Designation: F 558 – 98

Standard Test Method for Measuring Air Performance Characteristics of Vacuum Cleaners[1]

This standard is issued under the fixed designation F 558; 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 covers procedures for determining air performance characteristics of commercial and household upright, canister, stick, hand-held, utility, and combination-type vacuum cleaners having provisions for attaching a hose and incorporating a series universal motor. This test method does not apply to the carpet cleaning mode of operation.

1.2 These tests and calculations include determination of suction, airflow, air power, maximum air power, and input power under standard operating conditions (see Note 1).

NOTE 1—For more information on air performance characteristics, see Refs **(1-6)**.[2]

1.3 The foot-pound-inch system of units is used in this standard. The values in parentheses are given for information only.

1.4 This standard may involve hazardous materials, operations, and equipment. *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.* A specific precautionary statement is given in Note 2.

2. Referenced Documents

2.1 *ASTM Standards:*

E 1 Specification for ASTM Thermometers[3]

F 395 Terminology Relating to Vacuum Cleaners[4]

F 431 Specification for Air Performance Measurement Plenum Chamber for Vacuum Cleaners[4]

2.2 *AMCA Standard:*

210-85 Laboratory Methods of Testing Fans for Rating[5]

3. Terminology

3.1 *Definitions:*

3.1.1 *air power, AP, W, n— in a vacuum cleaner*, the net time rate of work performed by an air stream while expending energy to produce an airflow by a vacuum cleaner under specified air resistance conditions.

3.1.2 *automatic bleed valve, n*—any device a part of a vacuum cleaner's design which automatically introduces an intentional leak within the vacuum cleaner's system when manufacturer specified conditions are met.

3.1.3 *corrected airflow, Q, cfm, n—in a vacuum cleaner*, the volume of air movement per unit of time under standard atmospheric conditions.

3.1.4 *input power, W, n*—the rate at which electrical energy is absorbed by a vacuum cleaner.

3.1.5 *model, n*—the designation of a group of vacuum cleaners having the same mechanical and electrical construction with only cosmetic or nonfunctional differences.

3.1.6 *population, n*—the total of all units of a particular model vacuum cleaner being tested.

3.1.7 *repeatability limit (r), n*—the value below which the absolute difference between two individual test results obtained under repeatability condition may be expected to occur with a probability of approximately 0.95 (95 %).

3.1.8 *repeatability standard deviation* (S_r), *n*—the standard deviation of test results obtained under repeatability conditions.

3.1.9 *reproducibility limit (R), n*—the value below which the absolute difference between two test results obtained under reproducibility conditions may be expected to occur with a probability of approximately 0.95 (95 %).

3.1.10 *reproducibility standard deviation* (S_R), *n*—the standard deviation of test results obtained under reproducibility conditions.

3.1.11 *sample, n*—a group of vacuum cleaners taken from a large collection of vacuum cleaners of one particular model which serves to provide information that may be used as a basis for making a decision concerning the larger collection.

3.1.12 *standard air density*, ρ_{std}, lb/ft^3, *n*—atmospheric air density of 0.075 lb/ft^3 (1.2014 Kg/m^3).

3.1.12.1 *Discussion*—This value of air density corresponds to atmospheric air at a temperature of 68°F (20°C), 14.696 psi

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[1] This test method is under the jurisdiction of ASTM Committee F-11 on Vacuum Cleaners and is the direct responsibility of Subcommittee F11.22 on Air Performance.

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[2] The boldface numbers in parentheses refer to the list of references appended to this test method.

[3] *Annual Book of ASTM Standards*, Vol 14.03.

[4] *Annual Book of ASTM Standards*, Vol 15.07.

[5] Available from Air Movement and Control Association, 30 West University Dr., Arlington Heights, IL, 60004.

(101.325 kPa), and approximately 30 % relative humidity.

3.1.13 *suction, inch of water, n— in a vacuum cleaner*, the absolute difference between ambient and subatmospheric pressure.

3.1.14 *test run, n*—the definitive procedure that produces the singular result of calculated maximum air power.

3.1.15 *test station pressure, B_t, inch of mercury, n— for a vacuum cleaner*, the absolute barometric pressure at the test location (elevation) and test time.

