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Standard Practice for Determining the Adhesion of Prints and Laminating Films[1]

This standard is issued under the fixed designation F2226; 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.

ε[1] NOTE—The units of measure were editorially corrected in December 2009.

1. Scope

1.1 This practice covers procedures for printing a document, applying a laminating film and subsequently delaminating. The laminate film is used for encapsulating and mounting prints to preserve them in office and outdoor environments.

1.2 This practice describes procedures for determining the adhesion strength of lamination film when it is applied to black and white and color prints produced by printers, copiers and other reprographic devices.

1.3 This practice can be used to test different laminates with a given set of inks and media or it can be used to evaluate inks and media with a given laminate.

1.4 This practice specifies size of specimens and defines conditions for measurement of peel adhesion at a 180° angle and delamination speed.

1.5 This practice is applicable to constructions where the substrate surface is subject to failure under peel conditions.

1.6 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.7 *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. Terminology

2.1 *Definitions:*

2.1.1 *high temperature lamination*—lamination at temperature not lower than 180°F (80°C). The maximum applied temperature is 240 to 250°F (115 to 121°C).

2.1.2 *lamination film*—plastic film having an adhesive layer on one side. The film can be glossy, semi-glossy, or matte and contain additives modifying its optical properties. The film usually has a thickness between 1 to 10 mils (25 to 250 µ).

2.1.3 *low temperature lamination*—lamination at room temperature with applied pressure mostly to mounting board using a pressure-sensitive adhesive.

2.1.4 *mounting board*—paperboard, plastic board, or any supporting board, which could be used to display prints.

2.1.5 *printed media*—recording elements used by printers to receive inks or toners. The substrate may be paper, plastic, canvas, fabric, or other ink receptive material. The substrate may, or not, be coated with an ink receptive layer(s).

2.2 *Definitions of Terms Specific to This Standard:*

2.2.1 *adhesion strength of a laminate*—load per unit necessary to remove the laminate from a prescribed surface when measured in accordance with this test method.

2.2.2 *delaminating/debonding*—separation of a laminating film from a printed media.

2.2.3 *kinetic peak*—load per unit presenting the maximum force that occurs during the average time during the peel test. See Fig. 1.

2.2.4 *peel or stripping strength*—the average load per unit width of sample required to separate or peel the laminate from the printed media at the adhered interface at a separation angle of approximately 180° and at a separation rate of preferably 12 in. (308 mm) per minute. It is expressed in Newtons per meter width, grams per inch width, or ounces per inch width.

2.2.5 *root-mean-square (RMS)*—a mathematical treatment of the force data intended to qualify the extent to which the value deviates about its average value.

2.2.6 *static peak*—load per unit presenting the maximum force that occurs during the delay time before starting the peel test. See Fig. 1.

2.2.7 *valley*—load per unit presenting minimum force during the average time under kinetic conditions. See Fig. 1.

3. Summary of Practice

3.1 Coated or uncoated substrate is printed under standard conditions using four primary, three secondary colors and composite black. Eight color strips 1 in. (2.54 mm) wide and one unprinted are generated.

[1] This practice is under the jurisdiction of ASTM Committee F05 on Business Imaging Products and is the direct responsibility of Subcommittee F05.03 on Research.

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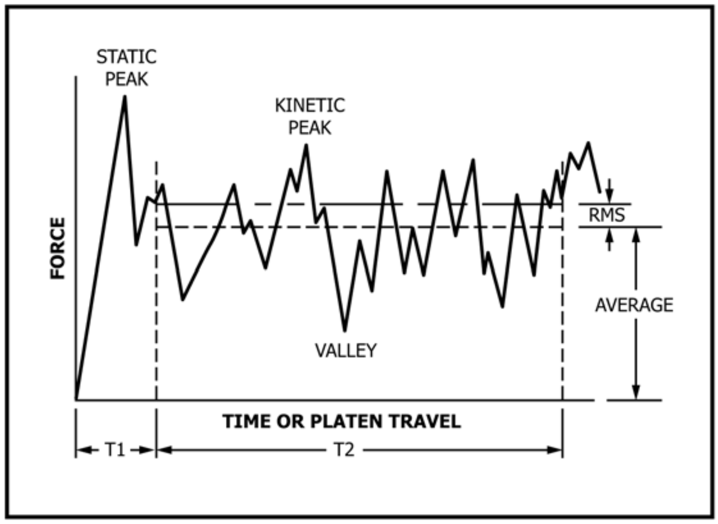

