Designation: D4417 − 19

Standard Test Methods for Field Measurement of Surface Profile of Blast Cleaned Steel[1]

This standard is issued under the fixed designation D4417; 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.

This standard has been approved for use by agencies of the U.S. Department of Defense.

1. Scope

1.1 These test methods cover the description of techniques for measuring the profile of abrasive blast cleaned surfaces in the field. There are other techniques suitable for laboratory use not covered by these test methods.

1.2 Method B may also be appropriate to the measurement of profile produced by using power tools.

NOTE 1—The Method B procedure in this standard was developed for use on flat surfaces. Depending on the radius of the surface, the results could have greater variability with lower values and averages.

1.3 SSPC standard SSPC-PA 17 provides additional guidance for determining conformance with surface profile requirements.

1.4 The values stated in SI units are to be regarded as the standard. The values given in parentheses are for information only.

1.5 *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.*

1.6 *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.*

[1] These test methods are under the jurisdiction of ASTM Committee D01 on Paint and Related Coatings, Materials, and Applications and are the direct responsibility of Subcommittee D01.46 on Industrial Protective Coatings.

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2. Referenced Documents

2.1 *ASTM Standards:*[2]

D7127 Test Method for Measurement of Surface Roughness of Abrasive Blast Cleaned Metal Surfaces Using a Portable Stylus Instrument

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

2.2 *SSPC Standard:*[3]

SSPC-PA 17 Procedure for Determining Conformance to Steel Profile/Surface Roughness/Peak Count Requirements

2.3 *ASME Standard:*[4]

ASME B46.1-2002 Surface Texture, Surface Roughness Waviness and Lay

2.4 *ISO Standards:*[5]

ISO 4287: 1997 Geometrical Product Specifications (GPS)—Surface Texture: Profile Method—Terms, Definitions, and Surface Parameters

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

[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 Society for Protective Coatings (SSPC), 800 Trumbull Dr., Pittsburgh, PA 15205, http://www.sspc.org.

[4] Available from American Society of Mechanical Engineers (ASME), ASME International Headquarters, Two Park Ave., New York, NY 10016-5990, http://www.asme.org.

[5] Available from International Organization for Standardization (ISO), ISO Central Secretariat, BIBC II, Chemin de Blandonnet 8, CP 401, 1214 Vernier, Geneva, Switzerland, http://www.iso.org.

3.1.1 *deadband, n*—that distance above and below the mean line that a continuous stylus trace line must cross in both directions (up and down) to count as a single peak.

3.1.2 *evaluation length, n*—a sequence of five consecutive stylus sampling lengths.

3.1.3 *H, n*—the average of the maximum peak-to-valley height distances obtained by measuring the thickness of replica tape.

3.1.3.1 *Discussion*—H_L is the thickness measurement adjusted for tape non-linearity.

3.1.4 *Pd (peak density), n*—the number of peaks per unit area obtained from burnished replica tape.

3.1.5 *peak, n*—a high point in a surface profile.

3.1.6 *Rpc (peak count), n*—the number of peak/valley pairs, per unit of length, extending outside a "deadband" centered on the mean line of a stylus trace.

3.1.6.1 *Discussion*—For the purpose of *Rpc*, a peak is defined relative to an upper and lower height threshold. This is a single number (peak count threshold) and is the distance from a lower threshold to an upper threshold centered on the mean line of the profile.

3.1.7 *Rt, n*—the vertical distance between the highest peak and the lowest valley within any given stylus evaluation length.

3.1.8 *sampling length, n*—the nominal distance parallel to the surface within which surface parameters are determined.

3.1.9 *surface profile, n*—the height of the major peaks relative to the major valleys.

3.1.10 *traversing length, n*—seven sampling lengths comprising the evaluation length and the stylus pre-travel and post-travel segments.

4. Summary of Test Method

4.1 The methods are:

4.1.1 *Method A*—The abrasive cleaned surface is compared to commercial replicas of various surface profile depths prepared by different blast media and the range determined. The geometry of the specific abrasive cleaned surface can also be observed. This does not apply when combinations of blast media, such as shot and grit, are used.