3.1.15.1 *Discussion*—It is not the equivalent mean sea level value of barometric pressure typically reported by the airport and weather bureaus. It is sometimes referred to as the uncorrected barometric pressure (that is, not corrected to the mean sea level equivalent value). Refer to 5.5 for additional information.

3.1.16 *unit, n*—a single vacuum cleaner of the model being tested.

4. Significance and Use

4.1 The test results allow the comparison of the maximum air power available for cleaning tasks other than carpet cleaning when tested under the conditions of this test method.

5. Apparatus

5.1 *Plenum Chamber*— See Specification F 431.

5.2 *Water Manometers*, or equivalent instruments. One to measure from 0 to 6 in. (152.4 mm) in increments of 0.01 in. (0.254 mm), and one with increments of 0.1 in. (2.54 mm) for use in making measurements above 6 in. (152.4 mm).

5.3 *Wattmeter*, to provide measurements accurate to within ±1 %.

5.4 *Voltmeter*, to provide measurements accurate to within ±1 %.

5.5 *Barometer*, with an accuracy of ±0.05 in. of mercury (1.27 mm of mercury), capable of measuring and displaying absolute barometric pressure, scale divisions 0.02 in. (0.51 mm) or finer.[6]

5.5.1 Mercury barometers, in general, measure and display the absolute barometric pressure. Some corrections may be needed for temperature and gravity. Consult the owner's manual.

5.5.2 When purchasing an aneroid or electronic barometer, be sure to purchase one which displays the absolute barometric pressure, not the mean sea level equivalent barometric pressure value. These types of barometers generally have temperature compensation built into them and do not need to be corrected for gravity.

5.6 *Sharp-Edge Orifice Plates*—See specifications in Specification F 431.

5.7 *Thermometer*— Solid-stem, ambient thermometer having a range from 18 to 89 °F (or –8 to +32° C) with graduations in 0.2 °F (0.1 °C), conforming to the requirements for thermometer 63 °F (63 °C) as prescribed in Specification E 1.[7]

5.8 *Psychrometer*— Thermometers graduated in 0.2 °F (0.1 °C).[8]

5.9 *Voltage-Regulator System*, to control the input voltage to the vacuum cleaner. The regulator system shall be capable of maintaining the vacuum cleaner's rated voltage ±1 % and rated frequency having a wave form that is essentially sinusoidal with 3 % maximum harmonic distortion for the duration of the test.

6. Sampling

6.1 A minimum of three units of the same model vacuum cleaner, selected at random in accordance with good statistical practice, shall constitute the population sample.

6.1.1 To determine the best estimate of maximum air power for the population of the vacuum cleaner model being tested, the arithmetic mean of the maximum air power of the sample from the population shall be established by testing it to a 90 % confidence level within ±5 %.

6.1.2 Annex A2 provides a procedural example for determining the 90 % confidence level and when the sample size shall be increased (see Note 2).

NOTE 2—See annex for method of determining 90 % confidence level.

7. Procedure

7.1 *Preparation for Test*:

7.1.1 Provide the vacuum with new filters.

7.1.2 Set the manometers to zero and check all instruments for proper operation.

7.1.3 Record the test station pressure and the dry-bulb and wet-bulb temperature readings within 6 ft of the test area. Read the barometric pressure to the nearest 0.02 in. of mercury (0.51 mm of mercury), and the dry-bulb and wet-bulb temperatures to the nearest 0.2 °F (or 0.1 °C)

7.1.3.1 The test area shall be free of major fluctuating temperature conditions due to air conditioners or air drafts that would be indicated by a thermometer at the immediate test area.

7.1.4 Connect a manometer or equivalent instrument to the plenum chamber.

7.1.5 Connect a wattmeter and a voltmeter in accordance with Fig. 1.

7.1.5.1 *Wattmeter Correction*—If needed, the indication may be corrected for voltmeter and wattmeter potential coil

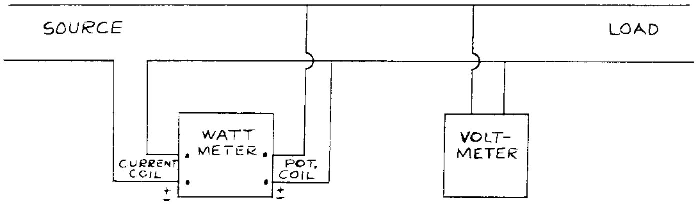

FIG. 1 Schematic Diagram of Meter Connections

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[6] Mercury Barometer #453 (National Weather Service Type) below 3000-ft (900-m) elevation (Model 453X to 12 000 ft (3700 m)), manufactured by Princo Instruments Inc., 1020 Industrial Way, Southampton, PA 18966, has been found satisfactory for this purpose.

