynes/cm), and
θ = contact angle of the wetting liquid with the sample (degrees).

Then simplifying for the case of a straight, cylindrical pore through a thin film where the contact angle is 0, and for isopropanol wetting liquid (see 8.1) with a surface tension of 21.2 dynes/cm at 77°F (25°C), converting p in kPa to inches of water using 0.24909 yields:

$$D = 340/p \quad (2)$$

where:

D = pore size diameter (µm), and
p = measured pressure (inches of water).

This measured pressure will be corrected for other test conditions (that is, surface tension as a function of temperature) to a standardized pressure P as in accordance with 15.1:

$$D = 340/P \quad (3)$$

4.2.1 However, this equation is only for this perfect model, and must be corrected based on either the actual contact angle or a tortuosity factor for the filter cloth. For the case of a bubble passing through the irregular, obtuse triangular opening formed by the round wires of woven filter cloth, the bubble does not stay circular and the contact angle can only be hypothesized. Based on glass bead testing data (see Specification E2814, Table 1), reverse calculation indicates a contact angle of 40–50 degrees is most likely for woven wire filter cloth (see the Discussion for 3.2.3, *hydraulic diameter bubble point pressure*). Alternatively, a tortuosity factor (TF) may be applied to correct for the path of the bubble:

$$D = 340/(P \cdot TF) \quad (4)$$

The same empirical data indicates a tortuosity factor in the range of 1.3 – 1.5 is most appropriate, and while SAE ARP901 suggests a value of 1.65 be used, it recognizes that significant variation is actually likely (see Specification E2814, 6.3.1). So for example, if TF = 1.45 is applied, $D = 235 / P$.

4.2.2 A new type of software-based conversion factor, the pore size CF, is suggested by this test method. The PoroDict module of the commercially available software GeoDict calculates the CF based on the non-circular cross-section of the bottle neck of the through-path of the filter cloth. The CF is different than the geometric tortuosity factor. In addition to improved correlation, the ability to generate a specific factor for each different filter cloth specification is achieved (see Appendix X1).

5. Significance and Use

5.1 Users of industrial woven wire filter cloth as covered by Specification E2814 commonly desire to specify the largest pore size as determined by converting the pressure result of a bubble point test to an absolute filtration rating in micrometres (also known as microns). This test method requires a comprehensive bubble point test method as well as a valid tortuosity or conversion factor for the calculation. This pore size result may be used as a standard rating of a material specification, a performance evaluation or acceptance criteria for material supplied, or a 1st article inspection requirement during the weaving of the cloth. The test is conducted using sample material cut from a woven roll of cloth, and hence should be indicative of the manufactured lot, given the application of appropriate tolerances.

5.2 While some users may desire a bubble point test conducted on some finished, fabricated filter unit, the test conditions for this type of test are outside the scope of this test method. The geometric test parameters for this type of specimen must be explicitly agreed to by the user and producer, and is to be considered a custom test method.

[6] FILTECH 2016 – L11 Filter Media – Pore Size Analysis, "The 'True' Pore Size of Textile Filter Media and its Relevance for the Filtration Process with Respect to the Interaction with Apparatus and Suspension," Harald Anlauf, Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany.

[7] Drioli, E., and Giorno, L., *Comprehensive Membrane Science and Engineering*, Elsevier, UK, 2010, p. 318.

6. Interferences

6.1 *Cleanliness of Test Specimen*—The specimen should be cleaned to be free of foreign contamination.

6.2 *Temperature of the Test Liquid*—The surface tension and density of the test liquid is a function of temperature (see 12.1).

6.3 *Rate of Gas Pressure Increase*—The bubble point test result is a function of gas pressure ramp rate, and excessive ramp rate will cause false readings (see 14.6).

6.4 *Test Specimen Immersion Depth*—While bubble point theory is based on surface tension being the dominant force, for larger pore size specifications where the test pressure is below ~2 in. of water, an excessive immersion depth may result in the fluid column head pressure force becoming significant, which will cause erroneous results (see 12.2 and Appendix X2).

6.5 *Depth of Test Fixture Gas Outlet*—There is the potential for bubble turbulence due to the gas outlet too close to the bottom surface of the test specimen (see 7.2.3).

6.6 *Cleanliness of Gas*—The gas should be sufficiently clean and dry to prevent variability of results.

6.7 *Specific Gravity of the Test Liquid*—For isopropyl alcohol within the range of typical room temperature, the effect of temperature on specific gravity is negligible to the test result.

6.8 It should be noted that as isopropyl alcohol is hygroscopic, it should be reasonably protected from excessive moisture and humidity or the surface tension may be affected.