FIG. 1 Data Trace

3.2 The prints having eight color strips are conditioned (preferably for 24 h) and subsequently laminated.

3.3 The laminated prints are conditioned (preferably for 24 h), cut into 1 in. (25.4-mm) strips and subsequently delaminated.

3.4 Comparative studies require testing under well-defined conditions.

4. Significance and Use

4.1 The image life of printed media displayed in both typical office and outdoor environments can be extended by lamination or encapsulation. While natural aging is the most reliable method of assessing lamination adhesion, the length of the time required makes this method impractical for most materials. The peel strength method allows comparative studies of prints and laminating films.

4.2 Good adhesion is prime consideration for laminating films and prints. A laminating film, which does not adhere to a print or vice versa generally, has no commercial value. This method is used to obtain comparative data of peel strength of encapsulated or laminated media.

4.3 Peel strength can be measured up to a point where the peel strength is equal to the tensile strength of the adhesive or the print.

4.4 In many applications, having sufficient laminate adhesion strength is important to give satisfactory performance. The property is also important in determining the uniformity of quality.

4.5 A rough or raspy peel test will produce a higher RMS value than one that is smooth and continuous. It can be related to "zippering," "shocking," or "stick-slip."

4.6 *Bond Strength and Interfacial Adhesion*—The bond strength of a laminate essentially depends on both the adhesive and the cohesive strength of the laminating system. Peel strength of the laminate is typically determined by debonding the laminate using 180° peel test. Fig. 2 presents five possible modes of failure: (*1*) debonding of the ink receptive underlayer from the substrate (*2*) debonding of the ink receptive top layer from the underlayer, (*3*) debonding of the adhesive from the top ink receptive surface, (*4*) debonding the adhesive from the laminating film, (*5*) the substrate or film failure tear. The failure of the laminate will occur at its weakest link. It is generally desirable to have high bond strength to the recording element with failure occurring where the adhesive debonds from the ink receptive.

5. Interferences

5.1 Since the ability of laminating film to adhere to printed media is dependent on temperature and humidity, it is important that lamination be assessed under the conditions appropriate to the end use applications. While printed media may be handled and displayed under a variety of conditions, this test practice is intended to measure peel strength in typical office environments.

5.2 It is recognized that the peel strength of the laminate to the printed media is dependent on toner or ink color, toner or ink load, temperature and relative humidity. Additionally, it is dependent on the substrate, type and coat weight of absorptive layer and the colorant type (dye versus pigment). Consequently, test results must be determined individually for each printed recording media/laminate.

5.3 The peel strength of the laminate is dependent on lamination temperature and should be tested at the manufacturers recommended temperature for the best performance.

5.4 Using a laminating film thicker than 75 μ (3 mil) can create a problem in obtaining a 180° angle at the start of the test. A starting angle of less than 180° can significantly change the peel speed and mostly lead to delamination from the support instead of the coating (tearing of paper base).

5.5 The variation in recording and laminating elements requires carrying out comparative tests under well-defined conditions.