[7] A thermometer and an armored shield, available from Thomas Scientific Co., Inc., 99 High Hill Rd., Swedsboro, NJ 08085, have been found satisfactory for this purpose.

[8] Aspirated psychrometer Model No. 27AM280, Kahl Scientific Instrument Corporation, P.O. Box 1166, El Cajon, CA, 92020, is regularly supplied under ASTM specifications. Specify Farenheit or Celsius thermometers when ordering.

loss by opening the load circuit on the load side of the wattmeter with the line voltage at the operating value. The wattmeter current connection may be at its most sensitive position. Subtract this loss value from the total load indication to obtain the true load. As an alternative method, use the following equation:

$$W_c = W_i - V^2/R_T \tag{1}$$

where:

W_c = corrected wattage,
W_i = indicated wattage,
V = voltmeter reading, and
R_T = $R_P \times R_V/(R_P + R_V)$,

where:

R_T = total resistance, Ω,
R_P = wattmeter potential coil resistance, Ω, and
R_V = voltmeter coil resistance, Ω.

7.2 *Test Procedure*:

7.2.1 Connect the hose assembly to the plenum chamber hose adapter and seal only this connection. See Fig. 2.

7.2.1.1 The end of the hose assembly should be inserted inside the hose connector adapter and be perpendicular to the plenum chamber.

7.2.1.2 The end of the hose assembly shall not project into the plenum chamber.

7.2.1.3 Any automatic bleed valve which affects the air performance of the vacuum cleaner shall not be defeated.

7.2.2 The hose should be supported and kept straight and horizontal. Maintain the vacuum cleaner in its normal operating orientation. If the hose is not intended to enter the vacuum cleaner horizontally, gradually bend the hose with a single bend from the intake port to the plenum chamber. Any restraining method should allow the hose coupling to seal at the cleaner. See Fig. 3.

7.2.3 Operate the vacuum cleaner with no orifice plate inserted in the plenum chamber inlet at nameplate rated voltage ±1 % and frequency ±1 Hz prior to the start of the test run to allow the unit to reach its normal operating temperature. For vacuum cleaners with dual nameplate voltage ratings, conduct testing at the highest voltage. Do this before each test run.

7.2.4 The vacuum cleaner is to be operated at its nameplate rated voltage ±1 % and frequency ±1 Hz throughout the test. For vacuum cleaners with dual nameplate voltage ratings, conduct the test at the highest voltage.

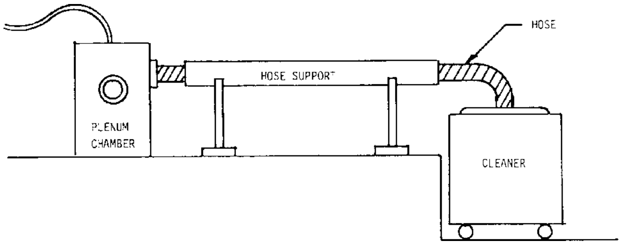

FIG. 3 Schematic for Air Performance Test

7.2.4.1 Allow the vacuum cleaner to operate at the open orifice for 1 to 2 min between test runs.

7.2.5 While operating the vacuum cleaner per 7.2.4, insert orifice plates sequentially into the orifice plate holder of the plenum chamber starting with the largest size orifice and following it with the next smaller orifice plate. Use the following orifice plates: 2.000, 1.500, 1.250, 1.000, 0.875, 0.750, 0.625, 0.500, 0.375, 0.250, and 0 in. (50.8, 38.1, 31.7, 25.4, 22.2, 19.0, 15.8, 12.7, 9.5, and 6.3 mm). The following optional orifice plates may also be used: 2.500, 2.250, 1.750, 1.375, and 1.125 in. (63.5, 57.2, 44.5, 34.9, and 28.6 mm).

7.2.6 For each orifice plate, record the suction, *h*, and input power, *P*, in that order. All readings should be taken within 10 s of the orifice insertion. Allow the vacuum cleaner to operate at the open orifice for 1 to 2 min before inserting the next orifice.