4.1.2 *Method B*—The depth of profile relative to the peaks is measured using a fine-pointed probe at a number of locations and the average of the maximum peak-to-valley distances (or alternatively, the average peak-to-valley distances) is determined.

4.1.3 *Method C*—A composite plastic tape is impressed into the blast cleaned surface forming a reverse image of the profile. The average maximum peak-to-valley distance can be measured using a suitable thickness gage. The average of these distances can be determined from a group of measurements. Specially designed optical readers can also determine the peak density from the tape replica.

4.1.4 *Method D*—A trace measurement is taken by a portable stylus surface roughness instrument to obtain maximum peak-to-valley distance. The average of these distances is determined from a group of five traces. These devices can also determine peak count information.

5. Significance and Use

5.1 The height of surface profile has been shown to be a factor in the performance of various coatings applied to steel. For this reason, surface profile should be measured prior to coating application to ensure conformance of a prepared surface to profile requirements specified by the manufacturer of a protective coating or the coating job specification. The instruments described are readily portable and sufficiently sturdy for use in the field.

NOTE 2—Methods C and D include determination of the peak count (number of profile peaks in a specified distance or unit area). According to research performed by Roper, Weaver and Brandon[6], an increase in peak count can improve the adhesion of some coatings to the prepared steel, as well as provide greater resistance to corrosion undercutting once the coating becomes damaged in service.

NOTE 3—Optical microscope methods serve as a referee method for surface profile measurement methods A and B. Profile depth designations are based on the concept of mean maximum profile (*h* max); this value is determined by averaging a given number (usually 20) of the highest peak to lowest valley measurements made in the field of view of a standard measuring microscope. This is done because of evidence that coating performance in any one small area is primarily influenced by the highest surface features in that area and not by the average roughness.[7]

6. Apparatus

6.1 *Method A*—A profile comparator consisting of a number of areas (each approximately one square inch in size), usually side by side, with a different profile or anchor pattern depth. Each area is marked giving the nominal profile depth in mils or micrometres. Typical comparator surfaces are prepared with steel shot, steel grit, or sand or other nonmetallic abrasive, since the appearance of the profile created by these abrasives may differ. The comparator areas are used with or without magnification of 5 to 10 power.

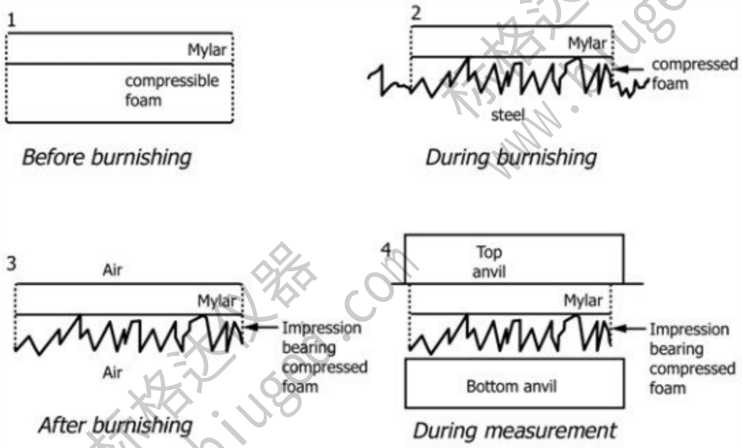
6.2 *Method B*—A depth micrometer fitted with a pointed probe. The probe is typically machined at a 60° included angle with a nominal radius of 50 µm and exerting a minimum force of 75 g. The base of the instrument rests on the tops of the peaks of the surface profile while the spring loaded tip projects into the valleys.

6.3 *Method C*—A replica tape[8] containing a compressible foam attached to a flexible, incompressible plastic substrate of uniform thickness. A burnishing tool, having a spherical rounded end approximately 8 mm (0.3 in.) in diameter, is used to impress the foam face of the tape into the surface to be measured, to create a reverse replica. The thickness of the reverse replica is then measured using a thickness gage specifically designed for use with this replica tape. This sequence of steps is illustrated in Fig. 1.