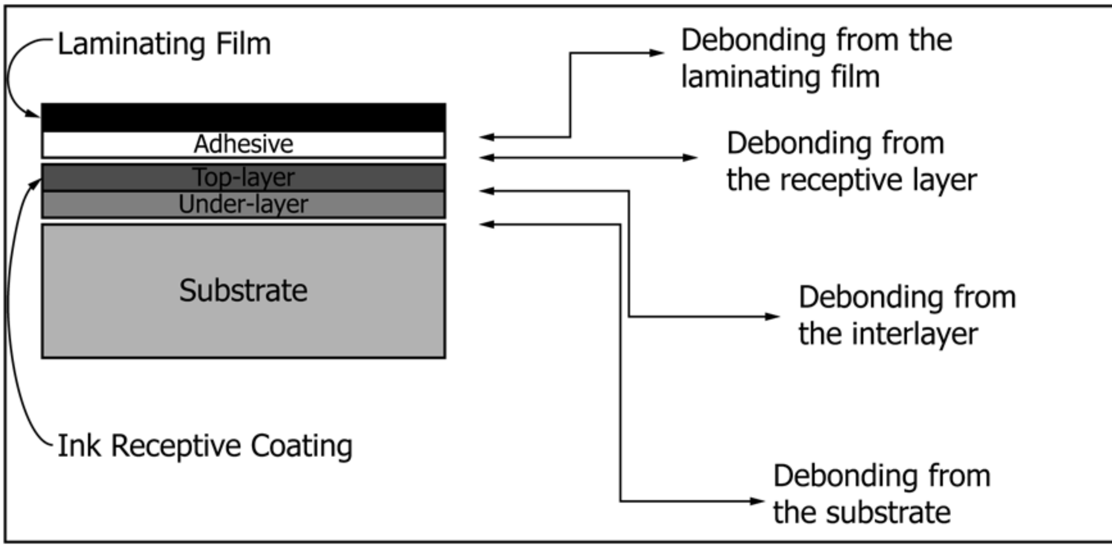

FIG. 2 Modes of Laminate Failure

5.6 Because these measurements concern surfaces, their condition is critical to the values obtained. Be sure to keep all print surfaces clean and free from contaminants, including fingerprints.

5.7 One of the most significant (and occasionally ignored) influences on peel values is the time that elapses from lamination until the test is performed. Values can change by 100 % depending on this "aging." Peel tests intrinsically produce quite a bit of data scatter from test to test. Keep a close watch on the results to be sure that your results are truly representative of your materials. Kinetic Peak and Valley provide important information about uniformity of lamination of the tested specimen.

5.8 Paper media have a tendency to tear the support after initial delamination from the bonding interface. It is well documented that at the same coat weight of ink receiving material, lighter paper media have higher tendency to support failure than heavier ones. Static Peak can be very useful in evaluation lamination performance of paper media. It is recommended to use Static Peak values to compare media having paper base failure. Additionally, it can also be used in evaluating media having delamination from the bonding interface. Media having paper failure but high Static Peak values are considered superior than media delaminated from the bond interface but having low peel strength.

5.9 Reducing laminating temperature could eliminate paper media failure. Lower laminating temperature reduces bonding strength between media and the laminate. In most cases, paper failure occurs when the laminate bonding strength is very high.

PRINTING

6. Test Specimen

6.1 The substrate, method of printing, ink or toner lay down, and handling of printed specimens shall be consistent with their anticipated end use.

6.2 The test image may be generated with personal computer using drawing/graphics, or page layout software able to generate composite black, saved as print file for each printer/method of printing (contributing its unique ink and ink/receiver interactions that may impact lamination.) Each print file should have its filename, type, and version identified in the image area and a place for experimental notes, for example, time, printer, environmental conditions, operator. The printer setting and a trial print of each print file version should be archived.

6.3 The recommended test image should consist of three primary and three secondary color strips 1 by 8.5 in. (25.4 by 215.9 mm) plus a non-printed strip 1 by 8.5 in. (25.4 by 215.9 mm). The colors should be printed in parallel in the following order: black (K), cyan, magenta, yellow, blue, green, red, white, composite black (C).

6.4 It is recommend to print in landscape mode having the 25.4-mm strips perpendicular to paper machine direction.

6.5 The test image used in comparison printers or inks (media laminated with the same film) should provide the same color elements.

7. Procedure

7.1 *Preparation of Printer*—When using an ink jet printer, print heads should be aligned, calibrated and checked for any nozzle clogging. Nozzle failure will reduce the ink lay down and can change peel strength.

7.2 The color strips printed should be generated using print files containing the appropriate printer setup specific for each application.

