Standard Test Method for Measuring Diameter of Fine Wire by Weighing[1]

This standard is issued under the fixed designation F 205; 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 the measurement of the average diameter of fine wire by weighing a known length; it applies particularly to sizes up to 0.13 mm (0.005 in.) used in electron devices and lamps.

1.2 The values stated in SI units are to be regarded as the standard. The values given in inch-pound units apply only for the diameter.

1.3 *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:*

F 180 Test Method for Density of Fine Wire and Ribbon for Electronic Devices[2]

3. Apparatus

3.1 The apparatus shall consist of a suitable torsion or other direct-reading balance capable of reading to 0.002 mg or 0.1 % of the weight to be weighed (whichever is larger), with an accuracy of 0.004 mg or 0.2 % (whichever is larger). The range of the balance (or the size of the specimen) shall be such that the reading will lie within the upper half of the scale.

4. Test Specimens

4.1 Test specimens shall be selected at least 1 m from the end of a spool or sufficiently far from the end to be free from kinks or other damage resulting in lack of straightness of the cut length.

4.2 The wire shall be drawn from the spool under a low even tension so that no elongation of the wire takes place.

4.3 Each test specimen shall be cut to a length of 200 ± 0.1 mm. To prevent stretching, care shall be taken so that the tension is just sufficient to eliminate the sag and curl. Any disagreement concerning the amount of tension to be used in cutting shall be resolved between the manufacturer and the purchaser.

4.4 The test specimen shall be folded upon itself several times and twisted to make a compact bundle with loop consisting of a single strand for hanging it on the balance beam. In the case of multiple specimens, all specimens shall be twisted together and hung by a loop consisting of a single strand. The specimen shall be handled as little as possible. The operator's hands shall be clean and dry.

5. Number of Specimens

5.1 Weigh a single specimen if its weight lies within the upper half of the scale of the instrument. When the weight is less than half of the scale of the instrument, weigh a sufficient number of specimens, 200 mm in length, simultaneously so that the total weight will register in the upper half of the scale, preferably as close to the limit of the balance as possible. Use the lowest range instrument compatible with the weight of the 200-mm weight specimen to reduce the number of 200-mm lengths that must be weighed together.

6. Repetition of Weighing

6.1 If the corrected weight of a single specimen lies within ±0.5 % of either the minimum or the maximum limit specified for the wire weight, cut and weigh two more specimens of wire in a similar manner. When two or more lengths of wire have been weighed simultaneously to produce a reading in the upper half of the scale because of the small size of the wire, cut and weigh two more sets of specimens in a similar manner.

7. Calibration and Checking of the Balance

7.1 Check the balance regularly in accordance with the recommendations of the manufacturer.

7.2 If a variety of weights are to be determined, calibrate the balance at five major points on the scale and at zero by determining the weights of calibrated check weights. If any point is in error by more than 1 %, remove the balance from service and repair it. Apply corrections determined by checking to the apparent readings to obtain corrected weights. Obtain corrections applied to apparent weights by interpolation between the closest calibrated points, one above and one below the reading.

7.3 If the amount of work to be weighed at one point on the scale justifies it, the balance may be calibrated with a standard weight (or combination of weights) deviating by not more than

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[2] *Annual Book of ASTM Standards*, Vol 10.04.

10 % from that of the weight to be determined. In this case, adjust the balance so that the balance reads the known weight of the check weight correctly when it is in balance, thereby reducing the correction to zero.

7.4 Calibrate the balance, at zero under no load, or at positive values when loaded to check weights, by using the average of three consecutive readings, taken under conditions specified in 7.2 or 7.3, whichever is applicable.

8. Calibration with Standard Weights

8.1 Check weights are subject to change of mass due to wear from handling and use, and from chemical action resulting from exposure. Depending on use, but not less than twice a year, compare the calibrated check weights with the primary weights, calibrated by the National Institute of Standards and Technology, and apply the necessary corrections.

8.2 The primary standard check weights shall be NIST Class M, or equivalent, for weight determinations of 2.00 mg or less, and Class S, or equivalent, for weight determinations over 2.00 mg.

9. Procedure

9.1 Handle and use the balance as recommended by the manufacturer. Direct particular attention to requirements for careful handling, protection from vibration and atmospheric dust, errors induced by temperature changes, and the necessity for avoiding paralax in reading.

10. Calculation

10.1 Calculate the average diameter of the wire from the following equation (see Appendix X1):

$$D = (3.1413/\sqrt{\Delta}) \times \sqrt{W},$$

where:

D = average diameter of wire, mils (mils × 0.0254 = mm),
Δ = density of wire, g/cm^3 (see Note 1),
W = weight of wire, mg/200 mm,

Also, let

$$K = 3.1413/\sqrt{\Delta},$$

then

$$D = K\sqrt{W} \text{ (see Note 2).}$$

NOTE 1—The density of wire for alloys not found in Table 1 may be determined at or near the finished size and the finished condition in accordance with Test Method F 180.

NOTE 2—Values for density and the constant *K* for several alloys are given in Table 1.

11. Interpretation of Results

11.1 If a single specimen or a single set of specimens is weighed, and its corrected weight, or average weight when multiple specimens are used, is found to lie between the point 0.5 % above the minimum limit and 0.5 % below the maximum limit, the wire shall be considered to meet the specified limits.

11.2 If the corrected wire weight is under 0.5 % below the minimum limit or over 0.5 % above the maximum limit, the wire is considered not to meet the specified limits.

