



# Standard Practice for Adhesive Bonding of Aluminum Facings in Foam and Beam Type Shelters<sup>1</sup>

This standard is issued under the fixed designation E 1801; 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 This practice covers the materials, processes, and quality controls to be used in the manufacture of adhesive-bonded, aluminum-faced, foam core sandwich panels for tactical shelters.

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

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:*

B 209 Specification for Aluminum and Aluminum-Alloy Sheet and Plate<sup>2</sup>

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<sup>1</sup> This practice is under the jurisdiction of ASTM Committee E06 on Performance of Buildings and is the direct responsibility of Subcommittee E06.53 on Materials and Processes for Durable Rigidwall Relocatable Structures.

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E 1730 Specification for Rigid Foam for Use in Shelter Sandwich Panel Cores<sup>3</sup>

E 1749 Terminology of Rigid Wall Relocatable Shelters<sup>3</sup>

E 1793 Practice for the Preparation of Aluminum Alloy for Bonding in Foam and Beam Type Transportable Shelters<sup>3</sup>

E 1794 Specification for Adhesive for Bonding Foam Cored Sandwich Panels (200°F Elevated Humidity Service), Type II Panels<sup>3</sup>

E 1800 Specification for Adhesive for Bonding Foam Cored Sandwich Panels (160°F Elevated Humidity Service), Type I Panels<sup>3</sup>

### 3. Significance and Use

3.1 The formation of reproducible, durable adhesive bonds in structural units requires great care in the performance of the steps in the bonding process. Experience has shown that adhesive bonding carried out in accordance with this practice produces reproducible adhesive bonds. This practice is applicable to both the Type 1, 71°C (160°F), and Type 2, 93°C (200°F), elevated humidity service type of foam and beam shelter.

### 4. Facilities

4.1 *Panel Assembly Layup Area*—The panel assembly layup area shall be a ventilated area maintained at a minimum temperature of 20°C (68°F). The area shall be free of oils, grease, silicone, lint, or other contaminants detrimental to the production of adhesive bonds.

4.2 *Post-Curing Rooms*—The post-curing rooms shall provide a uniform temperature distribution over all panels and over all portions of the panels exposed for post-curing. The total temperature range shall be no more than 14°C (25°F).

### 5. Apparatus

5.1 *Pressure Equipment*—Pressure equipment for bonding of shelter panels shall be large enough to permit the bonding of a complete panel in one step. The manufacturer shall provide calibration and test data demonstrating that the temperature on the two facings of the press platens during bonding will be equal and uniform within  $\pm 3^\circ\text{C}$  ( $\pm 5^\circ\text{F}$ ) of the indicated temperature. The platens shall be flat to within 0.08 mm/305 mm (0.003 in./ft) and shall be smooth having a maximum surface roughness of 125 rms. The pressure equipment shall be equipped with temperature and pressure recorders and controls that accurately control heat-up, pressure applied, and dwell time.

5.2 *Calibrations, Temperature and Pressure Requirements, and Controls*—Gages shall be calibrated every 6 months by an accredited independent laboratory or by the panel manufacturer if approved by the purchaser. All calibrations shall be traceable to the National Institute of Standards and Technology. The latest calibration certificate shall be attached to the equipment near each gage. Thermocouples placed at each corner and at the center of each facing shall be used to demonstrate the uniformity of the temperature. A permanent record of the pressure, time, and temperature during bonding shall be maintained.

5.3 *Calibration of Testing Equipment*—Calibration of the required testing equipment shall be done in accordance with the equipment manufacturer's instructions. All calibrations of test equipment required by this practice shall be traceable to the National Institute of Standards and Technology.

### 6. Materials

6.1 The materials used in bonded panels shall meet the requirements of the contract or specified drawings. All materials shall be stored and handled in such manner so as to provide protection against degrading environments and mechanical damage.

#### 6.2 Aluminum:

6.2.1 *Facings*—The facings shall be aluminum alloy conforming to Specification B 209 and shall be certified as complying with the alloy, temper, and thickness requirements of the shelter specification. Facings shall be free of corrosion, excessive oil canning (snap-buckling), dents, gouges, or other defects that may adversely affect the structural integrity of the bonded panel. Manufacturers' certification of reports of tests for mechanical properties and chemical composition shall be available or included with each shipment, or both.

#### 6.2.2 Preparation of Aluminum-Alloy Parts for Bonding:

6.2.2.1 *Type 1, 71°C (160°F), Elevated Humidity Service Shelters*—The aluminum-alloy parts used in the manufacture of Type 1 foam and beam panels shall be prepared for bonding in accordance with Specification ~~E 1800~~, E 1793. The surface resistance of 6061-T6 aluminum alloy test coupons cleaned by the same process, shall be no more than 100 microhms when measured under a nominal electrode force of  $4.14 \pm 1.70$  MPa ( $600 \pm 25$  psi) and a current of  $10 \pm 0.2$  amperes. Five coupons shall be tested during each 4 h of cleaning operations.