[6] The Effect of Peak Count or Surface Roughness on Coating Performance, *JPCL* Vol. 22, No. 6, pp 52-64.

[7] John D. Keane, Joseph A. Bruno, Jr., Raymond E. F. Weaver, "Surface Profile for Anti-Corrosion Paints," Oct. 25, 1976, Steel Structures Painting Council, 4400 Fifth Ave., Pittsburgh, PA 15213.

[8] The sole source of supply of suitable replica tape, Press-O-Film, known to the committee at this time is Testex, 8 Fox Lane, Newark, DE 19711. If you are aware of alternative suppliers, please proved 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.



1) The tape consists of a compressible foam coated onto an incompressible polyester substrate.
2) In use, the tape is compressed ("burnished") against the roughened surface to be measured.
3) After burnishing, the foam retains an impression of the surface.
4) Subsequent measurement of the replica's thickness, minus that of the substrate, yields surface roughness.

FIG. 1 Illustration of Replica Tape Principle of Measurement

6.3.1 Thickness gages suitable for use in this application have plane parallel circular contact surfaces with the top contact surface that touches the incompressible polyester side having a diameter of 6.3 mm (0.25 in.), a closing force of 100 grams-force ±15 g and an accuracy of at least ±5 µm (0.2 mils).

6.3.2 Peak density *Pd* is extracted from burnished replica tape with an instrument that counts bright spots on a photograph taken by a digital image sensor (camera).

6.4 *Method D*—An apparatus consisting of a portable skidded or non-skidded electronic surface roughness measurement instrument ("tester") capable of measuring *Rt* in compliance with ISO 4287 and *Rpc* in compliance with ASME B46.1. The apparatus should have a vertical range of at least 300 µm (12 mil) and permit a sampling length of 2.5 mm (0.1 in.) and an evaluation length of 12.5 mm (0.5 in.) (Laboratory experience suggests this vertical range is a practical requirement to meet the provisions of 6.4.1).

6.4.1 The apparatus should include a stylus with a tip radius of 5 µm (0.2 mil), and permit recording of *Rt* in the range 10 to 150 µm (0.4 to 6 mil) and *Rpc* up to 180/cm (450/in.).

6.4.2 Surface deviations are sensed by the stylus and converted to electrical signals within the device. Internal processing converts these signals into standard surface characterization parameters, which are then displayed or printed.

7. Calibration and Standardization

7.1 *Method A:*

7.1.1 Comparators require careful handling and if any surface wear is detected the comparator should be discarded.

7.2 *Method B:*

7.2.1 Before use, each instrument's accuracy shall be verified by the user in accordance with the instructions of the manufacturer, employing suitable standards and, if necessary, any deficiencies found shall be corrected.

7.3 *Method C:*

7.3.1 Before use, each replica tape micrometer's accuracy shall be verified by the user in accordance with the instructions of the manufacturer, employing suitable standards and, if necessary, any deficiencies found shall be corrected.

7.4 *Method D:*

7.4.1 Precision reproductions of standard surface profiles such as those used by the manufacturer of the equipment, or described in their operational literature, may be used as calibration standards for the apparatus.

8. Preparation of Apparatus

8.1 *Method A:*

8.1.1 Select the comparator standard appropriate for the abrasive used for blast cleaning.

8.2 *Method B:*

8.2.1 Prior to use verify that the gage reads zero by placing it on a piece of plate float glass. Hold the gage by its base and press firmly against the glass. Adjust the instrument to zero if necessary.

8.3 *Method C:*

8.3.1 Confirm that the target profile is within the primary profile measurement range for replica tape of 20 to 115 µm. Grades (thicknesses) of tape permit measurement outside this range, but these additional grades should only be used to check measurements near the ends of the primary range.

8.4 *Method D:*

8.4.1 Set the apparatus to display the chosen parameters in accordance with the manufacturers' instructions.

8.4.2 The evaluation length should be set to five sampling lengths. The sampling length and evaluation length should be set to 2.5 mm (0.1 in.) and 12.5 mm (0.5 in.), respectively.