7.3 It is recommended that the color strip be printed as Postscript 3 file without color corrections using standard ink load limits or media selection. The printing mode is dependent on media type such as glossy photo, semi-glossy, paper bond, heavy-coated bond, and so forth.

7.4 Printing mode of the test image should be the same as recommended for media applications and available associated literature or a flyer.

7.5 Potential variables, such as temperature and relative humidity, must be monitored and controlled to guard against sample-induced changes.

7.6 Printing should be carried out at 73.4 °F (23°C) and 50 % relative humidity.

7.7 Printing can be done at extreme conditions such as 15°C, 20 % relative humidity and 38°C, 80 % relative humidity, but information about these conditions should be recorded with the lamination data.

8. Conditioning

8.1 It is recommended that samples be conditioned at 73.4 °F (23°C) and 50 % relative humidity for at least 24 h prior to printing and for at least 24 h subsequent to lamination. Specimens should be visually inspected for color uniformity and surface irregularities, which could adversely affect color densities and subsequently lamination.

8.2 The above conditioning step is pertinent only where media evaluation or comparison is needed. Obviously, as a production tool, the conditioning period is not practical. Therefore, when media are coated in production, the specimens should be obtained from each roll and checked as soon as possible in a repeatable procedure appropriate to the operation. It is imperative that operators use caution in selecting and preparing specimens to maintain good uniformity.

LAMINATION

9. Apparatus

9.1 A laminator used for continuous laminating, mounting and encapsulating. The laminator should have precise temperature control and different operating speeds to ensure that outgassing from inks does not effect adhesion or cause bubbles in the print. The laminator should:

9.2 Be capable of applying heat-activated or pressure-sensitive materials, or a combination of both.

9.3 Have an infinitely variable nip opening for all materials up to 1.5 in. (40 mm).

9.4 Have a digital or analog readout of speed.

9.5 Downward pressure and vacuum table are recommended.

10. Procedure

10.1 The print samples should be laminated 24 h after printing. The actual lamination time after printing should be presented in the report.

10.2 Before lamination, a strip of paper 2 by 8.5 in. (50.8 by 216 mm) should be placed vertically on the top of a portion of the printed test pattern for each of the colors. About half of paper strip should cover the printed area and the other half should cover the unprinted area. This procedure allows the free end of the test specimen to be separated.

10.3 Laminating films that are 75 μ (3 mil) thick should be used for comparison purposes. Thicker films: 5, 7, and 10 mils (125, 175, and 250 μ) make it difficult to obtain the 180°C angle required in the test. At lower angles the film has a tendency to rip the support instead of delaminating from the coating. Films that are 1 or 2 mil (25 or 50 μ) thick have a tendency to elongate affecting the peel speed.

10.4 The temperature of the upper and lower rollers of laminator should be measured by infrared sensor and recorded. For precise measured and repeatability of the test, the difference between set up temperature and laminating rollers temperature should not be higher than ±5°C.

10.5 Speed of lamination for paper media having base weight in the range 90 to 170 gms should be 3 ft/min (0.9 m/min). Lower or higher speed can be used depending on film thickness, paper base weight, and lamination temperature.

10.6 Lamination pressure can be expressed as a half crank or bars (psi) value if a laminator is equipped with a gage.

10.7 The print should be placed centrally in the laminator to minimize temperature variation along the rollers.

10.8 The printed samples should be conditioned 24 h before lamination at 73.4 ± 3.6°F (23 ± 2°C) and 50 ± 5 %.

10.9 The laminations can be carried out in the office environment. However, samples printed and conditioned at different temperatures and humidities other than the ones above should be handled in sealed plastic bags and immediately laminated. This procedure preserves moisture in the media and provides reproducible tests.

DELAMINATION

11. Sampling and Specimen Preparation

11.1 *Materials*—Razor blade, single edge or cutting board. Cellophane tape, 1 in. (25 mm) wide, #610 "Scotch" brand or equivalent.

11.2 Using the specimen cutter, cut nine 8.5 by 1 in. (215.9 by 25.4 mm) specimens for each color and unprinted background from the test image.

