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Measurement of Surface Profile of Metal Surfaces Using a Replica Tape

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Foreword

Before the application of protective coatings to metal surfaces, the surfaces are frequently cleaned by abrasive impact or power tools. Such cleaning roughens the surface, assuring a surface profile (also known as an anchor pattern, anchor profile, or anchor-tooth profile). The resulting degree of surface roughness is affected by many variables, including the type, size, and shape of the abrasive or tool used, its velocity, and the angle of impact, etc. This surface profile enhances coating adhesion.

Many techniques and instruments are currently used to measure the surface texture or surface profile; however, those providing the highest degree of precision are suitable only for use in a laboratory. Because a surface profile range is frequently specified and the recommended surface profile is different for various types of coatings, a means to measure the surface profile at the work site is desirable.

The purpose of this standard is to describe and characterize one procedure for measuring the surface profile of metal surfaces. The measurement technique uses a compressible foam that replicates the surface profile. The thickness of the compressed foam (with the profile replicated) is then measured with a micrometric thickness gauge to determine the surface profile. Other common methods of measuring surface profile are not discussed.

The procedure described in this standard is limited to the measurement of the surface profile with a profile defined as 13 to 150 µm (0.5 to 6.0 mil).

Rationale

The 2024 version of this document contains substantial changes from the previous version, which was last revised in 2016. It reflects updates to the manufacturer's recommended instructions, including the use of the new High Accuracy Burnishing Tool and new conversion technique discussed in Appendixes A (nonmandatory) and B (nonmandatory). The methods outlined in the previous version remain valid and are included in this document.

Referenced Standards and Other Consensus Documents

Unless specifically dated, the latest edition, revision, or amendment of the documents listed in the table below shall apply.

ASTM International, www.astm.org:	
ASTM D4417	Standard Test Methods for Field Measurement of Surface Profile of Blast Cleaned Steel
International Organization for Standardization (ISO), www.iso.org:	
ISO 8503-5	Preparation of steel substrates before application of paints and related products–Surface roughness characteristics of blast-cleaned steel substrates–Part 5: Replica tape method for the determination of the surface profile

In AMPP standards, the terms *shall* and *must* are used to state requirements and are considered mandatory. The term *should* is used to state something that is recommended, but is not considered mandatory. The term *may* is used to state something considered optional.

Section 1: Scope

1.1 This standard provides procedures for measurement of the surface profile height of a part prepared by abrasive blast cleaning or another method, using replica tape.

1.2 The range for measurement of surface profile height by this method is 13–150 µm (0.5–6.0 mils).

1.3 This standard is not intended to suggest the appropriate surface profile height for an application. Appropriate surface profile height should be determined through agreement between interested parties and consultation with the manufacturer of the coating to be applied.

Section 2: Definitions

Burnish: The action of using a tool to apply force using a rubbing motion to compress the replica foam layer of the replica tape.

Replica Foam: A small square of foam with polyester backing, approximately 12 mm x 12 mm, which is the component of a piece of replica tape into which the surface profile replica is created.

Surface Profile: The series of peaks and valleys of a prepared surface, typically created through abrasive blast cleaning or another method of surface preparation, prior to the surface being coated.

Surface Profile Height: The distance between the highest peaks and lowest valleys in a surface profile. Equivalent to R_t as measured using a drag stylus profilometer in accordance with ASTM D4417 Method D.

Section 3: Apparatus

3.1 Replica Tape

Replica tape consists of compressible foam attached to an incompressible polyester film 50 µm (2.0 mils) thick.[1] The foam/polyester is affixed to an adhesive-backed tape for holding the replica foam on the surface. The tape has a circular cut-out 9.5 mm (0.38 in) in diameter that exposes the underlying replica foam.

Different grades of replica tape, with different foam thicknesses, are available depending on the height of the profile being measured. The grade of replica tape used should be selected based on the expected surface profile height, using the ranges in Table 1.