7.2.6.1 Read the suction to the nearest graduation of the instrument. Readings should be taken as soon as the manometer reaches a true peak. (When using a fluid type manometer, the liquid level may peak, drop, and peak again. The second peak is the true peak reading. A person conducting the test for the first time shall observe at least one run before recording data. See Specification F 431 for instructions on how to minimize the overshoot (first peak) of the liquid level).

8. Calculation

8.1 *Correction of Data to Standard Conditions*:

8.1.1 *Air Density Ratio*—The density ratio, D_r, is the ratio of the air density at the time of test ρ_{test}, to the standard air density, ρ_{std}= 0.075 lb/ft^3 (1.2014 kg/m ^{3}). It is used to correct the vacuum and wattage readings to standard conditions. Find ρ_{test} (lb/ft^3 or kg/m^3) from standard psychometric charts or ASHRAE tables and calculate D_r as follows:

$$D_r = \frac{\rho_{test}}{\rho_{std}} \tag{2}$$

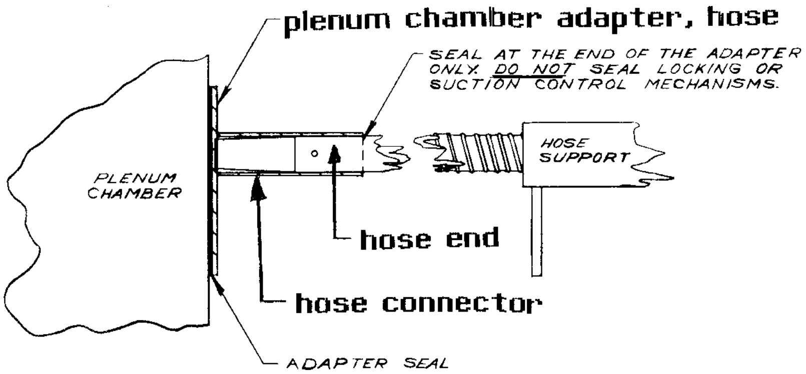

FIG. 2 Diagram of Hose and Adapter Connection

where:

ρ_{test} = the air density at the time of test, lb/ft^3, and
ρ_{std} = the standard air density, 0.075 lb/ft^3.

8.1.1.1 As an alternative, the following equation is intended to be used for correcting ambient conditions where the barometric pressure exceeds 27 in mercury and the dry-bulb and wet-bulb temperatures are less than 100°F (37.8°C); and may be used as an alternate method of calculating D_r (see Appendix X1 for derivation and accuracy analysis).

$$D_r = \frac{[17.68\ B_t - 0.001978\ T_w^2 + 0.1064\ T_w + 0.0024575\ B_t\ (T_d - T_w) - 2.741]}{T_d + 459.7}$$

where:

B_t = test station pressure at time of test, in. of mercury,
T_d = dry-bulb temperature at time of test, °F, and
T_w = wet-bulb temperature at time of test, °F.

8.1.2 *Corrected Suction*—Corrected suction, h_s, is the manometer reading, h, times the correction factor, C_s as follows:

$$h_s = C_s h \qquad (3)$$

8.1.2.1 For series universal motors (see Ref **(6)**) the correction factor, C_s, is calculated as follows:

$$C_s = 1 + 0.667\ (1 - D_r) \qquad (4)$$

8.1.2.2 This test method does not have any formulas available for correcting input power for any other type of motor (permanent magnet, induction, etc.)

8.1.3 *Corrected Input Power*—Corrected input power, P_s, expressed in watts, is the wattmeter reading, P, times the correction factor, C_p, as follows:

$$P_s = C_p P \qquad (5)$$

8.1.3.1 For series universal motors the correction factor, C_p, is calculated as follows:

$$C_p = 1 + 0.5(1 - D_r) \qquad (6)$$

8.1.3.2 This test method does not have any formulas available for correcting input power for any other types of motor (permanent magnet, induction, etc.)

8.2 *Corrected Airflow*—Calculate the corrected airflow, Q, expressed in cubic feet per minute (see Note 3 and Appendix X2) as follows:

$$Q = 21.844 D^2 K_1 \sqrt{h_s} \qquad (7)$$

where:

Q = corrected flow, cfm,
D = orifice diameter, in.,
K_1 = constant (dimensionless), orifice flow coefficients for orifices in the plenum chamber. See Table 1 for values for each orifice. See Ref **(1)** for the derivation of these flow coefficients.
h_s = corrected suction, in. of water.