11.3 Prepare three test specimens for each lamination condition.

12. Conditioning

12.1 Normally, condition all laminate specimens 24 h by exposure to a relative humidity of 50 ± 5 % at 73.4 ± 3.6°F (23 ± 2°C) to provide additional time for equilibration of adhesive containing interfaces.

12.2 The above conditioning step is pertinent only when doing comparative testing where laminate films and media evaluation or comparison is needed. Obviously, as a production tool, the conditioning period is not practical. Therefore, when laminate adhesion is measured in production, the specimens should be obtained from each laminate roll and checked as soon as possible in a repeatable procedure appropriate to the operation.

13. Apparatus

13.1 A constant-rate-of-extension (CER) tension tester available from Instrumentors, Inc. Strongville, OH, adequate load range to handle all materials of this type, appropriate grips, and variable or at least 12 in. (304.8 mm) per minute test speed. The tester shall have two clamps (or one) with centers in the same plane, parallel with the direction of the motion of the stressing clam, and so aligned that they will hold the specimen wholly in the same plane.

13.2 Ensure that the peel tester is level.

13.3 Follow the manufacturer's instructions for zeroing and calibrating the peel tester and setting it to the proper speed and load range to properly measure the anticipated load.

13.4 The instrument shall be calibrated to an accuracy of 0.5 % of full scale and the readings are between 30 and 90 % of the full load range.

14. Procedure

14.1 The hardware setup for a typical 180° peel test is shown in Fig. 3.

14.2 The testing speed should be of 12 in. (304.8 mm) per minute, although higher speeds can be used for release force measurements.

14.3 Conduct testing as soon as possible after removal of the test specimens from the conditioning atmosphere and preferably under the same environmental conditions.

14.4 To maintain a separation rate of 12 in. (304.8 mm) per minute, specimens must be relatively non-extensible in the expected loading range. Where a material is sufficiently extensible (that is, stretch is greater than about 15 %) to radically lower the stripping rate, reinforce the extensible member with 1 in. (25.4 mm) width non-extensible tape or change the thickness of laminating film. In reporting such a test, the backing material and method must be completely identified. It is recommended to use 3 mil laminating film for media evaluation.

14.5 Cohesive or adhesive failure may be determined by observation. Cohesive failure refers to failure in the adhesive or specimen material itself. Adhesive failure refers to the lack of adherence between materials.

14.6 Paper strips placed on top of the test image before lamination allow the free ends to be separated from the test specimen (by hand) for a distance of approximately 2 in. (51 mm). It is not recommended to initiate delamination by pulling the coating from the substrate or separating the plies of the lamination.

14.7 Place the specimen in the tester by clamping the free end of the film with the protective paper in the grip. Attach the free end of the print to the platform by pressure-sensitive tape. The peel strength of the tape has to be higher than the peel strength of the test specimen.

14.8 Align the free ends of the specimen symmetrically in the grips so that the tension is distributed uniformly.

14.9 During the actual peel test procedure, it takes a small, but finite, amount of time for the peel forces to reach a dynamic equilibrium. The selectable Delay Time for the instrument inhibits the measurement of kinetic peak, valley, average and PMS values during the Delay Time. For most standards work, a delay of 1 or 2 seconds is satisfactory. For higher speeds, a 1 second may "waste" too much of the sample.

14.10 Begin the test. After the platform starts moving, and at the end of your selected Delay Time, the Averaging light will come on, persisting for the length of time that you selected as Average Time.