Table 1
Range of Replica Tape Grades

Replica Tape Grade	Range (µm)	Range (mils)
Coarse Minus	13 – 25	0.5 – 1.0
Coarse	20 – 50	0.8 – 2.0
X-Coarse	38 – 115	1.5 – 4.5
X-Coarse Plus	100 – 150	4.0 – 6.0

If a measurement falls outside of the range of the grade of replica tape used, the measurement should be disregarded and a more appropriate grade should be selected.

[1] The sole source of supply of the tape known to the committee at this time is Testex, 800 Proctor Avenue, Ogdensburg, NY 13669, www.testextape.com. If you are aware of alternative suppliers, please provide this information to AMPP headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend.

If the expected surface profile height is unknown, an initial measurement should be taken using X-Coarse grade replica tape.

3.2 Burnishing Tool

A tool specifically designed for burnishing replica tape shall be used.

3.2.1 On flat and convex surfaces, a High Accuracy Burnishing Tool should be used.[2] It consists of a housing and finger grip, with a flat base, and a spring-loaded, non-rotating 8-mm (5/16-in) diameter metal sphere, which applies a constant force of 425 ± 25 g on the metal sphere when fully pressed on the surface.

Note: Only the High Accuracy Burnishing Tool has been demonstrated to provide the accuracy specified in Appendix A.

3.2.2 On concave surfaces, the rounded surface on the High Accuracy Burnishing Tool opposite to the flat end with the metal sphere should be used.

3.2.3 The legacy burnishing tool, consisting of an acrylic rod with an 8 mm (5/16 in) diameter rounded tip on one end, may also be used.

3.3 Micrometer

A micrometer gauge shall be used to measure the thickness of the compressed replica foam. The micrometer may be either a digital or analog-type instrument, featuring a pair of anvils and an output for reading the distance between the anvils.

The micrometer should have two anvils with flat parallel circular contact surfaces, having a diameter of 6.3 mm (0.25 in), a closing force of 1.1 ± 0.15 N, and an accuracy of ±5 µm (0.2 mils) or better.

Section 4: Procedure

4.1 Preparation of Surface

The measurement area shall be free of visible dirt, dust, residual blast media, and other debris. Cleaning putty, pressure-sensitive tape, compressed air, or another suitable method may be used to clean the measurement area.

4.2 Application

4.2.1 The release paper shall be removed from the replica tape without touching either side of the replica foam. The piece of replica tape should be inspected; the replica tape should not be used if the replica foam appears to be damaged.

4.2.2 The replica tape shall be placed on the surface. Pressure shall be applied to the adhesive backing of the replica tape to secure it to the surface.

[2] The sole source of supply of the tool known to the committee at this time is Testex, 800 Proctor Avenue, Ogdensburg, NY 13669, www.testextape.com. If you are aware of alternative suppliers, please provide this information to AMPP Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend.

4.3 Burnishing

4.3.1 The replica foam shall be burnished using a combination of linear and circular movements with the burnishing tool until a uniform stippled gray appearance is achieved across the entire replica foam.

The time required to fully burnish a piece of replica tape, and the appearance of a fully burnished piece of replica tape, will vary depending on the surface profile height and the grade of replica tape used. Profiles at the high end of a replica tape grade range may only require burnishing for 10-15 seconds. Profiles at the low end of the range may require up to 60 seconds.

Note: If using the legacy burnishing tool, or the rounded surface on the High Accuracy Burnishing Tool for concave surfaces, the burnishing force should be just sufficient to achieve a uniform stippled gray appearance across the entire replica foam. Excessive force may cause inaccurate readings.

4.4 Removal and Inspection

4.4.1 The replica tape shall be removed from the surface and inspected to ensure no contamination from the surface is present (e.g., dust, debris, residual blast media). If any contamination is present, the replica tape should be discarded and the procedure outlined in Paragraph 4.1 should be repeated.

4.4.2 To verify uniform and complete burnishing, the replica tape may be held up to a light source to ensure that points of light are visible consistently across the replica where the foam has been fully compressed by the peaks of the surface profile.