NOTE 3—For the corrected airflow expressed in liters per second, use the following equation:

$$Q = 10.309\ D^2 K_1 \sqrt{h_s}$$

where:

Q = corrected flow, L/s,
D = orifice diameter, m,
K_1 = constant (dimensionless), and
h_s = corrected suction, Pa.

TABLE 1 Orifice Flow Coefficient Equations (K_1)

NOTE 1—K_1 was determined experimentally using an ASTM plenum chamber (see Specification F 431) and an ASME flowmeter (see Ref **(1)**).

NOTE 2—Equations for K_1 in terms of B_t and h are given in Appendix X6.

Orifice Diameter, in. (mm)	Orifice Flow Coefficient Equation[A]
0.250 (6.3)	$K_1 = \frac{0.5575r - 0.5955}{r - 1.0468}$
0.375 (9.5)	$K_1 = \frac{0.5553r - 0.5754}{r - 1.0263}$
0.500 (12.7)	$K_1 = \frac{0.5694r - 0.5786}{r - 1.0138}$
0.625 (15.8)	$K_1 = \frac{0.5692r - 0.5767}{r - 1.0104}$
0.750 (19.0)	$K_1 = \frac{0.5715r - 0.5807}{r - 1.0138}$
0.875 (22.2)	$K_1 = \frac{0.5740r - 0.5841}{r - 1.0158}$
1.000 (25.4)	$K_1 = \frac{0.5687r - 0.5785}{r - 1.0146}$
1.125 (28.6)	$K_1 = \frac{0.5675r - 0.5819}{r - 1.0225}$
1.250 (31.7)	$K_1 = \frac{0.5717r - 0.5814}{r - 1.0152}$
1.375 (34.9)	$K_1 = \frac{0.5680r - 0.5826}{r - 1.0235}$
1.500 (38.1)	$K_1 = \frac{0.5719r - 0.5820}{r - 1.0165}$
1.750 (44.5)	$K_1 = \frac{0.5695r - 0.5839}{r - 1.0235}$
2.000 (50.8)	$K_1 = \frac{0.5757r - 0.5853}{r - 1.0157}$
2.250 (57.2)	$K_1 = \frac{0.5709r - 0.5878}{r - 1.0279}$
2.500 (63.5)	$K_1 = \frac{0.5660r - 0.59024}{r - 1.0400}$

[A]
$$r = \frac{B_t\ (0.4912) - h(0.03607)}{B_t\ (0.4912)}$$

where:

B_t = test station pressure at time of test, in. of mercury, and
h = uncorrected suction (manometer reading), in. of water.

8.3 *Air Power*—Calculate the air power, AP, in watts, as follows:

$$AP = 0.117354\ (Q)(h_s) \qquad (8)$$

where:

AP = air power, W,
Q = corrected flow, cfm, and
h_s = corrected suction, inch of water.

NOTE 4—See Appendix X3 for derivation.

8.4 *Maximum Air Power*—Determine the maximum air power using the method in Annex A1.

9. Report

9.1 For each vacuum cleaner sample from the population being tested, report the following information:

9.1.1 Manufacturer's name and product model name or number, or both.

9.1.2 Type of cleaner; that is, upright, canister, etc.

9.1.3 The corrected input power, corrected vacuum, corrected airflow, and air power for each orifice used.

9.1.4 Calculated maximum air power.

10. Precision and Bias

10.1 *Precision*—These statements are based on an interlaboratory test involving eleven laboratories and six units. The range of maximum air power of the units was from 17 to 197 W.[9]

10.1.1 *Repeatability (Single-Operator-Laboratory, Multiday)*:

10.1.1.1 For maximum air power values in excess of 20 W, the standard deviation divided by the average (coefficient of variation) with the same analyst was found to be 4 % or less. Two values from a sample of three tests in excess of 20 W should be considered suspect (at the 95 % confidence level) if they differ by more than 6 % (see Note 5).

NOTE 5—The % difference = [larger – smaller)/larger] × 100.

10.1.1.2 For maximum air power values less than 20 W, the standard deviation within a laboratory divided by the average (coefficient of variation) was found to be 6 % or less. Two values from a sample of three less than 20 W in value should be considered suspect if they differ by more than 9 % (see Note 5).