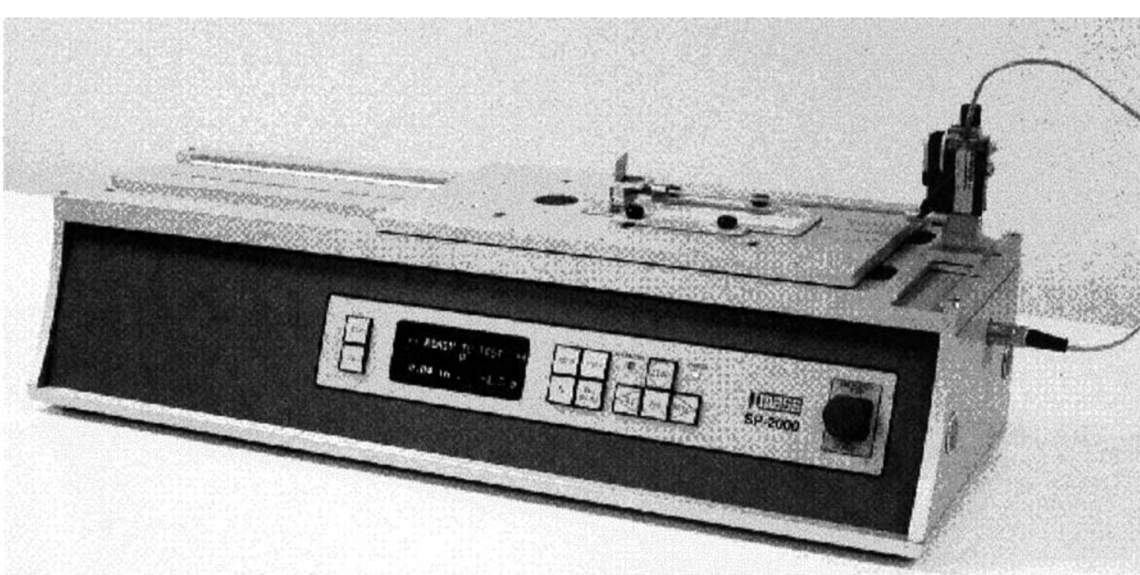

FIG. 3 Constant-Rate-of-Extension (CER) Tension Tester

14.11 At the end of that time, the platen will stop (depending on how you set up the (Platen Stop Mode) and the Results screen will display the test data.

14.12 Observe the peel force over a separation distance of at least 4 in. (101.6 mm) or the average time of at least 10 s. However, the time of 20 s is recommended. Then stop the tester and return the movable grip to its starting position. Remove the tested specimen.

14.12.1 The Average Time that you use will be dependent on the testing speed, the sample length, and, in certain instances, how much test time you can budget for each test. For lamination work, 10 s Average Time is a good value to start out with.

14.13 If the RMS is higher than 10 % of average load, the test should be repeated.

14.14 Repeat steps 14.3 – 14.12 with remaining specimens.

15. Interpretation of Results

15.1 Determine the peel or stripping strength for each specimen in Newtons per meter (or grams per 1 in.) width. For standard 1 in. (25.4 mm) width specimens, the peel value is equal to the recorded load. The average peel over the entire separation distance is the generally preferred value.

15.2 For each series of specimens, calculate the arithmetic average of all of the values obtained as the average for each color specimen and unprinted one.

15.3 Root-Mean-Square (RMS) is calculated according to the following formula:

$$RMS = \sqrt{\frac{\sum_{1}^{N} (L_N - L_{AVG})}{N}} \quad (1)$$

where:

L_N = instantaneous force sample,
L_{AVG} = previously determined mean of all N readings, and
N = total number of data samples.

NOTE 1—The type of equipment used to determine peel strength must be stated.

16. Report

16.1 Report the following information:

16.1.1 Specimen identification, including the printer, method of printing, and the media type.

16.1.2 Lamination temperature, speed, applied pressure on nip, relative humidity and temperature in the room, where lamination is carried out, and time after printing.

16.1.3 Individual test loads.

16.1.4 Average peel or stripping strength in Newtons per meter (or grams per 1 in.) width for each color and the unprinted area.

16.1.5 Type of failure (see 4.6).

16.1.6 In the case of paper failure the value of static peak should be also reported.

16.1.7 Any unusual characteristics. Include backing if required and the conditioning cycle if other than standard.

17. Precision and Bias

17.1 A statement of bias is not applicable in view of the unavailability of a standard reference for these properties.

18. Keywords

18.1 accelerate aging; adhesion; bond strength; debonding; delamination; encapsulating; high temperature laminates; ink jet; lamination; low temperature laminates; media; mounting; peel strength; pressure-sensitive laminates; printing; thickness

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