8.4.3 The traversing length of the apparatus should be set to include pre-travel and post-travel segments, usually equal to one sampling length at the beginning and one sampling length at the evaluation length. These portions of a traverse are discarded by the instrument in its calculation of surface parameters.

8.4.4 The low frequency ("long wavelength" or "cutoff") filter should be set to "Gaussian" or "Gaussian 50 %." In general, the default setting will be compliant.

8.4.5 If the apparatus has a high frequency ("short wavelength" or "Ls") filter, it should be set to "off."

8.4.6 The apparatus should be adjusted (if necessary) to a deadband width (C1 = –C2) in the range 0.5 to 2.0 µm (20 to 80 µin.). The choice of deadband for profiles as large as those discussed in this standard will have little effect on the measurements. In general, the default setting will be compliant.

8.4.7 The accuracy of the apparatus should be checked regularly using a calibration block available from the equipment manufacturer using their written procedure and at their recommended interval.

9. Preparation of the Sample

9.1 Use any metal surface that, after blast cleaning, is free of loose surface interference material, dirt, dust, and abrasive residue.

9.2 Select an area of the surface to be tested that is visibly free from obvious defects such as scratches, deep marks, or other construction or corrosion defects.

9.3 Using a stiff nylon bristle brush, remove any dust or abrasive particles from the surface in the selected sample evaluation area.

10. Procedure

10.1 There are four methods to measure the surface profile of the blast-cleaned steel.

NOTE 4—SSPC standard SSPC-PA 17 describes a procedure for determining the number of locations to characterize the surface and for determining compliance with specified profile range.

10.2 *Method A:*

10.2.1 Place the comparator directly on the surface to be measured and compare the roughness of the prepared surface with the roughness on the comparator segments. This can be done with the unaided eye, under 5 to 10 power magnification, or by touch. When using magnification, the magnifier should be brought into intimate contact with the replica, and the depth of focus must be sufficient for the standard and surface to be in focus simultaneously.

10.2.2 Select the comparator segment that most closely approximates the roughness of the surface being evaluated or, if necessary, the two segments to which it is intermediate.

10.2.3 Evaluate the roughness at a sufficient number of locations to characterize the surface as specified or agreed upon between the interested parties. Report the range of results from all locations as the surface profile.

10.3 *Method B:*

10.3.1 To take readings, hold the gage firmly against the prepared substrate. Do not drag the instrument across the surface between readings, or the spring-loaded tip may become rounded leading to false readings.

10.3.2 Measure the profile at a sufficient number of locations to characterize the surface, as specified or agreed upon between the interested parties. Discard any unusually high instrument readings that cannot be repeated in an area.

10.3.2.1 At each location make ten readings and record the maximum value. Then determine the average for all the location maximum values and report it as the profile height of the surface.

10.3.2.2 An alternate method is to make ten readings at each location and determine the average. Then determine the average for all the locations and report it as the profile height of the surface.

NOTE 5—The 'average of the location maximums' procedure in 10.3.2.1 has been shown to produce results that correlate well with methods A, C, and D in this standard, based on theory and experimental data. The alternate 'average of the averages' procedure in 10.3.2.2 has been shown to provide lower results than the other methods in this standard, but reduces the impact of outliers that the operator may fail to discard.

10.4 *Method C:*

10.4.1 Follow manufacturer instructions to obtain the first (of two) profile height readings (*H*) and, optionally, the first (of two) peak density (*Pd*) readings.

10.4.2 The average of two "readings" is a "profile measurement." Manufacturer recommendations provide guidance on whether these two readings should both be obtained with the same tape grade or two different grades.

10.5 *Method D:*

10.5.1 Obtain an initial trace measurement (2 parameters), then four additional trace measurements taken in the compass directions from the original measurement and about 3 cm (1 in.) away for a total of 5 traces, avoiding obvious surface defects.

10.5.2 If the stylus is prevented from making a complete trace due to a physical interference, such as a deep scratch on the surface, move the apparatus to a close adjacent area away from the obvious defect and repeat the trace.