7. Apparatus

7.1 *Test Liquid*—the test liquid shall be reagent grade isopropyl alcohol (also know ask IPA, 2-propanol, isopropanol), clean, virgin, unfiltered, and 99.5 % minimum purity.

7.2 *Test Fixture*—suitable to accommodate up to a 20 in.^{2} test area, symmetrical (either square or round) (see Fig. 1).

7.2.1 *Reservoir depth* shall be 0.5 in. minimum/2.0 in. maximum.

7.2.2 *Gas inlet diameter* shall be 0.12 in. diameter minimum.

7.2.3 *Gas Inlet Depth*—the center of the inlet shall be no less than 3× the inlet diameter below the bottom of the test specimen (which results in 0.36 in. minimum depth for a minimum inlet diameter, and effectively limits the inlet diameter to ~0.57 in. maximum at a 2.0 in. reservoir depth).

7.3 *Manometer*—accuracy within ±0.1 % (full scale), readability 0.01 inches of water if ability to record maximum pressure (recommended), readability 0.1 inches of water if visual only.

7.4 *Compressed air (or nitrogen)* with dual pressure regulators

7.5 *Liquid temperature measurement,* accuracy ±0.5°F

7.6 *Scale*—to measure specimen immersion depth within 0.1 in. (use of gauge strip recommended).

8. Reagents and Materials

8.1 The standard test liquid shall be reagent grade isopropanol (isopropyl alcohol), 99.5 % minimum purity, standard density of 0.782 g per cm^3, which should then have surface tension 21.2 dynes/cm ±0.1 dynes/cm at 25°C (77°F) and temperature coefficient –0.10 dynes/cm/°C (–0.0556/°F).[8] Actual surface tension as a function of temperature shall be calculated accordingly (see 12.1). Substitutions are only allowed for referee tests if agreed to and documented.

9. Hazards

9.1 Due to air pressure being applied to a confined fluid, appropriate safety procedures should be observed including the

[8] *ACS Journal of Chemical and Engineering Data*, 1995, Vol 40, p. 611.

FIG. 1 Test Fixture

use of safety glasses. Avoid open flames using IPA. See Safety Data Sheet for IPA for full precautions.

10. Sampling, Test Specimens, and Test Units

10.1 The test specimen may be either a size piece to yield a further fabricated filter unit, or piece indicative of the manufactured lot quality, but in any case must be cut to fit the test fixture (for example, 1 in. diameter, 3 in. × 3 in.). Typically it will be the interior area of the piece that is tested, as a mounting perimeter is required. (for example. a 3 in. × 3 in. test area using a 4 in. × 4 in. overall piece). The test specimen must be degreased to remove contaminants and foreign particles or debris; typically using cleaning grade IPA in a pan, or a vapor degreaser and ultrasonics (depending on the level of contamination) with a solvent such as N-propyl-bromide.

11. Preparation of Apparatus

11.1 The test fixture should be clean of any contamination and free of any residual liquids.

11.2 The test fluid should be allowed to stabilize to the temperature of the test fixture environment.

11.3 The supply of compressed gas should be introduced at a temperature that does not affect the test fluid temperature.

12. Calibration and Standardization

12.1 The actual test fluid surface tension will be determined in accordance with Table 1 based on the fluid temperature when the test is conducted, which for IPA is found as follows based on 8.1.

12.2 The test specimen immersion depth shall be 0.3 in. maximum.

13. Conditioning

13.1 The test shall be performed at typical room temperature, limited to the range 65°F–80°F as in accordance with the test fluid surface tension Table 1 in accordance with 12.1.

14. Procedure

14.1 *Manometer:*

TABLE 1 Test Fluid Surface Tension

Surface Tension dynes/cm	Temperature	
	°F	°C
21.87	65	18.3
21.81	66	18.9
21.76	67	19.4
21.70	68	20.0
21.64	69	20.6
21.59	70	21.1
21.53	71	21.7
21.48	72	22..2
21.42	73	22.8
21.37	74	23.3
21.31	75	23.9
21.26	76	24.4
21.20	77	25.0
21.14	78	25.6
21.09	79	26.1
21.03	80	26.7

