



Designation: D6412/D6412M – 99 (Reapproved 2020)

## Standard Specification for Epoxy (Flexible) Adhesive For Bonding Metallic And Nonmetallic Materials<sup>1</sup>

This standard is issued under the fixed designation D6412/D6412M; 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 ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

### 1. Scope

1.1 The specification covers a two-part modified epoxy paste adhesive for bonding metallic and nonmetallic materials. The adhesive should be suitable for forming bonds that can withstand environmental exposure to temperatures from  $-184$  to  $82$  °C [ $-300$  to  $180$  °F] when exposed to an expected combination of stress, temperature, and relative humidity to be encountered in service.

NOTE 1—When coordinated through the Department of Defense (DoD) and the National Aeronautics and Space Administration (NASA), this practice will be a direct replacement of MIL-A-82720 (OS), MIS-26872, and MSFC-SPEC-2037.

1.2 The values stated in SI units or inch-pound units are to be regarded separately as standard. Within the text, the inch-pound units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with this specification.

1.3 The following precautionary statement pertains to the test method portion only, Section 8, of this specification: *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.*

1.4 *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.*

### 2. Referenced Documents

#### 2.1 ASTM Standards:<sup>2</sup>

**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)<sup>3</sup>

**B209** Specification for Aluminum and Aluminum-Alloy Sheet and Plate

**D907** Terminology of Adhesives

**D1002** Test Method for Apparent Shear Strength of Single-Lap-Joint Adhesively Bonded Metal Specimens by Tension Loading (Metal-to-Metal)

**D1876** Test Method for Peel Resistance of Adhesives (T-Peel Test)

**D2240** Test Method for Rubber Property—Durometer Hardness

**D2393** Test Method for Viscosity of Epoxy Resins and Related Components (Withdrawn 1992)<sup>3</sup>

**D2651** Guide for Preparation of Metal Surfaces for Adhesive Bonding

**D3951** Practice for Commercial Packaging

**D4142** Guide for Testing Epoxy Resins

**E595** Test Method for Total Mass Loss and Collected Volatile Condensable Materials from Outgassing in a Vacuum Environment

#### 2.2 National Aeronautics and Space Administration (NASA):<sup>4</sup>

**JSC Sp-R-0022** General Specification, Vacuum Stability Requirement of Polymeric Material for Spacecraft Application

**MSFC-HDBK-527/JSC-09604** Material Selection List for Hardware Systems

<sup>1</sup> This specification 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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<sup>2</sup> For referenced ASTM standards, visit the ASTM website, [www.astm.org](http://www.astm.org), or contact ASTM Customer Service at [service@astm.org](mailto:service@astm.org). For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

<sup>3</sup> The last approved version of this historical standard is referenced on [www.astm.org](http://www.astm.org).

<sup>4</sup> Unless otherwise indicated, copies of the above documents are available from any NASA installation library or document repository.



## GSFC RP 1124 Outgassing Data for Selecting Spacecraft Materials

NOTE 2—Copies of specifications, standards, drawings and publications required by suppliers in connection with specific purchases should be obtained from the purchaser or as directed by his contracting officer.

### 3. Terminology

3.1 *Definitions*—Many terms in this specification are defined in Terminology **D907**.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *epoxy-polyamide high viscosity adhesive, n*—an epoxy paste base (B) and a modified amide paste accelerator (A) when mixed in a proper ratio results in a viscous paste.

3.2.2 *epoxy-polyamide low viscosity adhesive, n*—an epoxy liquid base (B) and a modified amide liquid accelerator (A) when mixed in a proper ratio results in a viscous liquid.

### 4. Significance and Use

4.1 *General*—This specification provides testing procedures and specimen requirements to differentiate between the physical and adhesive bonding properties of two types of epoxy-polyamide adhesive.

### 5. Classification

5.1 The epoxy-polyamide adhesive shall be furnished as one of the following types:

5.1.1 *Type I*—Consists of two-part kits of Part B, base and Part A, accelerator.

