



Standard Test Method for Apparent Shear Strength of Single-Lap-Joint Adhesively Bonded Metal Specimens by Tension Loading (Metal-to-Metal)¹

This standard is issued under the fixed designation D1002; 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.

INTRODUCTION

The accuracy of the results of strength tests of adhesive bonds will depend on the conditions under which the bonding process is carried out. Unless otherwise agreed upon by the manufacturer and the purchaser, the bonding conditions shall be prescribed by the manufacturer of the adhesive. In order to ensure that complete information is available to the individual conducting the tests, the manufacturer of the adhesive shall furnish numerical values and other specific information for each of the following variables:

(1) Procedure for preparation of surfaces prior to application of the adhesive, the cleaning and drying of metal surfaces, and special surface treatments such as sanding that are not specifically limited by the pertinent test method.

(2) Complete mixing directions for the adhesive.

(3) Conditions for application of the adhesive, including the rate of spread or thickness of film, number of coats to be applied, whether to be applied to one or both surfaces, and the conditions of drying where more than one coat is required.

(4) Assembly conditions before application of pressure, including the room temperature, relative humidity, length of time, and whether open or closed assembly is to be used.

(5) Curing conditions, including the amount of pressure to be applied, the length of time under pressure, method of applying pressure (pressure bag, press platens, etc.), heat-up rate, and the temperature of the assembly when under pressure. It should be stated whether this temperature is that of the bondline or of the atmosphere at which the assembly is to be maintained.

(6) Conditioning procedure before testing, unless a standard procedure is specified, including the length of time, temperature, and relative humidity.

A range may be prescribed for any variable by the manufacturer of the adhesive if it can be assumed by the test operator that any arbitrarily chosen value within such a range, or any combination of such values for several variables will be acceptable to both the manufacturer and the purchaser of the adhesive.

1. Scope

1.1 This test method covers the determination of the apparent shear strengths of adhesives for bonding metals when tested

on a standard single-lap-joint specimen and under specified conditions of preparation and test.

1.2 The values stated in SI units are considered to be the standard. The values given in parentheses are for information only.

¹ This test method is under the jurisdiction of ASTM Committee D14 on Adhesives and is the direct responsibility of Subcommittee D14.80 on Metal Bonding Adhesives.

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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. Referenced Documents

2.1 ASTM Standards:²

- A109/A109M Specification for Steel, Strip, Carbon (0.25 Maximum Percent), Cold-Rolled
- A167 Specification for Stainless and Heat-Resisting Chromium-Nickel Steel Plate, Sheet, and Strip (Withdrawn 2014)³
- B36/B36M Specification for Brass Plate, Sheet, Strip, and Rolled Bar
- B152/B152M Specification for Copper Sheet, Strip, Plate, and Rolled Bar
- B209 Specification for Aluminum and Aluminum-Alloy Sheet and Plate
- B265 Specification for Titanium and Titanium Alloy Strip, Sheet, and Plate
- D907 Terminology of Adhesives
- D4896 Guide for Use of Adhesive-Bonded Single Lap-Joint Specimen Test Results
- E4 Practices for Force Verification of Testing Machines
- 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*—Many terms in this test method are defined in Terminology D907.

4. Significance and Use

4.1 This test method is primarily comparative. However, it does have application as a discriminator in determining variations in adherend surface preparation parameters and adhesive environmental durability. The test method has found applications in controlling surface preparations, primer, and adhesive systems for determining strength properties of tested systems.

4.2 The misuse of strength values obtained from this test method as design-allowable stress values for structural joints could lead to product failure, property damage, and human injury. The apparent shear strength of an adhesive obtained from a given small single-lap specimen may differ from that obtained from a joint made with different adherends or by a different bonding process. The normal variation of temperature and moisture in the service environment causes the adherends and the adhesive to swell or shrink. The adherends and adhesive are likely to have different thermal and moisture coefficients of expansion.

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 The last approved version of this historical standard is referenced on www.astm.org.

4.3 Even in small specimens, short-term environmental changes may induce internal stresses or chemical changes in the adhesive that permanently affect the apparent strength and other mechanical properties of the adhesive. The problem of predicting joint behavior in a changing environment is even more difficult if a different type of adherend is used in a larger structural joint than was used in the small specimen.

4.4 The apparent shear strength measured with a single-lap specimen is not suitable for determining design-allowable stresses for designing structural joints that differ in any manner from the joints tested without thorough analysis and understanding of the joint and adhesive behaviors.

