



Designation: B636/B636M – 15 (Reapproved 2021)

Standard Test Method for Measurement of Internal Stress of Plated Metallic Coatings with the Spiral Contractometer¹

This standard is issued under the fixed designation B636/B636M; 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 use of the spiral contractometer for measuring the internal stress of metallic coatings as produced from plating solutions on a helical cathode. The test method can be used with electrolytic and autocatalytic deposits.

1.2 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 *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.*

1.4 *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:*

[E177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods](#)

[E691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method](#)

3. Terminology

3.1 *Definitions:*

3.1.1 *compressive stress* (–)—stress that tends to cause a deposit to expand.

¹ This test method is under the jurisdiction of ASTM Committee B08 on Metallic and Inorganic Coatings and is the direct responsibility of Subcommittee B08.10 on Test Methods.

Current edition approved Oct. 1, 2021. Published October 2021. Originally approved in 1978. Last previous edition approved in 2015 as B636 – 15. DOI: 10.1520/B0636_B0636M-15R21.

3.1.2 *internal stress*—the net stress that remains in a deposit when it is free from external forces. The internal stress tends to compress or stretch the deposits.

3.1.3 *tensile stress* (+)—stress that tends to cause a deposit to contract.

4. Summary of Test Method

4.1 The test method of measuring stress with the spiral contractometer is based on plating on the outside of a helix. The helix is formed by winding a strip around a cylinder, followed by annealing. In operation, one end of the helix is fixed and the other is allowed to move as stresses develop. The free end is attached to an indicating needle through gears that magnify the movement of the helix. As the helix is plated, the stress in the deposit causes the helix to wind more tightly or to unwind, depending on whether the stress is compressive (–) or tensile (+). From the amount of needle deflection and other data, the internal stress is calculated.

4.2 With instrument modifications, the movement of the helix can be measured electronically instead of mechanically as described in 4.1.

5. Significance and Use

5.1 The spiral contractometer, properly used, will give reproducible results (see 9.5) over a wide range of stress values. Internal stress limits with this method can be specified for use by both the purchaser and the producer of plated or electroformed parts.

5.2 Plating with large tensile stresses will reduce the fatigue strength of a product made from high-strength steel. Maximum stress limits can be specified to minimize this. Other properties affected by stress include corrosion resistance, dimensional stability, cracking, and peeling.

5.3 In control of electroforming solutions, the effects of stress are more widely recognized, and the control of stress is usually necessary to obtain a usable electroform. Internal stress limits can be determined and specified for production control.

5.4 Internal stress values obtained by the spiral contractometer do not necessarily reflect the internal stress values found on a part plated in the same solution. Internal stress varies with many factors, such as coating thickness, preparation of

substrate, current density, and temperature, as well as the solution composition. Closer correlation is achieved when the test conditions match those used to coat the part.

6. Apparatus

6.1 The spiral contractometer is described by A. Brenner and S. Senderoff.²

NOTE 1—Spiral contractometers are available from many of the suppliers of nickel sulfamate.

6.2 Helices shall be stopped-off on the inside to prevent plating. Helices are available with or without a permanent inert coating on the insides (see [Appendix X1](#)).

6.3 The clamps holding the helix to the contractometer shall be coated with an inert nonconductive coating to prevent their plating and acting as thieves.

6.4 For testing electroplating solutions, anodes are placed equidistant from the helix and symmetrically positioned to produce even plate distribution. A minimum of four anodes is required. A concentric anode arrangement is preferred.

6.5 Laboratory tests on electroplating solutions shall utilize at least 3.7 L of solution. A 4-L beaker with an annular anode arrangement is convenient. Use of this volume or larger will minimize solution changes due to electrolysis during the test.

6.6 Laboratory tests on autocatalytic plating solutions are done in a 1-L, tall-form beaker. Obviously, no anodes are used.

7. Factors Affecting Accuracy

7.1 Variations in the preparation of the helix may cause substantial variations in results.

7.1.1 Stop-off material shall be applied properly to the interior of the helix. The stop-off material shall be thin and flexible to permit the helix to move freely during the test. A coating weight of less than 3 mg/in.² is satisfactory.