6.2.2.2 *Type 2, 93°C (200°F), Elevated Humidity Service Shelters*—The aluminum-alloy parts used in the manufacture of Type 2 foam and beam panels shall be prepared for bonding in accordance with Specification E 1794~~3~~. The surface resistance of the cleaned parts, or test coupons of the same alloy and cleaned by the same process, shall be no more than 100 microhms when

<sup>2</sup> Annual Book of ASTM Standards, Vol 02.02.

<sup>3</sup> Annual Book of ASTM Standards, Vol 04.11.

measured under a nominal electrode force of  $4.14 \pm 1.7$  MPa ( $600 \pm 25$  psi) and a current of  $10 \pm 0.2$  amperes. Five coupons shall be tested during each 4 h of cleaning operations.

6.3 *Foam Core*—The foam core material shall be as specified in the shelter specification and shall meet the requirements of Specification E 1730. Manufacturers' certification or reports of tests for conformance to this specification shall be available or included with each shipment, or both.

6.4 *Adhesives*—The adhesive shall conform to Specification E 1800 for Type 1 shelters or Specification E 1794 for Type 2 shelters. The adhesive shall be stored and used in accordance with the manufacturer's recommendations. Manufacturers' certification or reports of tests for conformance to this specification shall be available or included with each shipment, or both.

6.5 *Preparation of Nonmetallic Parts Prior to Bonding* —If necessary, all plastic, wood, and foam parts used in the construction of these shelters shall be prepared for bonding prior to the application of the adhesive. Parts with gouges, broken edges, splits or cracks, or other defects shall not be used.

## 7. Bonding and Curing

7.1 *Preparation of Materials Bonding*— All cutting, trimming, and sizing of aluminum, plastic, and wood parts shall be made prior to surface preparation or on the panel following completion of the bonding operation. The faying surfaces of aluminum parts to be bonded shall be prepared as designated in 7.2.2. All prepared aluminum for bonded panels shall be stored to prevent contamination of the bonding surface. Prepared parts that are not bonded within 72 h after cleaning shall be reprocessed as designated in 7.2. The faying surfaces of plastic and foam and wood parts to be bonded shall be as designated in 7.5 and 7.6 respectively. All material prepared for bonding shall be handled with clean cotton gloves to prevent contamination of surfaces prior to bonding.

7.1.1 *Adhesive Application*—Adhesive shall be applied uniformly on all faying surfaces of the parts being bonded. It shall be applied in such a manner and in sufficient quantity to fill all voids between faying surfaces and to ensure a continuous bond between parts as evidenced by adhesive flash (squeeze-out) at the edges when the parts are cured.

### 7.2 Assembly of Panels:

7.2.1 *Type 1 Panels*—No more than 75 min at 25°C (77°F) (45 min at 38°C (100°F)) shall elapse between the first application of adhesive to the panel and the application of pressure to that panel.

7.2.2 *Type 2 Panels*—No more than 2 h at 25°C (77°F) (45 min at 38°C (100°F)) shall elapse between the application of adhesive to the panel and the application of pressure to that panel.

### 7.3 Cure of Bonded Panels:

7.3.1 *Type 1 Panels*—Panels shall be cured at a temperature of not less than 52°C (125°F) for 4 h or at a temperature of 63°C ( $145 \pm 5$ °F) for not less than 1 h. Timing of the cure shall not start until the panel skins have reached the specified temperature. Either cure shall be under a pressure of  $0.05 \pm 0.007$  MPa ( $8.0 \pm 0.5$  psi). The temperature for either cure shall be fully attained within 2 h after the application of adhesive.

7.3.2 *Type 2 Panels*—Panels shall be cured at a temperature of not less than 93°C (200°F) for 90 min or at a temperature of 107°C (225°F) for 60 min. Timing of cure shall not start until the panel skins have reached the specified temperature. Either cure shall be under a pressure of  $0.05 \pm 0.007$  MPa ( $8.0 \pm 0.5$  psi). The temperature for either cure shall be fully attained within 3 h after the application of adhesive.

7.3.3 *Post-Curing*—When required by the contract or adhesive manufacturer's recommendation, bonded panels shall be stored at  $27 \pm 5$ °C ( $80 \pm 10$ °F) for a minimum of 24 h before further handling.

7.4 *Bonding Operation*—The bonding pressure shall be recorded for each bonding cycle. The pressure shall be maintained within 10 % of indicated pressure during the bonding cycle. Charts relating to the pressure and temperature shall be maintained as a permanent record.