4.5 Single-lap tests may be used for comparing and selecting adhesives or bonding processes for susceptibility to fatigue and environmental changes, but such comparisons must be made with great caution since different adhesives may respond differently in different joints. See Guide D4896 for further discussion of the concepts relative to interpretation of adhesive-bonded single-lap-joints.

5. Apparatus

5.1 The testing machine shall conform to the requirements of Practices E4. The testing machine shall be so selected that the breaking load of the specimens falls between 15 and 85 percent of the full-scale capacity. The machine shall be capable of maintaining a rate of loading of 80 to 100 kg/cm² (1200 to 1400 psi)/min, or, if the rate is dependent on crosshead motion, the machine should be set to approach this rate of loading, approximately 0.05 in./min. It shall be provided with a suitable pair of self-aligning grips to hold the specimen. It is recommended that the jaws of these grips shall engage the outer 25 mm (1 in.) of each end of the test specimen firmly.

5.2 The grips and attachments shall be so constructed that they will move into alignment with the test specimen as soon as the load is applied, so that the long axis of the test specimen will coincide with the direction of the applied pull through the center line of the grip assembly.

5.3 The length of overlap of the specimen may be varied where necessary. The length of the specimen in the jaws, however, must not be varied. The distance from the end of the lap to the end of the jaws should be 63 mm (2½ in.) in all tests.

6. Test Specimens

6.1 Test specimens shall conform to the form and dimensions shown in Fig. 1. These shall be cut from test panels prepared as prescribed in Section 7. The recommended thickness of the sheets is 1.62 ± 0.125 mm (0.064 ± 0.005 in.). The

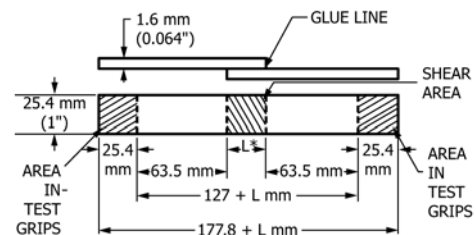


FIG. 1 Form and Dimensions of Test Specimen

recommended length of overlap for most metals of 1.62 mm (0.064 in.) in thickness is 12.7 ± 0.25 mm (0.5 ± 0.01 in.).

6.2 Since it is undesirable to exceed the yield point of the metal in tension during test, the permissible length of overlap in the specimen will vary with the thickness and type of metal, and on the general level of strength of the adhesive being investigated. The maximum permissible length may be computed from the following relationship:

$$L = F_{ty} t / \tau \quad (1)$$

where:

- L = length of overlap, in.,
- t = thickness of metal, in.,
- F_{ty} = yield point of metal (or the stress at proportional limit), psi, and
- τ = 50 percent of the estimated average shear strength in adhesive bond, psi.

6.3 A variation in thickness of the metal, and the length of overlap, will likely influence the test values and make direct comparison of data questionable. For this reason, in comparative or specification tests, the thickness should preferably be 1.62 ± 0.125 mm (0.064 ± 0.005 in.) and the length of overlap should preferably be 12.7 ± 0.25 mm (0.5 ± 0.01 in.), or not in excess of the value computed in 6.2. For development tests values could be different, but should then be constant.

6.4 The following grades of metal are recommended for the test specimens:

Metal	ASTM Designation
Brass	B36/B36M, C26800 (Alloy 8)
Copper	B152/B152M, C11000
Aluminum	B209, Alloy 2024, T3 temper
Steel	A109/A109M, Grade 2
Corrosion-resisting steel	A167, Type 302
Titanium	B265

6.5 At least 30 specimens shall be tested, representing at least four different joints. However, if statistical analysis of data and variance is employed, it should be possible to reduce this number.