5.1.1.1 *Grade 1*—The high viscosity adhesive system is composed of an epoxy base (B) and a modified polyamide accelerator (A).

5.1.1.2 *Grade 2*—The low viscosity adhesive system is composed of an epoxy liquid base (B) and a modified polyamide liquid accelerator (A).

5.1.2 *Type II*—Consists of premixed, frozen, Type I, Grade 1 or Type I, Grade 2.

### 6. Ordering Information

6.1 *Procurement Documents*—Purchasers may select any of the desired options offered herein and the procurement documents should specify the following:

6.1.1 Title, number and dated revision letter of this specification,

6.1.2 Adhesive type and grade numbers,

6.1.3 Amounts and unit quantities of adhesive required,

6.1.4 Curing conditions,

6.1.5 Level of Packaging and packing required, and

6.1.6 Whether or not qualification (see **6.2**) is necessary.

6.2 *Qualification*—In the case the adhesives for which the purchaser requires qualification, the procurement documents should state that the awards will be made only for adhesives that are qualified at the time set for opening of bids.

### 7. Test Requirements

7.1 *Material*—The adhesive shall be thermosetting and, when tested using the tests described in Section 8 shall meet the strength requirements of this specification. The adhesive

shall not have a detrimental effect on the surfaces being bonded over the range of temperatures at which the adhesives will be used.

7.2 *Qualification*—The adhesive shall be qualified at the time for opening of bids. The qualification shall only apply to the formulation on which the qualification tests have been made (see **6.2**). Any changes by the manufacturer in formulation or in the method of manufacturing, shall be cause of designating the adhesive as a new product.

7.3 *Processing*—Methods of specimen surface preparation, that is, cleaning and etching adherends, cure time, temperature and pressure shall be in accordance with the manufacturer's recommendation.

7.4 The physical, mechanical and outgassing properties of the adhesive shall meet the requirements specified in **Table 1**. Although, it is not listed in **Table 1**, Type II materials shall meet the same requirements as Type I materials.

### 8. Test Methods

8.1 *Qualification Tests*—For qualification, the adhesive shall be tested using the tests described in this section. Test methods and requirements are included in **Table 1**.

8.2 *Preparation of Test Specimens:*

8.2.1 *Tensile Shear:*

8.2.1.1 *Adherend*—The metal bonded shall be 6061-T6 or 2024-T3 aluminum alloy.

NOTE 3—The use of steel substrates for the evaluation and lot acceptance of the material is optional at the discretion of the procuring agency. Use Specification **A109/A109M** Grade 2 Steel or Specification **A167**, Type 302 corrosion resistant steel.

8.2.1.2 *Surface Treatment*—Adherend surfaces shall be cleaned and etched in accordance with Guide **D2651**.

8.2.1.3 *Cure*—Cure time, temperature and pressure shall be in accordance with the adhesive manufacturer's recommendation.

NOTE 4—Test panels or specimens, or both, other than the breakaway type shall be cut in such a manner that minimum vibration or heat is generated during the cutting operation.

NOTE 5—Adhesive bondline thickness for tensile shear specimens shall be 0.05 to 0.13 mm [0.002 in. to 0.005 in.] and 0.25 to 0.43 mm [0.010 to 0.017 in.] for T-Peel specimens. Control of bondline thickness shall be accomplished by placing two lengths of appropriate diameter stainless wire [0.13 mm for tensile shear and 0.43 mm for T-Peel] in the lengthwise direction on the specimen bond area during the adhesive bonding operation; the use of the same diameter glass beads approximately 0.5 % by weight, thoroughly mixed in the adhesive may also be used to maintain uniform bondline thickness.

8.2.2 Hardness specimens shall be prepared using a mixture of resin and catalyst for Type I Grades 1 or 2 in the ratios specified by the manufacturer or Type II premixed. Pour the thoroughly mixed material into an aluminum foil cup approximately 7.6 cm [3.0 in.] in diameter to a minimum thickness of 6.3 mm [0.25 in.]; cure per manufacturer's recommendation.