10.1.2 *Reproducibility (Multilaboratory, Multiday)*:

10.1.2.1 For maximum air power values in excess of 20 W, the standard deviation divided by the average (coefficient of variation) with a single unit tested in different laboratories was found to be 4 % or less. Two values from a sample of three tests in excess of 20 W should be considered suspect (at the 95 % confidence level) if they differ by more than 13 % (see Note 5).

10.1.2.2 For maximum air power values less than 20 W, the standard deviation between laboratories divided by the average (coefficient of variation) was found to be 10 % or less. Two values from a sample of three less than 20 W in value should be considered suspect (at the 95 % confidence level) if they differ by more than 28 % (see Note 5).

10.2 *Bias*—No justifiable statement can be made on the accuracy of this test method for testing the properties listed. The true values of the properties cannot be established by acceptable referee methods.

11. Keywords

11.1 air performance; air power; vacuum cleaner

ANNEXES

(Mandatory Information)

A1. MATHEMATICAL METHOD FOR DETERMINING MAXIMUM AIR POWER POINT

A1.1 The following, second degree polynomial equation, is assumed to provide the best mathematical approximation of the air power versus airflow relationship.

NOTE A1.1—See Ref **(4)** for additional information.

$$Y = A_1 + A_2X + A_3X^2 \tag{A1.1}$$

where:

Y = air power (AP),
X = airflow (Q), and
A_1, A_2, and A_3, = arbitrary constants.

A1.1.1 Use X and Y values obtained from only five specific orifices selected as follows:

A1.1.1.1 Using the test data, determine the orifice size that produced the highest air power value.

A1.1.1.2 Use the air power and airflow values at this orifice, and the next two smaller and the next two larger orifices in the following computations:

A1.1.1.3 If the highest air power value calculated from the observed data is at the 2.0 in. (50.8 mm) orifice or larger, then use the air power and airflow values from the five largest orifices.

A1.2 To determine the values of A_1, A_2, and A_3, use the X and Y values obtained from the five specified orifices and solve the following set of normalized equations:

$$\Sigma Y_i = NA_1 + A_2 \Sigma X_i + A_3 \Sigma X_i^2 \tag{A1.2}$$

$$\Sigma X_iY_i = A_1 \Sigma X_i + A_2 \Sigma X_i^2 + A_3 \Sigma X_i^3 \tag{A1.3}$$

$$\Sigma X_i^2Y_i = A_1 \Sigma X_i^2 + A_2 \Sigma X_i^3 + A_3 \Sigma X_i^4 \tag{A1.4}$$

where:

N = 5 (number of orifices selected),
i = 1 to N, and
X_i and Y_i = the values obtained during testing (X_1Y_1, X_2Y_2, . . . X_NY_N) at the five orifices specified in A1.1.1.

A1.3 Setting the derivative of Eq A1.1 equal to zero and solving for X will determine the value of X_m where Y is at its maximum value (Y_{max}) as follows:

$$\frac{dy}{dx} = \frac{d}{dx}[A_1 + A_2X + A_3X^2] = 0 \tag{A1.5}$$

$$\frac{dy}{dx} = A_2 + 2A_3X = 0$$

Substitute X_m as the value of X at Y_{max} and solve for X_m:

$$X_m = -\frac{A_2}{2A_3} \tag{A1.6}$$

Substituting this value of X_m, and A_1, A_2, and A_3, into Eq 1

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[9] Complete data on the round-robin test is available from ASTM Headquarters. Request RR:F11-1000.

will determine the value of Y_{max} (AP_{max}) as follows:

$$Y_{max} = A_1 + A_2 X_m + A_3 X_m^2 \tag{A1.7}$$

A1.4 Calculate the goodness of fit, R (correlation coefficient) as follows:

$$R = 1 - \frac{\Sigma\,(Y_{i\,\mathrm{OBS}} - Y_{i\,\mathrm{CAL}})^2}{\Sigma\,(Y_{i\,\mathrm{OBS}} - Y_{\mathrm{OBS}})^2} \tag{A1.8}$$

where:

$$Y_{i\,\mathrm{CAL}} = A_1 + A_2 X_{i\,\mathrm{OBS}} + A_3 X^2_{i\,\mathrm{OBS}} \tag{A1.9}$$

and:

$$Y_{\mathrm{OBS}} = \frac{1}{N} \Sigma\, Y_{i\,\mathrm{OBS}} \tag{A1.10}$$

and:

i = 1 to N orifices used in 7.2,
OBS = observed data,
CAL = calculated data, and
$Y_{i\,\mathrm{OBS}}$ = is the air power (AP) obtained from the calculations in 8.3 for the corresponding value $X_{i\,\mathrm{OBS}}$ (airflow, Q) at any of the N orifices selected.