7. Preparation of Test Joints

7.1 It is recommended that test specimens be made up in multiples of at least five specimens, and then cut into individual test specimens (Note 1), Fig. 2 and Fig. 3. Cut sheets of the metals prescribed in 6.1 and 6.4 to suitable size. All edges of the metal panels and specimens which will be within (or which will bound) the lap joints shall be machined true (without burrs or bevels and at right angles to faces) and smooth (rms 160 max) before the panels are surface-treated and bonded. Clean and dry the sheets carefully, according to the procedure prescribed by the manufacturer of the adhesive, and assemble in pairs. Prepare and apply the adhesive according to the recommendations of the manufacturer of the adhesive. Apply the adhesive to a sufficient length in the area across the end of one or both metal sheets so that the adhesive will cover a space approximately 6 mm (¼ in.) longer than the overlap as selected in Section 6. Assemble the sheets so that

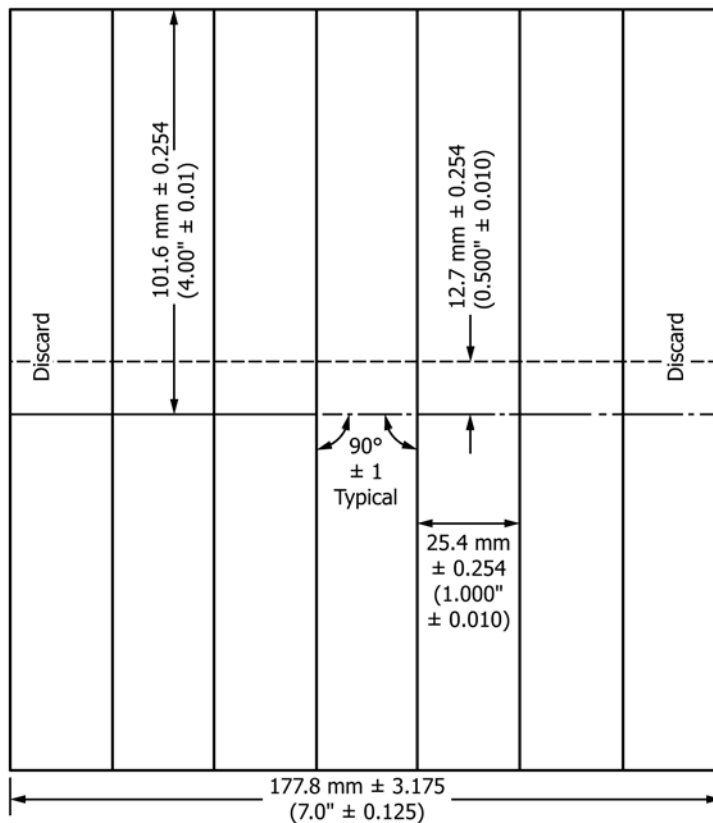


FIG. 2 Standard Test Panel

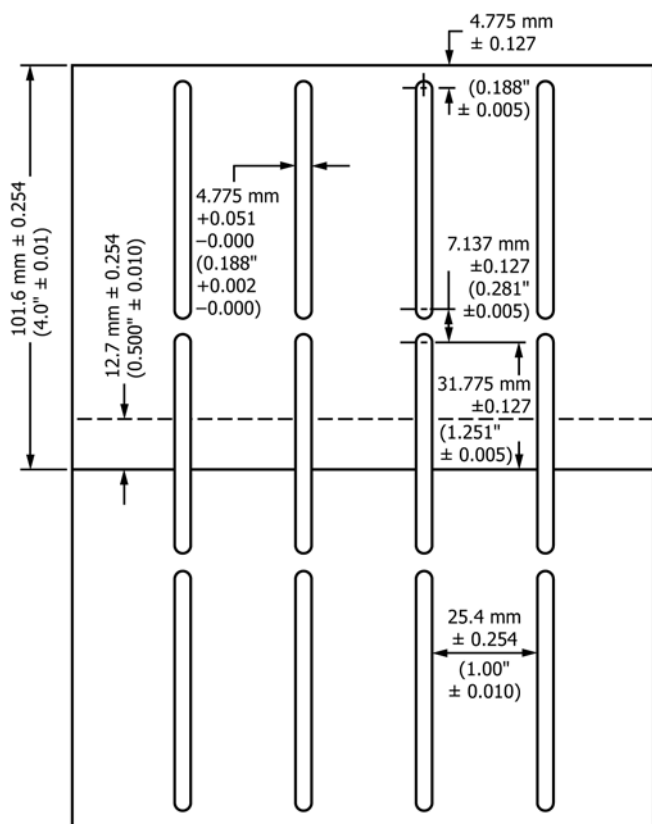


FIG. 3 Optional Panel for Acceptance Tests Only

they will be held rigidly so that the length of the overlap will be controlled, as indicated in Section 6, within 0.25 mm (± 0.01 in.), and the adhesive allowed to cure as prescribed by the manufacturer of the adhesive.