NOTE 2—The inside shall be stopped-off with some inert, flexible coating. One acceptable stop-off material is “Microstop.” One part of “Microstop” is diluted with two parts of acetone before use. Any nickel deposited on the inside of the helix will exhibit an opposing effect.

7.1.2 Helices that have been permanently coated on the inside with TFE-fluorocarbon may give variable results when testing near-zero stresses.

7.1.3 Cleaning variations and surface preparation of the helix before the test can produce varying results. For example, electrocleaning of the helix shall always be cathodic and controlled with respect to current, time, and temperature. Anodic cleaning at this stage can give wide variations. Abrasive cleaning of the helix and the use of etchants shall be avoided.

7.1.4 Very thin deposits of less than about 3 μm [1.18 × 10⁻⁴ in.] are influenced more by the surface conditions and preparation of the helix than are thicker deposits.

7.2 Internal stress varies with current density used in electroplating. The variation is not predictable and depends on the metal being deposited, impurities or additives, and the current

density range under consideration. It is important that the current be measured and controlled closely throughout the stress test. Variations in currents shall be held to less than 2 %.

7.3 Because the temperature of the plating solution may affect the internal stress, it shall be maintained within 2°C [6.5°F] during the test. The initial rest point of the indicator and the final rest point are both taken at the operating temperature of the plating solution to eliminate thermal stresses.

7.4 The solution composition shall not vary during the test. Usually, if the repeatability tests in [9.5](#) are met, the solution can be assumed to be unchanged during the test runs. Conversely, when the repeatability tests are not met, the plating solution shall be analyzed to determine if any changes in solution composition have occurred during the test.

7.4.1 Tests run on electroplating solutions using insoluble or inefficient anodes could result in significant solution changes during the test.

7.4.2 When testing autocatalytic plating solutions, the constituents of the plating solution may be significantly depleted during the test, unless replenished.

7.5 A relationship between the surface area to be plated and the volume of autocatalytic plating solutions exists that may affect the character of the deposit. In testing autocatalytic plating solutions, the ratio of plated surface area to the volume of solution that is normally used in the plating tank shall be maintained. When using proprietary solutions, the supplier’s recommendation shall be followed.

8. Calibration

8.1 Calibrate the instrument as directed in the manufacturer’s instructions.

8.2 The frequency of calibration will vary with use and extent of attack on the helices from the chemical stripping. When visible attack is noted, discard the helix.

8.3 The calibration procedure consists essentially of determining the force required per degree of dial deflection. A known mass is suspended over a small pulley on a lever arm with the helix mounted in place. The degree of deflection is read from the dial. The data required for the calibration calculations as expressed in metric units are as follows:

- w = mass used in calibrating, kg,
- a = length of lever arm, m,
- p = pitch of helix, m,
- t = thickness of the strip used to make the helix, m,
- deg_{def} = degree deflection; difference in dial readings caused by mass,
- g = 9.8 m/s² (acceleration of free fall), and
- Z = calibration constant of the helix

$$\left(\frac{\text{MPa}}{\text{m deg}_{\text{def}}} \right)$$

where

$$Z = \frac{2(w)(a)(g)}{p(t)\text{deg}_{\text{def}}} \times 10^{-6}$$

² Brenner, A., and Senderoff, S., *Proceedings of the American Electroplaters Society*, Vol 35, 1948, p. 53.

9. Procedure

9.1 The procedure will vary with the solution being tested. Follow the instructions given by the supplier carefully. Variations in the procedure can produce variations in results. Give appropriate attention to the factors in Section 7. A detailed procedure for nickel plating solutions appears in **Appendix X1**.

9.2 Position the spiral contractometer in electroplating solutions so that it is equidistant from the anodes. Position the anodes on at least four sides when they are used in a production tank or use a concentric anode arrangement. Do not place the spiral contractometer between the tank anodes and the work being plated in a production tank. A separate ammeter and current control are required. If the test is run on a sample of the solution, use a 4-L beaker.