8.3 *Test Procedures:*

8.3.1 *Room-Temperature Tensile Shear*—Subject at least five specimens to a tensile shear test at normal temperature  $25 \pm 3^\circ\text{C}$  [ $77 \pm 5^\circ\text{F}$ ] in accordance with Test Method **D1002**.



**TABLE 1 Property Requirements for the Epoxy (Flexible) Adhesive**

Test <sup>A</sup>	Test Method	Requirement	
		Type I, Grade 1	Type I, Grade 2
Uncured Property			
Resin Weight, kg/liter (lb/gal)			
Part A		1.26 [10.5]-1.32 [11.0]	0.96 [8.0]-1.02 [8.5]
Part B		1.33 [11.1]-1.39 [11.6]	1.13 [9.4]-1.17 [9.8]
Viscosity, CPS @ 25 ± 3°C [77 ± 5°F]	D2393		
Part A		40 000-80 000 @ 20 rpm min	5000-9000 @ 20 RPM
Part B		75 000-150 000 @ 20 rpm min	1100-1500 @ 20 RPM
Cured Property			
Type I, Grade 1			
Cured at 25 ± 3°C [77 ± 5°F] for 7 days, or 2 h @ 66 ± 3°C [150 ± 5°F], or 30 min @ 93 ± 3°C [200 ± 5°F]			
Type I, Grade 2			
Cured at 25 ± 3°C [77 ± 5°F] for 30 days, or 4 h at 66 ± 3°C [150 ± 5°F], or 30 min @ 93 ± 3°C [200 ± 5°F]			
Room-Temperature Shear, MPa [psi]	D1002		
25± 3°C [77 ± 5°F]		17.2 [2500] min	8.2 [1200] min
High-Temperature Shear, MPa [psi]	D1002		
82± 3°C [180 ± 5°F]		2.8 [400]	1.42 [200]
Low-Temperature Shear, MPa [psi]	D1002		
55± 3°C [−67 ± 5°F]		20.7 [3000]	20.7 [3000]
Room-Temperature T-Peel, Kg/m [lb/in.]	D1876		
25± 3°C [77 ± 5°F]		466 [25]	446 [25]
Room-Temperature Shore D Hardness	D2240		
25± 3°C [77 ± 5°F]		50	40
Outgassing Characteristics	E595		
Total mass Loss (TML), %		≤1.00	≤1.00
Vacuum Condensible Material (VCM), %		≤0.10	≤0.10
Storage Life Test		A	A

<sup>A</sup> The storage life at the maximum recommended temperature and under the recommended storage conditions shall be stated in the manufacturer's data sheet.

**8.3.2 High-Temperature Tensile Shear**—Test at least five specimens at 60 ± 3°C [140 ± 5°F] and 82 ± 3°C [180 ± 5°F] in accordance with Test Method **D1002**. Bring the specimen to temperature as indicated by a temperature at the bondline and stabilize for 10 min. Stabilize the chamber at the test temperature for 45 min prior to testing.

**8.3.3 Low-Temperature Tensile Shear**—Test at least five specimens at 55 ± 3°C [-67 ± 5°F] in accordance with Test Method **D1002**. Bring the specimen to temperature as indicated by a thermocouple at the bondline and stabilize for 10 min. Stabilize the chamber at the test temperature for 45 min prior to testing.

**8.3.4 Room-Temperature T-Peel**—Test at least five specimens in accordance with Test Method **D1876** constructed from 2024-T3 alclad aluminum alloy or 6061-T6 aluminum 0.8 mm [0.032 in.] thick. T-peel specimens shall be etched in accordance with Guide **D2651**.

**8.3.5 Room-Temperature Shore D Hardness**—Conduct at least ten Shore hardness readings as required. Test in accordance with Test Method **D2240** at 25 ± 3°C [77 ± 5°F].