NOTE 1—Bonding specimens in multiple panels is believed to give more representative specimens. However, individual specimens may be prepared if agreeable to the supplier or the purchaser of the adhesive.

8. Preparation of Test Specimens

8.1 Cut the test specimens, as shown in Fig. 1, from the panels, Figs. 2 and 3. Perform the cutting operation so as to avoid overheating or mechanical damage to the joints (Note 2). For final preparation trim panel area according to Fig. 2. Measure the width of the specimen and the length of the overlap to the nearest 0.25 mm (0.01 in.) to determine the shear area.

NOTE 2—A five-tooth, typesetter’s circular saw has been found suitable for such purposes.

9. Procedure

9.1 Test the specimens, prepared as prescribed in Section 8, as soon after preparation as possible. The manufacturer of the adhesive may, however, prescribe a definite period of conditioning under specific conditions before testing.

9.2 Place the specimens in the grips of the testing machine so that the outer 25 mm (1 in.) of each end are in contact with the jaws (see 5.3) and so that the long axis of the test specimen coincides with the direction of applied pull through the center

line of the grip assembly. Apply the loading immediately to the specimen at the rate of 80 to 100 kg/cm² (1200 to 1400 psi) of the shear area per min. Continue the load to failure. This rate of loading will be approximated by a free crosshead speed of 1.3 mm (0.05 in.)/min.

10. Calculations

10.1 Record the load at failure and the nature and amount of this failure (cohesion in adhesive or metal, or adhesion) for each specimen. Express all failing loads in kilograms per square centimeter (pounds per square inch) of shear area, calculated to the nearest 0.06 cm² (0.01 in.²).

11. Report

11.1 Report the following:

11.1.1 Complete identification of the adhesive tested, including type, source, date manufactured, manufacturers’ code numbers, form, etc.,

11.1.2 Complete identification of the metal used, its thickness, and the method of cleaning and preparing its surfaces prior to bonding,

11.1.3 Application and bonding conditions used in preparing specimens,

11.1.4 Average thickness of adhesive layer after formation of the joint within 0.001 in. (0.025 mm). The method of obtaining the thickness of the adhesive layer shall be described including procedure, location of measurements, and range of measurements.

11.1.5 Length of overlap used,

11.1.6 Conditioning procedure used for specimens prior to testing,

11.1.7 Number of specimens tested,

11.1.8 Number of joints represented and type of joint if other than single overlap,

11.1.9 Maximum, minimum, and average values for the failing load, and

11.1.10 The nature of the failure, including the average estimated percentages of failure in the cohesion of the adhesive, contact failure, and adhesion to the metal.

12. Precision and Bias

12.1 The precision of this test method is based on an interlaboratory study of D1022, Test Method for Apparent Shear Strength of Single-Lap-Joint Adhesively Bonded Metal Specimens by Tension Loading (Metal-to-Metal), conducted in 2006. Eleven laboratories tested four different adhesive/substrate combinations for calculated failing stress, percent adhesion to metal, and percent cohesion of adhesive. Every “test result” represents an individual determination. The laboratories were asked to report five replicate test results from each of two different times (a.m. and p.m.) for every adhesive/substrate combination. Following the initial data review, and internal investigations by the participants, qualified data from only five of the laboratories were utilized in determining the final precision statistics. Practice E691 was followed for the design and analysis of the data; the details describing the

TABLE 1 Calculated Failing Stress (Kg/cm^2)

Combination/Time	Average Failing Stress (Kg/cm^2) ^A	Repeatability Standard Deviation	Reproducibility Standard Deviation	Repeatability Limit	Reproducibility Limit
	\bar{x}	s_r	S_R	r	R
Adhesive A, Substrate 1 AM	170.48	8.39	10.79	23.49	30.20
Adhesive A, Substrate 1 PM	163.18	8.67	20.19	24.26	56.53
Adhesive B, Substrate 1 AM	134.89	10.51	12.64	29.43	35.40
Adhesive B, Substrate 1 PM	131.58	7.49	12.56	20.98	35.17
Adhesive A, Substrate 2 AM	203.88	8.45	9.89	23.67	27.69
Adhesive A, Substrate 2 PM	193.56	7.01	22.96	19.63	64.29
Adhesive B, Substrate 2 AM	148.72	8.89	9.71	24.90	27.18
Adhesive B, Substrate 2 PM	144.47	7.66	10.47	21.45	29.31

^A The average of the laboratories' calculated averages.