7.5 *Storage and Handling of Bonded Panels*—Panels shall be handled with care to avoid damage such as skin punctures, dents, and delaminations. Unreinforced edges are particularly susceptible to damage. Clamps shall be applied to panels only in areas reinforced with structural members.

7.6 *Panel Cleanup*—Adhesive squeeze-out from the bond line shall be removed whenever part function or dimensional tolerances are adversely affected. The adhesive shall be removed by mechanical means such that dimensional tolerances are maintained and to preclude delaminations and grinding damage to the panel. Chemical strippers shall not be used.

## 8. Process Control

8.1 *Aluminum Facings*—Upon completion of the cleaning cycle per Specification E 1793, the aluminum facings shall be identified with a label or tape indicating the date and time of cleaning cycle. This label shall be used for determining the bonding time period per 7.2. The label or tape shall not transfer any residue to the facing when removed.

8.2 *Adhesive*—At the beginning of each bonding shift a calibration check of the mix ratio of the adhesive shall be performed. The ratio shall be within 10 % of the manufacturer's recommended mix ratio. For each 8 h of bonding operations, five adhesive lap shear test coupons 25.4 by 102 by 2.29 mm 6061-T6 aluminum alloy (1 by 4 by 0.090 in.) shall be cleaned per 8.1 and bonded with 12.7 mm ( $\frac{1}{2}$  in.) overlap using production adhesive. The test coupons shall be cured at production time and temperature and, when tested at room temperature, shall provide a minimum bond strength of 10.3 MPa (1500 psi) for Type 1 adhesive and 13.7 MPa (2000 psi) for Type 2 adhesive.

8.3 *Wood Parts*—During bonding operations, five wood production parts shall be tested at the beginning of the shift and at 4-h intervals for moisture content. Parts which have in excess of 12 % moisture content shall be redried prior to use. Testing shall be done using a wood moisture detector.<sup>4</sup>

8.4 *Fabricated Shelter Panels*—Completely fabricated shelter panels processed in accordance with the requirements of this practice shall be inspected and tested as specified. Each panel shall be inspected prior to subsequent processing. The shelter panels shall be inspected and tested in accordance with Section 10.

8.5 *Handling*—The laminated panels shall be handled with due care to avoid damage that would cause their rejection.

8.6 *Storage*—Bonded panels prepared in accordance with this practice shall be stored until required in such a manner as to protect them against damage and deterioration.

## 9. Certification

9.1 At the request of the purchaser in the contract or order, a manufacturer's certification shall be provided indicating that the panel-bonding process complied with this practice.

## 10. Quality Assurance

10.1 *Responsibility for Inspection*— Unless otherwise specified by the purchaser, the manufacturer is responsible for meeting all inspection requirements. The manufacturer may use his/her own or any other suitable facilities approved by the purchaser. The purchaser has the right to perform any of the tests and inspections set forth in this practice, and shall be provided every facility for careful inspection and sampling.

10.2 *Acceptability Criteria*—The bonding process shall conform to all requirements specified herein, and the test specimens shall pass all applicable examinations and tests in Section 10 of this practice. Failure to meet any test shall be cause for complete review of each process variable and for requalification of each constituent material to the extent necessary to determine the cause of the failure and take necessary corrective action. Items not in compliance with this practice and referenced documents in regard to materials, dimensions, tolerances, and workmanship shall be rejected.

10.3 *Component and Material Inspection*— The manufacturer is responsible for assuring that components and materials used are manufactured, examined, and tested in accordance with the requirements of the referenced standard.

10.4 *Visual Inspection of Panels*—After the bonded panels have cooled to the ambient temperature, and before further processing, visually inspect each bonded panel. Reject any panel that has a bulge, depression, or dent greater than twice the facing thickness. Reject any panel that has a bulge, depression, or dent greater than the facing thickness and an area greater than 5000 mm<sup>2</sup> (8 in.<sup>2</sup>). Reject any panel with a facing gouge deeper than one fourth the facing thickness. Measure deviation from flatness with a 1 m (39.4 in.) long straightedge and thickness gage while the panel is supported on a flat surface.

10.5 *Tapping Test*—Inspect both sides of each bonded panel for unbonded areas by either the tapping test or other nondestructive test approved by the purchaser to ensure that there are no delaminations or voids, or both, in the bonded areas. Tap test the panel in each 150 by 150 mm (6 by 6 in.) square of panel surface area. Perform the tapping test with a suitable tool chosen especially for the panel material being tested and by an inspector who has demonstrated that he/she has the ability to detect unbonded areas by the tapping test.

## 11. Keywords

11.1 bonding; foam and beam; tactical shelters

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<sup>4</sup> Delmhurst, Model G-30, or equivalent, has been found satisfactory.

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