10.5.3 Record the 10 parameters resulting from these five traces (2 parameters per trace).

10.5.4 Calculate the five measurement average for each of the two parameters (*Rt* and *Rpc*).

11. Report

11.1 At a minimum, the report should contain the following items:

11.1.1 Type of instrument used including manufacturer, model number, serial number, and date of calibration.

11.1.2 Report the number of locations measured, and the approximate total area covered.

11.1.3 For Method A, for each location, the surface profile is determined by comparing the abrasive cleaned surface between two replica plates.

11.1.4 For Method B, the average of the maximum values at each location, or if the alternate method is used, the average of 10 readings at each location and a notation that the alternate method was used.

11.1.5 For Method C, the average of each pair of replica tape readings (H *or* H_L) and, optionally, *Pd*, at each location.

11.1.6 For Method D, the sampling length, evaluation length, and the values of the five trace measurements for each of the parameters measured (*Rt and Rpc*) and their averages, for each location. Note whether a skidded or non-skidded instrument is used.

12. Precision and Bias

12.1 *Test Method A:*

12.1.1 *Applicability*—Based on measurements of profiles on surfaces of eight steel panels, each blast cleaned with one of eight different abrasives to a white metal degree of cleaning, having known ratings of profile height ranging from 37 µm (1.5 mils) to 135 µm (5.4 mils), the correlation coefficient for Test Method A was found to be 0.75 and the coefficient of determination was found to be 0.54.

12.1.2 *Precision*—In an interlaboratory study of Test Method A in which two operators each running two tests on separate days in each of six laboratories tested eight surfaces with a broad range of profile characteristics and levels, the intralaboratory coefficient of variation was found to be 20 % with 141 df and the interlaboratory coefficient was found to be 19 % with 40 df, after rejecting three results for one time because the range between repeats differed significantly from all other ranges. Based on these coefficients, the following criteria should be used for judging, at the 95 % confidence level, the acceptability of results:

12.1.2.1 *Repeatability*—Two results, each the mean of four replicates, obtained by the same operator should be considered suspect if they differ by more than 56 %.

12.1.2.2 *Reproducibility*—Two results, each the mean of four replicates, obtained by operators in different laboratories should be considered suspect if they differ by more than 54 %.

12.2 *Test Method B:*

12.2.1 *Applicability*—Based on measurements of profiles on surfaces of eight steel panels, each blast cleaned with one of eight different abrasives to a white metal degree of cleaning, having known ratings of profile height ranging from 37 µm (1.5 mils) to 135 µm (5.4 mils), the correlation coefficient for Test Method B was found to be 0.99 and the coefficient of determination was found to be 0.93.

12.2.2 *Precision*—In an interlaboratory study of Test Method B in which two operators, each running two tests on separate days, in each of five laboratories tested eight surfaces with a broad range of profile characteristics and levels, the intralaboratory coefficient of variation was found to be 19 % with 113 df and the interlaboratory coefficient was found to be 28 % with 32 df, after rejecting three results for one time because the range between repeats differed significantly from all other ranges. Based on these coefficients, the following criteria should be used for judging, at the 95 % confidence level, the acceptability of results:

12.2.2.1 *Repeatability*—Two results, each the mean of four replicates, obtained by the same operator should be considered suspect if they differ by more than 54 %.

12.2.2.2 *Reproducibility*—Two results, each the mean of four replicates, obtained by operators in different laboratories should be considered suspect if they differ by more than 79 %.

12.3 *Method C and D:*

12.3.1 The precision of Test Method C is based on an intralaboratory study conducted in 2011. Eleven laboratories participated in this study, analyzing materials representing five different property types. Each "test result" reported represents an individual determination and the participating labs reported three replicate test results for each material type. Practice E691 was followed for the design and analysis of the data; the details are given in ASTM Research Report: RR:D01-1177[9] (Test Method C) and RR:D01-1169[10] (Test Method D and Test Method D7127).Values in Tables 1 and 2 appearing in this section are taken from the foregoing reports.

