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Standard Practice for Qualitative Adhesion Testing of Metallic Coatings[1]

This standard is issued under the fixed designation B571; 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 This practice covers simple, qualitative tests for evaluating the adhesion of metallic coatings on various substances.

1.2 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this 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 and health practices and determine the applicability of regulatory limitations prior to use.*

2. Significance and Use

2.1 These tests are useful for production control and for acceptance testing of products.

2.2 Interpreting the results of qualitative methods for determining the adhesion of metallic coatings is often a controversial subject. If more than one test is used, failure to pass any one test is considered unsatisfactory. In many instances, the end use of the coated article or its method of fabrication will suggest the technique that best represents functional requirements. For example, an article that is to be subsequently formed would suggest a draw or a bend test; an article that is to be soldered or otherwise exposed to heat would suggest a heat-quench test. If a part requires baking or heat treating after plating, adhesion tests should be carried out after such post-treatment as well.

2.3 Several of the tests are limited to specific types of coatings, thickness ranges, ductilities, or compositions of the substrate. These limitations are noted generally in the test descriptions and are summarized in Table 1 for certain metallic coatings.

2.4 "Perfect" adhesion exists if the bonding between the coating and the substrate is greater than the cohesive strength of either. Such adhesion is usually obtained if good electroplating practices are followed.

2.5 For many purposes, the adhesion test has the objective of detecting any adhesion less than "perfect." For such a test, one uses any means available to attempt to separate the coating from the substrate. This may be prying, hammering, bending, beating, heating, sawing, grinding, pulling, scribing, chiseling, or a combination of such treatments. If the coating peels, flakes, or lifts from the substrate, the adhesion is less than perfect.

2.6 If evaluation of adhesion is required, it may be desirable to use one or more of the following tests. These tests have varying degrees of severity; and one might serve to distinguish between satisfactory and unsatisfactory adhesion in a specific application. The choice for each situation must be determined.

2.7 When this guideline is used for acceptance inspection, the method or methods to be used must be specified. Because the results of tests in cases of marginal adhesion are subject to interpretation, agreement shall be reached on what is acceptable.

2.8 If the size and shape of the item to be tested precludes use of the designated test, equivalent test panels may be appropriate. If permitted, test panels shall be of the same material and have the same surface finish as the item to be tested and shall be processed through the *same* preplating, electroplating, and postplating cycle with the parts they represent.

3. Bend Tests

3.1 Bend the part with the coated surface away over a mandrel until its two legs are parallel. The mandrel diameter should be four times the thickness of the sample. Examine the deformed area visually under low magnification, for example, 4×, for peeling or flaking of the coating from the substrate, which is evidence of poor adhesion. If the coating fractures or blisters, a sharp blade may be used to attempt to lift off the coating. With hard or brittle coatings, cracking usually occurs in the bend area. Such cracks may or may not propagate into the substrate. In either case, cracks are not indicative of poor adhesion unless the coating can be peeled back with a sharp instrument.

[1] This practice 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.

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TABLE 1 Adhesion Tests Appropriate for Various Coatings

Adhesion Test	Coating Material[A]											
	Cadmium	Chromium	Copper	Lead and Lead/Tin Alloy	Nickel	Nickel and Chromium	Palladium	Rhodium	Silver	Tin and Tin/Lead Alloy	Zinc	Gold
Bend	+	–	+	+	+	+	+	+	+	+	+	+
Burnish	–	+	+	–	+	+	–	–	+	–	+	–
Chisel/knife	+	+	+	+	+	–	+	–	+	+	–	+
Draw	–	–	+	–	+	+	–	–	–	–	+	–
File	–	+	+	+	+	+	–	+	+	+	–	+
Grind and saw	+	+	–	–	+	+	+	–	–	+	+	–
Heat/quench	–	+	+	+	+	+	–	–	+	+	–	+
Impact	+	–	+	–	+	+	–	–	–	–	+	–
Peel	–	+	+	–	+	–	–	–	+	+	–	+
Push	–	–	–	–	+	+	–	–	–	–	+	–
Scribe	–	–	+	–	+	–	–	–	–	–	–	–

[A] + Appropriate; – not appropriate.