4.5 Measurement of Replica Tape

4.5.1 The anvils of the micrometer shall be cleaned and the instrument zeroed following the manufacturer's instructions. The micrometer may be set to a value of -50 µm (-2.0 mils) when the anvils are closed, to compensate for the thickness of the incompressible polyester layer.

4.5.2 Micrometer accuracy should be verified using a certified standard, such as a gauge block or plastic shim with assigned values traceable to a national metrology standard. Ensure that the anvils are clean, and measure the standard. Ensure that the reading on the micrometer matches the stated thickness of the standard within their combined tolerance.

4.5.3 If using a digital micrometer, the gauge should be configured according to the manufacturer's instructions, and the correct grade of replica tape should be selected.

4.5.4 The thickness of the replica foam shall be measured by placing the replica tape between the anvils of the micrometer and centering the circular opening of the tape between the anvils.

NOTE If the micrometer was not set to -50 µm (-2.0 mils) before taking a measurement, 50 µm (2.0 mils) shall be subtracted from the reading value.

4.5.5 The replica tape shall be removed from the micrometer and may be retained as a permanent replica of the surface profile.

4.6 Conversion of Reading

To extend the range of each grade of replica tape, and to improve accuracy, a conversion or averaging procedure shall be used.

4.6.1 **Conversion –** Measurements should be converted to the resulting surface profile height using the values in Appendix B: Conversion Tables for Replica Tape Readings. Alternatively, digital micrometers are available that automatically apply the conversion values in Appendix B.

4.6.2 **Averaging** – As prescribed by the instrument manufacturer, in some measurement ranges the thickness results from two different grades of replica tape may be averaged to determine the resulting surface profile height.

4.7 Number of Measurements

At least two replicas shall be taken at each location on the surface being measured. If the measured values of the two replicas differ by 5 µm (0.2 mils) or less, their average shall be recorded as the surface profile height.

If the two initial replicas differ by more than 5 µm (0.2 mils), a third replica should be taken. The average of the two closest replicas shall be recorded as the surface profile height.

Section 5: Reporting

5.1 Reporting Requirements

The following information should be included when reporting results:

5.1.1 The location where measurements were taken.

5.1.2 The type of micrometer used, including manufacturer, model number, and serial number.

5.1.3 The type of burnishing tool used.

5.1.4 The type of conversion method used.

5.1.5 The average of each group of readings as specified in Paragraph 4.7.

Other Referenced Documents

1. M. Beamish, “Improvements to the Replica Tape Test Method (ASTM D4417/NACE SP0287/ISO 8503-5),” AMPP Annual Conference + Expo 2024, paper no. 21157 (Houston, TX: AMPP, 2024).

Appendix A
Replica Tape Accuracy
(Nonmandatory)

This appendix is considered nonmandatory, although it may contain mandatory language. It is intended only to provide supplementary information or guidance. The user of this standard is not required to follow, but may choose to follow, any or all of the provisions herein.

This appendix is a review of the results of a 2023/2024 study that is the basis for many of the changes in the 2024 version of this standard.[1] Participants in the study measured a variety of panels, prepared by different methods, and with different target surface profiles, using several different tools and methods. Measurements taken with replica tape were compared to the surface profile height measured as R_t with a drag stylus profilometer operated in accordance with ASTM D4417 Method D.

The paper concludes that updates to the burnishing tool and conversion method used for correcting results provided improved accuracy and precision for the test method.

A1 Conversion of Reading

It has long been known that replica tape responds non-linearly at the lower and upper end of its range. Because of this, a method of averaging the readings taken with two different replica tape grades has been widely used, which makes a rough correction in some ranges, but does not cover all tape grades and ranges.

Based on the results of the study, a new conversion was created which corrects readings to more accurately represent surface profile height for Coarse, X-Coarse, and X-Coarse Plus grade tapes across their full range.