12.3.2 The reproducibility standard deviation (S_R) documented in Table 1 (Test Method C) and profile reproducibility standard deviation (Profile S_R), documented in Table 2 (Test Method D) for each of five levels of profile, is key to assessing

TABLE 1 Profile Measurement Statistics

Coded Surface ID Number	Average Replica Tape Profile (mils)	Replica Tape Reproducibility Standard Deviation (mils) S_R
102	1.29	0.12
114	2.65	0.23
124	2.79	0.18
121	3.75	0.15
119	4.22	0.18

[9] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:D01-1177. Contact ASTM Customer Service at service@astm.org.

[10] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:D01-1169. Contact ASTM Customer Service at service@astm.org.

TABLE 2 Test Method D Profile Measurement Statistics

Coded Surface ID Number	Stylus Instrument Average Profile – Rt (mils)	Stylus Instrument Profile – Rt Reproducibility Standard Deviation (mils) S_r	Stylus Instrument Average Peak Count (mils)	Stylus Instrument Peak Count Reproducibility Standard Deviation (mils) S_r
102	1.18	0.076	174.8	8.4
114	2.50	0.210	140.2	7.8
124	2.91	0.286	159.3	12.9
121	4.06	0.345	92.1	6.7
119	4.52	0.356	51.3	3.5

whether a given measurement is statistically different from either an upper or lower profile limit established in advance by the interested parties.

12.3.3 The term "reproducibility standard deviation" is used as specified in Practice E177.

12.3.4 Similarly, the Peak Count Standard Deviation (PC S_R), also documented in Table 2, is key to assessing whether a given measurement is statistically different from either an upper or lower peak count limit established in advance by the interested parties.

12.3.5 A measured profile height or peak count that is within either limit of a pre-specified range by an amount equal to S_R has a 68 % probability of satisfying specification. A profile within 1.5 S_R of a specified limit has an 86 % probability of satisfying specification and a profile within 2.0 S_R of a specified limit has a 95 % probability of satisfying the specification. Fig. 2 is a plot, using the data in Table 1, of peak count versus measured profile.

12.3.6 The precision statement was determined through statistical examination of 160 test results, reported by eleven laboratories, on five surfaces of differing profile covering the approximate profile range of 30 to 110 µm (1.2 to 4.4 mils). The five surfaces bore the internal control code numbers 102, 114, 124, 124, and 119.

12.4 *Bias*—At the time of this study, there was no generally accepted reference method suitable for determining the bias for this test method, therefore no formal statement regarding bias is being made.

12.4.1 Nevertheless, testing in support of Test Method D relied on measurements of the same roughness test panels used to determine precision for method C of this standard. Comparison of data obtained using these two procedures gives a measure of relative method bias. Table 3 presents these data.

TABLE 3 Comparison of Test Methods C and D for Bias Estimation

Coded Surface ID Number	Average Replica Tape Profile (mils)	Replica Tape Reproducibility Standard Deviation (mils) S_R	Average Test Method D7127 Determined Profile Rt (mils)	Test Method D7127 Rerpoducibility Standard Deviation (mils) S_R
102	1.29	0.12	1.18	0.076
114	2.65	0.23	2.50	0.210
124	2.79	0.18	2.91	0.286
121	3.75	0.15	4.06	0.345
119	4.22	0.18	4.52	0.356

12.4.2 Fig. 3 is a plot of replica tape-determined profile against the Portable-Stylus-Instrument-determined parameter Rt showing good agreement within the error associated with each of the two methods. A least-square straight line fitted to profiles for the five surfaces measured using both methods has a slope of 0.9. Over the tested range, the straight line fit suggests that profiles measured with the two methods nowhere differ by more than about 8 µm (0.3 mils).

NOTE 6—The test methods measure different values and the qualitative rating on which the applicability was determined also measures a different value. The mode is determined with the comparator of Test Method A. The height of a single valley below a plane at the level of the highest surrounding peaks is measured with the fine pointed probe of Test Method B. The distance from the bottoms of many of the deepest valleys to the tops of the highest peaks (maximum profiles) are measured with the composite plastic of Test Method C. The height of a single peak above an adjacent valley below is measured with a microscope for the qualitative rating that is compared with each of the methods in correlation calculations. Because the results for the microscope and for the fine pointed probe are measurements to an individual valley, the readings range over much broader limits than the results of the tape or the comparator.