A1.4.1 If R is not greater than or equal to 0.900, the test must be performed again and the new set of data used.

A2. DETERMINATION OF 90 % CONFIDENCE INTERVAL

A2.1 *Theory*:

A2.1.1 The most common and ordinarily the best estimate of the population mean, μ, is simply the arithmetic mean, $\bar{x}$, of the individual scores (measurements) of the units comprising a sample taken from the population. The average score of these units will seldom be exactly the same as the population mean; however, it is expected to be fairly close so that in using the following procedure it can be stated with 90 % confidence that the true mean of the population, μ, lies within 5 % of the calculated mean, $\bar{x}$, of the sample taken from the population as stated in Section 6.

A2.1.2 The following procedure provides a confidence interval about the sample mean which is expected to bracket μ, the true population mean, 100(1-α) % of the time where α is the chance of being wrong. Therefore, 1-α is the probability or level of confidence of being correct.

A2.1.3 The desired level of confidence is 1-α = 0.90 or 90 % as stated in Section 10. Therefore α = 0.10 or 10 %.

A2.1.4 Compute the mean, $\bar{x}$, and the standard deviation, s, of the individual scores of the sample taken from the population:

$$\bar{x} = \frac{1}{n} \sum_{i=1}^{n} X_i \tag{A2.1}$$

$$s = \sqrt{\frac{n \sum_{i=1}^{n} X_i^2 - (\sum_{i=1}^{n} X_i)^2}{n\,(n-1)}} \tag{A2.2}$$

where:

n = number of units tested, and
X_i = the value of the individual test unit score of the ith test unit. As will be seen in the procedural example to follow, this is the average value of the results from three test runs performed on an individual test unit with the resulting set of data meeting the repeatability requirements of Section 10.

A2.1.5 Determine the value of the t statistic for $n - 1$ degrees of freedom, df, from Table A2.1 at a 95 % confidence level.

NOTE A2.1—The value of t is defined as $t_{1-\alpha/2}$ and is read as "t at 95 % confidence."

$$t \text{ statistic} = t_{1-\alpha/2} = t_{0.95} \tag{A2.3}$$

TABLE A2.1 Percentiles of the *t* Distribution

df	$t_{0.95}$
1	6.314
2	2.920
3	2.353
4	2.132
5	2.015
6	1.943
7	1.895
8	1.860
9	1.833
10	1.812
11	1.796
12	1.782
13	1.771
14	1.761
15	1.753

where:
1-α/2 = 1 – 0.10/2 = 1 – 0.05 = 0.95, or 95 %.

A2.1.6 The following equations establish the upper and lower limits of an interval centered about $\bar{x}$ that will provide the level of confidence required to assert that the true population mean lies within this interval:

$$CI_U = \bar{x} + ts/\sqrt{n} \tag{A2.4}$$

$$CI_L = \bar{x} - ts/\sqrt{n} \tag{A2.5}$$

where:

CI = Confidence Interval (U - upper limit; L - lower limit),
$\bar{x}$ = mean score of the sample taken from the population,
t = t statistic from Table A2.1 at 95 % confidence level,
s = standard deviation of the sample taken from the population, and
n = number of units tested.

A2.1.7 It is desired to assert with 90 % confidence that the true population mean, μ, lies within the interval, CI_U to CI_L, centered about the sample mean, $\bar{x}$. Therefore, the quantity $ts/\sqrt{n}$ shall be less than some value, A, which shall be 5 % of $\bar{x}$ in accordance with the sampling statement of 6.1.

A2.1.8 As $n \to \infty$, $ts/\sqrt{n} \to 0$. As this relationship indicates, a numerically smaller confidence interval may be obtained by using a larger number of test units, n, for the sample. Therefore, when the standard deviation, s, of the sample is large and the level of confidence is not reached after testing three units, a larger sample size, n, shall be used.