TABLE 2 Percent Adhesion to Metal (%)

Combination/Time	Average Adhesion to Metal (%) ^A	Repeatability Standard Deviation	Reproducibility Standard Deviation	Repeatability Limit	Reproducibility Limit
	\bar{x}	s_r	S_R	r	R
Adhesive A, Substrate 1 AM	0.0	0.0	0.0	0.0	0.0
Adhesive A, Substrate 1 PM	0.0	0.0	0.0	0.0	0.0
Adhesive B, Substrate 1 AM	36.2	23.0	48.2	64.3	100 ^B
Adhesive B, Substrate 1 PM	47.2	12.2	51.3	34.3	100 ^B
Adhesive A, Substrate 2 AM	0.0	0.0	0.0	0.0	0.0
Adhesive A, Substrate 2 PM	0.0	0.0	0.0	0.0	0.0
Adhesive B, Substrate 2 AM	33.2	20.6	46.1	57.8	100 ^B
Adhesive B, Substrate 2 PM	40.8	4.2	51.1	11.7	100 ^B

^A The average of the laboratories' calculated averages.

^B Percent adhesion and cohesion cannot exceed 100 %.

distinct data populations and outliers that were identified are given in ASTM Research Report RR:D14-1017.⁴

12.1.1 *Repeatability Limit (r)*—Two test results obtained within one laboratory shall be judged not equivalent if they differ by more than the “*r*” value for that material; “*r*” is the interval representing the critical difference between two test results for the same material, obtained by the same operator using the same equipment on the same day in the same laboratory.

12.1.1.1 Repeatability limits are listed in [Tables 1-3](#).

12.1.2 *Reproducibility Limit (R)*—Two test results shall be judged not equivalent if they differ by more than the “*R*” value for that material; “*R*” is the interval representing the critical

difference between two test results for the same material, obtained by different operators using different equipment in different laboratories.

12.1.2.1 Reproducibility limits are listed in [Tables 1-3](#).

12.1.3 The above terms (repeatability limit and reproducibility limit) are used as specified in [Practice E177](#).

12.1.4 Any judgment in accordance with statements [12.1.1](#) and [12.1.2](#) would have an approximate 95 % probability of being correct for similar data populations.

12.2 *Bias*—At the time of the study, there was no accepted reference material suitable for determining the bias for this test method, therefore no statement on bias is being made.

12.3 The precision statement was determined through statistical examination of the results from eleven laboratories, on four adhesive/substrate combinations which were described as follows:

⁴ Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:D14-1017. Contact ASTM Customer Service at service@astm.org.

TABLE 3 Percent Cohesion of Adhesive (%)

Combination/Time	Average Cohesion of Adhesive (%) ^A	Repeatability Standard Deviation	Reproducibility Standard Deviation	Repeatability Limit	Reproducibility Limit
	\bar{x}	s_r	S_R	r	R
Adhesive A, Substrate 1 AM	100.0	0.0	0.0	0.0	0.0
Adhesive A, Substrate 1 PM	100.0	0.0	0.0	0.0	0.0
Adhesive B, Substrate 1 AM	63.8	23.0	48.2	64.3	100 ^B
Adhesive B, Substrate 1 PM	52.8	12.2	51.3	34.3	100 ^B
Adhesive A, Substrate 2 AM	100.0	0.0	0.0	0.0	0.0
Adhesive A, Substrate 2 PM	100.0	0.0	0.0	0.0	0.0
Adhesive B, Substrate 2 AM	66.8	20.6	46.1	57.8	100 ^B
Adhesive B, Substrate 2 PM	59.2	4.2	51.1	11.7	100 ^B

^A The average of the laboratories' calculated averages.

^B Percent adhesion and cohesion cannot exceed 100 %.

Adhesives

Adhesive A: two-component methacrylate-epoxy hybrid

Adhesive B: toughened two-component epoxy

Substrates

Substrate 1: B209 aluminum (2024T3) 0.063 in. thick

Substrate 2: A109 cold rolled steel (1008) 0.063 in. thick

Surface Preparation

All substrates were cleaned using clean, and frequently replaced cloths soaked with isopropyl alcohol.

12.3.1 To judge the equivalency of two test results, it is recommended to choose the combination closest in characteristics to the test combination.

13. Keywords

13.1 adhesives; metal-to-metal; shear strength; single-lap joint; tension loading

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