TABLE 2 Temperature Test Guide

Substrate	Coating Material						
	Chromium, Nickel, Nickel + Chromium, Copper, Temperature, °C	Tin, Temperature, °C	Lead, Tin/Lead, Temperature, °C	Zinc, Temperature, °C	Gold and Silver, Temperature, °C	Palladium, Temperature, °C	Rhodium, Temperature, °C
Steel	250	150	150	150	250	350	185
Zinc alloys	150	150	150	150	150	150	150
Copper and copper alloys	250	150	150	150	250	350	185
Aluminum and aluminum alloys	220	150	150	150	220	220	185

3.2 Bend the part repeatedly, back and forth, through an angle of 180° until failure of the basis metal occurs. Examine the region at low magnification, for example, 10×, for separation or peeling of the coating. Prying with a sharp blade will indicate unsatisfactory adhesion by lift off of the coating.

4. Burnishing Test

4.1 Rub a coated area of about 5 cm with a smooth-ended tool for approximately 15 s. A suitable tool is a steel rod 6 mm in diameter with a smooth hemispherical end. The pressure shall be sufficient to burnish the coating at each stroke but not so great as to dig into it. Blisters, lifting, or peeling should not develop. Generally, thick deposits cannot be evaluated satisfactorily.

5. Chisel-Knife Test

5.1 Use a sharp cold chisel to penetrate the coating on the article being evaluated. Alternatively the chisel may be placed in back of an overhang area of the coating or at a coating-substrate interface exposed by sectioning the article with a saw. A knife may be substituted for the chisel with or without hammering or light tapping. If it is possible to remove the deposit, the adhesion is not satisfactory. Soft or thin coatings cannot be evaluated for adhesion by this method.

6. Draw Test

6.1 Form a suitable sample about 60 mm in diameter into a flanged cap approximately 38 mm in diameter, to a depth up to 18 mm, through the use of a set of adjustable dies in an ordinary punch press.[2] Penetration of the male die may be continued until the cap fractures. The adhesion of the coating may be observed directly or evaluated further by techniques described in Section 5 for detachment from the substrate. If there is peeling or flaking of the coating or if it can be detached, the adhesion is not satisfactory.

6.2 Results from this technique must be interpreted cautiously, because the ductilities of both the coating and substrate are involved.

7. File Test

7.1 Saw off a piece of the coated specimen and inspect it for detachment at the deposit/substrate interface. Apply coarse mill file across the sawed edge from the substrate toward the coating so as to raise it, using an approach angle of approximately 45° to the coating surface. Lifting or peeling is evidence of unsatisfactory adhesion.

7.2 This technique is not suitable for thin or soft coatings.

8. Grind-Saw Test

8.1 Hold the coated article against a rough emery wheel so that the wheel cuts from substrate toward the deposit in a jerky or bumpy fashion. A hack saw may be substituted for the wheel, making sure to saw in the direction that tends to

[2] Romanoff, F. P., *Transactions*, Electrochem. Soc., Vol 65, 1934, p. 385; *Proceedings*, Amer. Electroplaters Soc. Vol 22, 1934, p. 155; *Monthly Review*, Amer. Electroplaters Soc., Vol 22, April 1935, p. 8.

separate the coating from the substrate. Lifting or peeling is evidence of unsatisfactory adhesion.

8.2 This technique is especially effective on hard or brittle coatings but is not suitable for thin or soft coatings.

9. Heat-Quench Test

9.1 Heat the coated article in an oven for a sufficient time for it to reach the temperature shown in Table 2. Maintain the temperature of the oven within 10°C of the nominal. Coatings and substrates that are sensitive to oxidation should be heated in an inert or reducing atmosphere or a suitable liquid. Then quench the part in water or other suitable liquid at room temperature.

9.2 Flaking or peeling of the deposit is evidence of unsatisfactory adhesion. Blisters may erupt during the heat and quench test when plating solution is entrapped in substrate surface pits or pores which are bridged by the deposit. If the deposited coating cannot be peeled or lifted from the substrate in an area adjacent to the blister(s), the appearance of blisters should not be interpreted as evidence of inferior adhesion.