14.1.1 Connect the manometer with fixture empty and air supply disconnected.

14.1.2 Zero the manometer.

14.2 *Test Fluid:*

14.2.1 Verify the fixture drain is closed.

14.2.2 Fill the reservoir with test fluid.

14.2.3 Adjust the fixture so the fluid surface is level to the fixture.

14.2.4 Record the fluid temperature after stabilization.

14.3 *Air Regulator:*

14.3.1 Close the air regulators.

14.3.2 Connect the air supply.

14.4 *Gasket and Clamping:*

14.4.1 Insert the bottom gasket in the fixture.

14.4.2 Insert the sample, assuring it is parallel to the fluid surface.

14.4.3 Insert the top gasket.

14.4.4 Insert the hold down frame and check for reasonable alignment to edges.

14.4.5 Secure the clamping mechanism.

14.5 *Pre-Test Preparation:*

14.5.1 Add additional test fluid to fully wet sample surface.

14.5.2 Measure the immersion depth to the sample surface, add/remove fluid to achieve depth of 0.10 in. ± 0.05 in.

14.5.3 Confirm the manometer is on and reset maximum reading.

14.6 *Introduce Air Pressure:*

14.6.1 Verify the air supply pressure at the 1st stage regulator is no more than 20 psi.

14.6.2 Open the 2nd stage air regulator and observe slow and steady pressure increase to approximately 80 % of the expected bubble point pressure.

14.6.3 As the pressure builds, check for leaks around interior gasket edges and adjust clamping mechanism to stop if necessary.

14.6.4 Slowly increase the pressure; 5 inches of water pressure per minute maximum.

NOTE 1—Increasing the pressure slowly near the expected bubble point pressure yields most accurate results.

14.7 *Test Result:*

14.7.1 Observe to locate the first bubble point stream location (vs. single random trapped bubble) on the specimen surface

14.7.2 At this location, record the pressure (pressure will build to bubble point, then fall slightly during bubble flow).

14.8 *Conclusion:*

14.8.1 Close the air regulators

14.8.2 Open the fixture drain valve to remove fluid from surface of sample, thus depressurizing (this procedure will prevent pressure from inadvertently forcing fluid into the manometer which may not be intended for wet duty).

14.8.3 Remove the hold down clamping mechanism and gasket.

14.8.4 Remove the sample.

14.8.5 Insert the next sample and repeat if desired (if test is to be re-run, pressure must be completely relieved to allow re-wetting, or erroneous low readings may result).

15. Calculation or Interpretation of Results

15.1 The test result pressure *p* shall then be standardized to pressure *P* (see Appendix X3) as follows,:

$$P = (21.2/S)(p - d \cdot h) \quad (5)$$

where:

S = actual liquid surface tension (dynes/cm) (see 12.1),
p = measured pressure (inches of water),
d = test fluid density (0.782 g/cm^3) (dimensionless as specific gravity), and
h = specimen immersion depth (in.).

15.2 To determine the pore size CF for the filter cloth specification of interest, the module PoroDict in the software program GeoDict may be used (see 4.2.2), which is alternative to the traditional tortuosity factor, TF (see 4.2.1). The pore size in micrometres is then calculated using the CF as follows:

$$D = 340/(P * CF) \quad (6)$$

16. Report

16.1 The test fundamentally determines a standardized pressure, commonly expressed in inches of water (see 15.1) which shall be reported.

16.2 However, it is commonly desirous to convert the resulting standardized pressure to a pore size diameter, commonly expressed in micrometres (see 15.2), which if reported shall include the conversion method.

17. Keywords

17.1 absolute filtration rating; bubble point pressure; bubble point test; capillary flow porometry; hydraulic diameter factor; micron rating; pore size; standardized pressure; tortuosity factor

APPENDIXES

(Nonmandatory Information)

X1. DEPICTIONS OF PORE SIZE CALCULATION FACTOR AND PORE THROAT PLOT

X1.1 Depictions in accordance with the PoroDict module of the software GeoDict 2021, by Math2Market GmbH.[9] See Table X1.1 and Fig. X1.1.

TABLE X1.1 Pore Size Calculation Factor

NOTE 1—Reproduced, by permission from Math2Market GmbH, Kaiserslautern, Germany, from GeoDict User Guide, PoroDict 2021, https://doi.org/10.30423/userguide.geodict2021-porodict.

ASTM Pore Size Calculation Factor (CF)
In accordance with Test Method E3278 with pore size CF. Using physical properties of isopropanol (standard test liquid) with standard density of 0.782 g per cm^3 and surface tension of 21.2 dynes/cm (= 0.02115 N/m). Fitting partial diameter = Geometric pore size is: *d* = 1.106e-04 m = 110.567 inches of water Hydraulic bubble point pressure is: *p* = 633.800 Pa = 2.547 inches of water Corresponding pore size CF is: $CF = 1.2073$ Corresponding equation is: $D = 340/(P * 1.2073)$ where: *D* = pore size diameter (μm), and *P* = measured pressure (inches of water).

[9] Reproduced, by permission from Math2Market GmbH, Kaiserslautern, Germany, from GeoDict User Guide, PoroDict 2021, https://doi.org/10.30423/userguide.geodict2021-porodict.