9.3 When testing autocatalytic plating solutions, maintain the proper surface area-to-solution volume ratio (see 7.5).

9.4 The conditions of the test are usually chosen to match those of the production parts as closely as practicable.

9.4.1 The thickness of the deposit plated on the helix may not be required to be the same as the thickness plated on production parts. This is especially true when production part thickness requirements are greater than about 15 μm [5.9 μin].

9.4.2 The current density used for the spiral contractometer is sometimes lower than that of production parts. Electroplating at the lower current density will often indicate the cumulative effects of solution impurities before these have much effect on the work being plated at the higher currents. This information can be used as a measure of the solution purity and will allow planning for corrective or purification procedures.

9.5 Repeatability:

9.5.1 Consider the procedure repeatable if the results of three consecutive tests on the same solution sample produce internal stress values that do not vary more than $\pm 10\%$ from the mean of the three values.

9.5.2 For near zero stress values, -10 to $+10$ MPa [-1450 to $+1450$ psi], it is more difficult to detect small changes with the contractometer and an acceptable range for repeatability is -5 to $+5$ MPa [-725 to $+725$ psi].

9.6 Solution adjustments may be made during the test, especially when testing autocatalytic solutions and electroplating solutions using insoluble anodes.

9.7 Clean the instrument after each use and before storage. This is to prevent solution that may creep up the shaft from crystallizing and binding or corroding the instrument.

10. Stress Calculations

10.1 Data Required:

Z = calibration constant for the helix, MPa/(m deg_{def}),

D = change in dial reading during the test, deg, and

τ = thickness of the deposit on the helix, m.

τ can be calculated from the additional data:

A = plated area, m²,

W = mass of deposit, kg, and

d = density of deposit, kg/m³.

Then $\tau = W/(d)A$

$$\text{Internal stress, } S, \text{ in MPa} = \frac{Z \times D}{\tau} \quad (1)$$

NOTE 3—This value is an average stress and is uncorrected for the effects of the differences in Young's modulus between the helix and the deposit. It also assumes a relatively thin deposit on the helix. If a corrected or truer stress, S_T , is desired:

$$S_T = S \left[1 + \left(\frac{E_0 \times t}{E \times \tau} \right) \right] \quad (2)$$

where:

E_0 = Young's modulus of the deposit, and

E = Young's modulus of the helix.

Normally, the correction made above is less than the experimental errors in the procedure and is infrequently used.

11. Report

11.1 When reporting internal stress values, it is necessary to include the following:

11.1.1 Metal deposited and the plating solution composition,

11.1.2 Instrument used (spiral contractometer),

11.1.3 Thickness of deposit on helix,

11.1.4 Current density (omit if autocatalytic deposits are being tested),

11.1.5 Temperature, and

11.1.6 pH (if it is a controllable variable).

11.2 The unit for expressing internal stress is the megapascal (MPa). One megapascal is one meganewton per square metre (MN/m²), approximately 145 psi.

12. Precision and Bias³

12.1 The precision of this test method is based on an interlaboratory study of Test Method B636/B636M for Measurement of Internal Stress of Plated Metallic Coatings with the Spiral Contractometer conducted in 2013. Six laboratories tested triplicate specimens of both bright and matte samples. Every "test result" represents an individual determination. Practice E691 was followed for the design and analysis of the data; the details are given in ASTM Research Report No. B08-1008.

12.1.1 *Repeatability (r)*—The difference between repetitive results obtained by the same operator in a given laboratory applying the same test method with the same apparatus under constant operating conditions on identical test material within short intervals of time would in the long run, in the normal and correct operation of the test method, exceed the following values only in 1 case in 20.

12.1.1.1 Repeatability can be interpreted as the maximum difference between two results, obtained when repeating the test under identical conditions, that is accepted as plausible because of random causes under normal and correct operation of the test method.

³ Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:B08-1008. Contact ASTM Customer Service at service@astm.org.