A2 Burnishing Tool

Compared to previously performed studies, the 2023/2024 study recruited participants with varying levels of experience with replica tape, including several with no experience. When using the Testex High Accuracy Burnishing Tool, experienced users of replica tape were able to achieve accuracy and precision specifications, but inexperienced users had significant difficulty replicating the results.

When using the updated burnishing tool design and the procedure detailed in this standard, including the conversion of results as specified by Paragraph 4.6.1, results, independent of the experience level of the user, were found to have improved accuracy and precision. Between 95% and 100% of readings were found to be within the 95% confidence interval of the drag stylus measurement, depending on the tape grade used. No statistically significant difference was found between the results obtained by new and experienced operators.

A3 Conclusion

Based on the results of the study, the precision and accuracy statements in Table A1 were determined for replica tape used in accordance with the procedures detailed in this standard (using the High Accuracy Burnishing Tool and Lookup Table Conversion method):

Table A1
Precision and Accuracy Statements for Each Grade of Replica Tape

Replica Tape Grade	Precision	Accuracy
Coarse	±2 µm (0.1 mils)	±8 µm (0.3 mils)
X-Coarse	±6 µm (0.2 mils)	±8 µm (0.3 mils)
X-Coarse Plus	±8 µm (0.3 mils)	±10 µm (0.4 mils)

Appendix B
Conversion Tables for Replica Tape Readings
(Nonmandatory)

This appendix is considered nonmandatory, although it may contain mandatory language. It is intended only to provide supplementary information or guidance. The user of this standard is not required to follow, but may choose to follow, any or all of the provisions herein.

Tables B1, B2, and B3 outline the suggested conversion result, based on the reading taken with a micrometer gauge, for three grades of replica tape.

Table B1
Conversion Table for Coarse Grade Replica Tape

Reading µm	Result µm		Reading mils	Result mils
20	**19**		0.9	**0.8**
22	**21**		1.0	**1.0**
24	**24**		1.1	**1.1**
26	**27**		1.2	**1.3**
28	**29**		1.3	**1.4**
30	**32**		1.4	**1.6**
32	**35**		1.5	**1.7**
34	**37**		1.6	**1.8**
36	**40**		1.7	**2.0**

Table B2
Conversion Table for X-Coarse Grade Replica Tape

Reading µm	Result µm		Reading mils	Result mils
50	**40**		1.9	**1.5**
53	**44**		2.0	**1.6**
55	**47**		2.1	**1.8**
58	**51**		2.2	**1.9**
60	**54**		2.3	**2.0**
63	**57**		2.4	**2.2**
65			2.5	**2.3**
58	**64**		2.6	**2.4**
70	**67**		2.7	**2.6**
73	**71**		2.8	**2.7**
75	**74**		2.9	**2.8**
78	**78**		3.0	**3.0**
80	**81**		3.1	**3.1**
83	**85**		3.2	**3.2**
85	**87**		3.3	**3.4**

Reading µm	Result µm		Reading mils	Result mils
88	**89**		3.4	**3.5**
90	**94**		3.5	**3.6**
93	**98**		3.6	**3.8**
95	**101**		3.7	**3.9**
98	**105**		3.8	**4.1**
100	**108**		3.9	**4.2**
103	**112**		4.0	**4.3**
105	**115**		4.1	**4.5**

Table B3
Conversion Table for X-Coarse Plus Grade Replica Tape

Reading µm	Result µm		Reading mils	Result mils
105	**100**		4.2	**4.0**
108	**105**		4.3	**4.2**
110	**107**		4.4	**4.3**
113	**112**		4.5	**4.5**
115	**114**		4.6	**4.6**
118	**118**		4.7	**4.7**
120	**121**		4.8	**4.9**
123	**125**		4.9	**5.0**
125	**128**		5.0	**5.1**
128	**132**		5.1	**5.3**
130	**134**		5.2	**5.4**
133	**139**		5.3	**5.5**
135	**141**		5.4	**5.7**
138	**145**		5.5	**5.8**
140	**150**		5.6	**6.0**