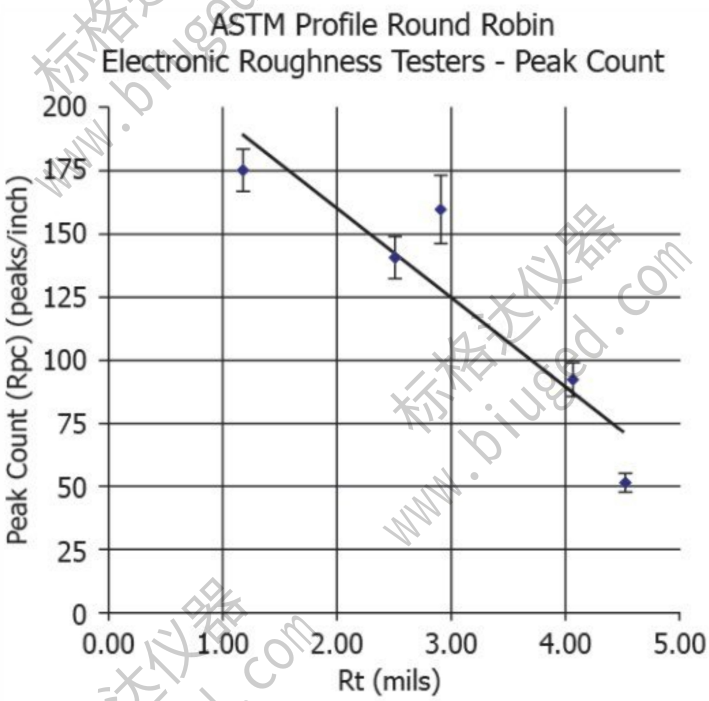
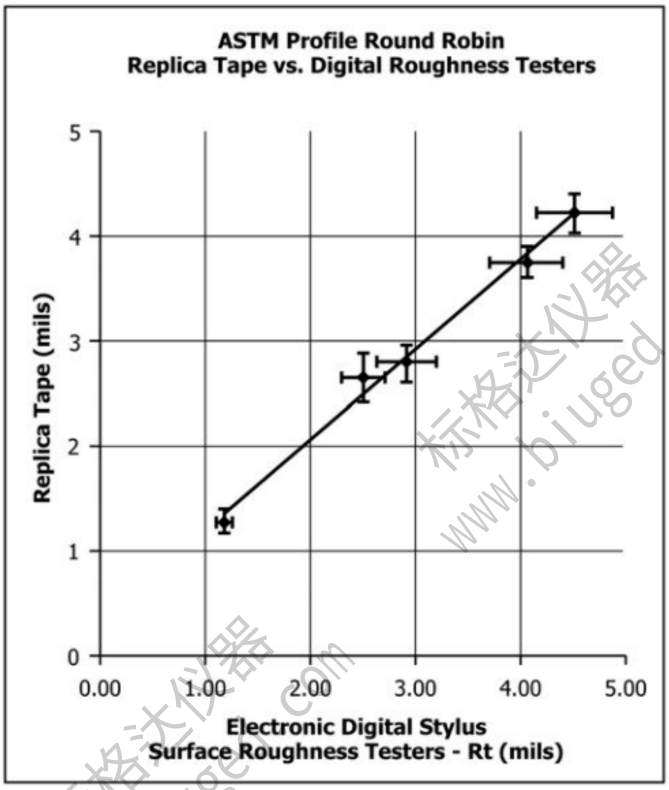


FIG. 2 Electronic Roughness Testers – Peak Count



Comparison method (horizontal axis) is that referenced in Test Method D, describing use of electronic stylus surface roughness testers. Grit blasted panels were measured using both method and plotted against one another. Each plotted point's x-value and horizontal error bar was deduced from 99 electronic stylus measurements (Test Method D). Each point's y-value and vertical error bar was deduced from 33 replica tape measurements (Test Method C).

FIG. 3 Illustration of Replica Tape Surface Roughness Precision and Bias

13. Keywords

13.1 abrasive; abrasive blast cleaning; anchor pattern; peak count; peak density; peak height; surface profile; surface roughness