9.3 Diffusion and subsequent alloying of metals may improve the bond strength of electrodeposits. In some cases, a brittle layer may be created by the materials involved causing peeling as a result of fracture rather than poor adhesion. This would not give a correct indication of the as-plated bond strength.

9.4 This test is nondestructive if the procedure does not create unwanted effects on parts.

10. Impact Test

10.1 Use a hammer or impact device coupled with a suitable backing block to support the article to be tested to deform the sample. Reproducible results are more easily obtained by the use of a suitably modified impact tester where the force is reproducible and the impact head contour is in the form of a 5-mm diameter ball, shock loaded by a falling weight or swinging pendulum weight. The severity of the test may be altered by changing the load and diameter of the ball. Exfoliation or blisters in and around indentations are evidence of inadequate adhesion.

10.2 This test is sometimes difficult to interpret. Soft and ductile coatings are generally not suited for evaluation.

11. Peel Test

11.1 Bond a strip of steel or brass about 1.5 mm thick and 20 mm wide by solder or suitable adhesive to a properly flat area of the coated surface of the article. Adhesive-backed tape may be considered as a possible alternative. Heat curing of the adhesive may be used, keeping in mind considerations noted in 9.3. The angle of pull shall be 90° to the surface. For reproducible results, the rate of pull, the thickness and width of the strip, and deposit thickness must be standardized. Failure in the coating/substrate interface is evidence of inadequate adhesion.

11.2 The tensile and shear strengths of adhesives and solders limit the range of adhesion strengths that can be evaluated. A quantitative analysis of the factors involved has been published.[3]

12. Push Test

12.1 Drill a blind hole 0.75 cm in diameter from the underside until the point of the drill tip comes within approximately 1.5 mm of the deposit/substrate interface on the opposite side. Supporting the material on a ring about 2.5 cm in diameter, apply steady pressure over the blind hole using a hardened steel punch 0.6 cm in diameter until a button sample is pushed out.[3] Exfoliation or peeling of the coating in the button or crater areas is evidence of inadequate adhesion.

12.2 Soft, very ductile, and thin deposits are generally not suited for this technique.

13. Scribe-Grid Test

13.1 Scribe three or more parallel lines or a rectangular grid pattern on the article using a hardened steel tool ground to a sharp (30°) point with a distance between the scribed lines of approximately ten times the nominal coating thickness, with a minimum distance of 0.4 mm. In scribing the lines, use sufficient pressure to cut through the coating to the substrate in a single stroke. If any portion of coating between the lines breaks away from the substrate, the adhesion is inadequate.

13.2 When apparently satisfactory adhesion is indicated, apply a pressure-sensitive tape, having an adhesion bond strength of at least 45 g/mm, using firm finger pressure onto a clean grid area. Make sure that any loose coating particles from scribing do not remain. Shortly thereafter, remove the tape by seizing a free end and pulling it off rapidly (not jerked) back upon itself as close to an angle of 180° as possible. The adhesion is not adequate if the tape has deposit adhering to it that comes from the area between the scribed lines. Deposit continuous to the scribed lines is not considered.

13.2.1 The tape supplier[4] shall specify that their tape has a sufficient adhesion bond strength. The tape shall be wide enough to cover three or more parallel lines of the scribed area.

13.3 Generally, thick deposits are not suitable for evaluation unless a chisel or other sharp instrument is used to pry the exposed coating/substrate interface, in which case this technique becomes a variant of Section 5.

14. Test-Coating Systems

14.1 Recommended adhesion tests for a variety of coating systems are given in Table 1.

15. Precision and Bias

15.1 No statement is made about the precision and bias of these tests because of their qualitative nature.

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[3] Saubestre, E. B., Durney, L. J., Hajdu, J., and Bastenbeck, E., *Plating*, Vol 52, October 1965, pp. 982–1000.

[4] Permacel 99, a product of and manufactured by Permacel, New Brunswick, NJ 08903, is reported to be a suitable product for this purpose.

16. Keywords

16.1 adhesion; metallic coatings