11.3 If the corrected weight of a single specimen, or the average weight when multiple specimens are used, lies within the range of ± 0.5 % of the maximum or ±0.5 % of the minimum limit, exactly three specimens or three sets of specimens shall be weighed, and the average corrected value compared with the maximum and minimum limits. If the average of the three readings lies between the maximum limit and the minimum limit, the weight of the wire is considered to lie within these limits.

TABLE 1 Density and Constant K for Diameter Calculations

Alloy	Density,[A] g/cm^3	Constant *K*
Aluminum + 1 % magnesium	2.7	1.912
Aluminum + 1 % silicon	2.7	1.912
Gold	19.32	0.715
85 % nickel, 15 % chromium	8.47	1.079
58 % nickel, 20 % molybdenum, 20 % iron, 2 % manganese	8.78	1.060
95 % nickel, 5 % manganese	8.74	1.063
Permanickel	8.77	1.061
Monel	8.81	1.058
Molybdenum	10.14	0.986
Tantalum	16.59	0.771
Tungsten	19.17	0.717

[A] The density values in this table have been determined by ASTM Test Method F 180.

NOTE 3—The following is an example of the evaluation of results. If a specified weight of 8.00 mg/200 mm and a specified tolerance of ±3 % (±0.24, mg/200 mm) is assumed, the range determined by these specifications must be 7.76 to 8.24 mg/200 mm. The working zones for weighing will be:

Minimum limit:
+ 0.5 %, 7.76 + 0.04 = 7.80 mg/200 mm
−0.5 %, 7.76 − 0.04 = 7.72 mg/200 mm

Maximum limit:
−0.5 %, 8.24 − 0.04 = 8.20 mg/200 mm
+ 0.5 %, 8.24 + 0.04 = 8.28 mg/200 mm

The corrected weight of a single cut length of wire found to lie between 7.80 and 8.20 mg/200 mm will suffice to accept the wire. The corrected weight on a single cut length of wire found to be less than 7.72 mg/200 mm or more than 8.28 mg/200 mm will suffice to reject the wire as outside the specified limits.

If the corrected weight of a single cut length is found to be between either 7.72 and 7.80 mg/200 mm, or 8.20 and 8.28 mg/200 mm, two more pieces shall be cut, weighed, and averaged with the first weight. If the average of the three weights lies between 7.76 and 8.24 mg/200 mm, inclusive, the wire is considered to meet the specified range; if outside these limits, it is considered not to meet it.

12. Dimensions, Mass, and Permissible Variations

12.1 Permissible variations from the specified weight shall be designated by maximum and minimum weights, or as a plus-and-minus percentage tolerance to be applied to the normal weight.

13. Report

13.1 The report shall consist of the number of readings, and the average corrected weight of the wire to three significant figures in milligrams per 200 mm, except that for sizes under 1.00 mg/200 mm only two significant figures shall be reported. The value reported shall be the weight of the outside end of the spool unless it shall have been agreed otherwise between the manufacturer and the purchaser.

14. Precision and Bias

14.1 *Precision*—The precision of this test method has not been formally evaluated using an interlaboratory testing program. However, it is possible to evaluate the standard deviation of the wire diameter, $\sigma(D)$, for a given experimental setup, using the following equation which is based on propagation of errors:

$$\sigma(D) = \sqrt{\{(\delta D/\delta\Delta)^2 \sigma^2(\Delta) = (\delta D/\delta W)^2 \sigma^2(W) + (\delta D/\delta L)^2 \sigma^2(L)\}}.$$

where each of the partial derivative terms are obtained from appropriate differentiation of the definition of specimen wire diameter, D, shown in 10.1 and L is the wire length.

14.2 *Bias*—Proper measurement technique for all the variables shown in the equation which defines $\sigma(D)$ in 14.1 should eliminate bias from this test method.

15. Keywords

15.1 electronic devices; fine wire; wire bonding

APPENDIX

(Nonmandatory Information)

X1. DERIVATION OF DIAMETER CALCULATION EQUATION

X1.1 The diameter calculation equation in Section 12 was derived as follows:

$$\text{Wire weight} = \text{x}^{-}\text{ sectional area} \times \text{length} \times \text{density, or}$$

$$W = (\pi D^2/4) \times L \times \Delta,$$

where:

W = wire weight,
D = wire diameter,
L = wire length, and
Δ = wire density.

Rearranging,

$$D^2 = 4W/\pi L\Delta$$

or

$$D = \sqrt{4W/\pi L\Delta} = 1.1284\sqrt{W/L\Delta}.$$

Let

$$W' = W/L,$$

then

$$D = 1.1284\sqrt{W'/\Delta}.$$

Correcting for unit:

W' = weight in mg/200 mm (or mg/20 cm),
Δ = density in gm/cm^3 (or 1000 mg/cm^3), and
D = diameter in mils (where 1 mil = 0.00254 cm),

then

$$D = 1.1284\sqrt{\frac{W'\text{ (mg/20 cm)}}{\Delta\text{ (1000 mg/cm}^3)}} / \frac{0.00254\text{ cm}}{\text{mil}},$$

or

$$D = 1.1284\sqrt{(W'/\Delta)(\text{cm}^2/20000)}\ /0.00254\text{ cm},$$

or

$$D = 1.1284\text{ (cm/141.42)}\sqrt{W'/\Delta}\ /0.00254\text{ cm},$$

or

$$D = 3.1413\sqrt{W'/\Delta}.$$

Other useful equations:

$$W' = 0.10134\,\Delta D^2, \text{ and}$$

$$\Delta = 9.868\,(W/D^2).$$