**8.3.6 Outgassing Requirements**—Outgassing shall meet the requirements of National Aeronautics and Space Administration (NASA) specification SP-R-0022 tested in accordance with Test Method **E595**.

## 9. Inspection

**9.1 Responsibility for Inspection**—Unless otherwise specified in the contract or purchase order, the supplier is responsible for the performance of all inspection requirements as specified herein. Except as otherwise specified in the contract or purchase order, the supplier may use his own or any other facility suitable for the performance of inspection requirement specified herein. The purchaser has the right to perform any of the inspections set forth in this specification where such inspections are deemed necessary to assure compliance with the requirements.

**9.2 Classification of Inspections**—The inspection requirements are classified as follows:

9.2.1 Qualification inspection (see **9.3**), and

9.2.2 Quality conformance inspection (see **9.4**).

**9.3 Qualification Inspection:**

**9.3.1 Qualification Test**—Unless otherwise specified by the purchaser, adhesives that have not passed the qualification tests, must be tested against this specification and proved to meet all its specified requirements.

9.3.1.1 At the option of the purchaser qualification tests may be performed at any time.



9.3.1.2 *Data Sheet*—A dated, coded, and titled data sheet stating the adhesive material property data and instructions for mixing, curing, application, handling, storage and shelf life shall be supplied by the manufacturer upon the initial purchase order. Reorders of the same material do not require a duplicate copy of the data sheet unless otherwise requested. The data sheet shall be forwarded along with the test report (see 9.3.2) when requesting qualification.

9.3.2 *Test Report*—In addition to the qualification test samples, the manufacturer shall furnish a certified, dated and numbered report giving the results of all tests listed in Section 8. The individual and average values for the test shall be reported. The test report shall include all the requirements of Section 7. The type of adherends, surface preparation including cleaning, etching and application of primer, assembly conditions, pressure, temperature and time of curing used in the preparation of the test panels shall be reported. The report shall certify that the preparation of the adhesive and test specimens conformed to the description given in the instruction sheet.

9.3.2.1 *Test Report*—The manufacturer shall submit with the test report (see 9.3.2) a copy of the data sheet that contains the information specified in 9.3.1.2.

#### 9.4 *Quality Conformance Inspection:*

9.4.1 *Lot Acceptance Tests*—Samples of each lot of adhesive delivered on contract or purchase order shall be subjected to the following: a test report shall be furnished for all quality conformance test specimen in this specification, and shall be signed by an authorized representative of the laboratory making the tests.

9.4.1.1 *Room-Temperature Tensile Shear Strength*—The room temperature tensile shear strength test shall be conducted in accordance with 8.3.1.

9.4.1.2 *High-Temperature Tensile Shear Strength*—Test shall be conducted in accordance with 8.3.2.

9.4.1.3 *Low-Temperature Tensile Shear Strength*—Test shall be conducted in accordance with 8.3.3.

9.4.1.4 *Room-Temperature T-Peel*—The room-temperature T-peel test shall be conducted in accordance with 8.3.4.

9.4.1.5 *Room-Temperature Shore D Hardness*—The room-temperature hardness test shall be conducted in accordance with 8.3.5.

9.4.1.6 *Outgassing Characteristics*—Outgassing characteristics for adhesive applications shall meet the outgassing requirements of NASA/JSC specification SP-R-0022A tested in accordance with Test Method E595.

### 10. Rejection

10.1 If the results of any test do not conform to the requirements prescribed in this specification, the lot shall be rejected.

### 11. Product Safety

11.1 A copy of the Safety Data Sheet (SDS) of the adhesive material shall be supplied by the manufacturer along with the data sheet upon the initial purchase order; reorders of the same adhesive material do not require an additional SDS copy accompanying the data sheet unless otherwise requested.

### 12. Packaging

12.1 *Packaging*—Packaging, packing and marking shall be in accordance with Practice D3951.

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