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LIGHTWEIGHT COMPOSITE FIGHTING COVER PROTOTYPE DEVELOPMENT PROGRAM

FINAL REPORT

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R. C. Gwaltney
M. A. Akerman

MASTER

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LOCKHEED MARTIN ENERGY RESEARCH CORPORATION
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Engineering Technology Division

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ABSTRACT

The U.S. Army Field Assistance Science and Technology Program requested Oak Ridge National Laboratory (ORNL) to demonstrate the use of lightweight composite materials in construction of overhead covers for reinforced infantry fighting positions. In recent years, ORNL researchers have designed and tested several concepts for lightweight ballistic protection structures, and they have developed numerous prototype composite structures for military and civilian applications. In the current program, composite panel designs and materials are tested and optimized to meet anticipated static and dynamic load conditions for the overhead cover structure. Ten prototype composite covers were built at ORNL for use in Army field tests. Each composite cover has a nominal surface area of 12 ft^2 and a nominal weight of 8 lb. Four of the prototypes are made with folding sections to improve their handling characteristics. The composite covers exhibit equivalent performance in Army field tests to covers made with conventional materials that weigh four times as much.

1. INTRODUCTION

1.1. Background

Oak Ridge National Laboratory (ORNL) recently developed several lightweight composite fighting cover concepts for the United States Army Field Assistance Science and Technology (FAST) Program. The ORNL concepts incorporate design elements for minimizing total weight of the fighting cover structure, while providing ballistic protection against grenade fragments and direct fire from small-caliber weapons. At the request of FAST, ORNL provided plans for development of a very lightweight fighting cover concept that would have high load-bearing and blast capability, but would offer little ballistic protection when used alone. This plan also provided the opportunity for demonstrating lightweight composite cover concepts, including the manufacture of up to ten prototype covers for the Army.

1.2. Objective

ORNL has undertaken the mission to develop and demonstrate composite cover concepts that minimize overall weight of the cover structure and offer high static and dynamic load-bearing capabilities. Prototype development and demonstration activities are performed under an interagency work agreement between the Army (Number 93-4D116) and the Department of Energy (Number 1644-C002-A1). The prototype composite covers utilize technologies and expertise developed previously by ORNL in other lightweight multilayer ballistic shielding programs and in composite materials fabrication programs sponsored by the Department of Defense, the Department of Energy, and other federal agencies.

ORNL proposed several options to enhance the structural performance of Army fighting covers:

(1) Build a honeycomb-core panel that has graphite/epoxy veneers and carrying straps bonded to outside surfaces. The composite panel provides little or no ballistic protection, but it is able to withstand high static and dynamic loads with minimum weight.

(2) Divide the structural panel into three sections that are connected with hinges. This enhancement allows the composite cover to be folded for easier transportation by infantry personnel, and offers additional ballistic protection while folded.

(3) Panels described in Option 1 and Option 2 may be slipped into a ballistic nylon envelope that contains additional ballistic protection layers made from polyethylene (Spectra) or aramid (Kevlar or Nomex) fiber materials.

At the direction of the Army, inherent ballistic protection features are not included in the ORNL prototype demonstration. The demonstration is limited to minimizing the weight of the basic fighting cover structure. ORNL is to provide ten prototype composite covers that are designed to withstand high static and dynamic loads, using the lightweight graphite/epoxy composite concept (Option 1). Hinged sections (Option 2) are to be included on four of the ten panels.

1.3. Possible Uses

Composite covers are being considered for use in reinforcing infantry fighting positions. Dirt berms (or sandbags) are built up around the sides of a fighting position. The cover is placed over the fighting position, with two ends supported by the berms. Dirt (or sandbags) is piled on top of the cover to a depth of about two feet. The prepared position offers protection against shrapnel from near-miss artillery barrages, and is designed to withstand the a direct hit from a light mortar round without collapsing. Overall weight of the fighting cover should be no more than 35 lb.

The composite cover must suffer no degradation of its structural integrity from exposure to an outdoor environment. The most damaging conditions are caused by tropical environments, which expose the cover to heat and moisture for extended periods of time. In the past, the Army has used logs or plywood reinforced with wooden beams as fighting position covers. Tropical environments degrade the structural integrity of these wooden structures in only a few weeks. Furthermore the plywood covers, which must be used in areas without available timber, are not able to withstand a light mortar direct hit without collapsing.

The Army has conducted field tests to evaluate the performance of fighting covers in simulated battlefield conditions. Two parallel rows of sandbags are set up 24-30 in. apart. The fighting cover is placed on top of the sandbags, then covered over its entire surface with sandbags to a height of 24 in. The fighting cover is evaluated for a period of 30 days to determine if there is any deflection in addition to the initial deflection that occurred during loading. At the end of 30 days, ballistic tests are performed. An artillery barrage may be fired in the vicinity of the fighting position to produce near-miss shrapnel. Following the barrage, a charge containing 2 lb. of high explosive is set off on top of the sandbag-covered fighting cover to simulate a direct hit from a light mortar round. The direct force of this explosion is dampened by the 24-in. layer of sandbags, however a distributed dynamic load is still transmitted to the fighting cover. The cover is expected to deflect from the over pressure pulse and return to its normal position.

2. TECHNICAL APPROACH

2.1. Conceptual Design

ORNL has developed several ballistic protection concepts that are based on multiple-layer shields with significant internal spacing between selected layers. These designs offer inherent structural rigidity, as well as improved ballistic protection at reduced weight in comparison to either bulk materials or material laminates with no spacing. The ballistic protection features constitute the major source of weight in the ORNL shield concepts. Development of a composite cover that has no inherent ballistic protection allows ORNL researchers to focus on the lightweight structural characteristics of the multiple-layer spaced-shielding designs.

Performance tests for composite covers, as conducted in Army field exercises, can be reduced to equivalent worst-case static and dynamic load requirements for the evaluation of materials options and structural design details. The static load requirement is represented by the weight per unit area of sandbags or wet soil placed on top of the cover.

Static Load on Composite Panel

Wet soil or sand - 110 lb./ft.^{3}, 2 ft. depth
Total load on panel (12 ft.^{2}) = 2640 lb.
Unsupported load on panel (7.5 ft.^{2}) = 1650 lb.
Unit Area Static Load = 1.53 lb./in.^{2}

The dynamic load requirement is based on the over pressure pulse that is transmitted to the composite cover structure, through the 24-in. layer of soil from an explosive charge. The over pressure is related to the intensity of the blast and the distance from the explosion to the surface upon which the over pressure pulse is applied. The relationship is described by the following formula:

$$P^3 = L^3/W$$

in which
P is over pressure
L is distance from the blast
W is weight of explosive

The soil mass provides considerable attenuation of blast effects, as compared to a blast in air.

Dynamic Load on Composite Panel

Explosive Charge - 2 lb. C4, 2 ft. from cover
Over pressure (with attenuation through
24 in. of soil) = 25 lb./in.^{2}
Duration of pulse = 2.5 ms

2.2. Materials Selection

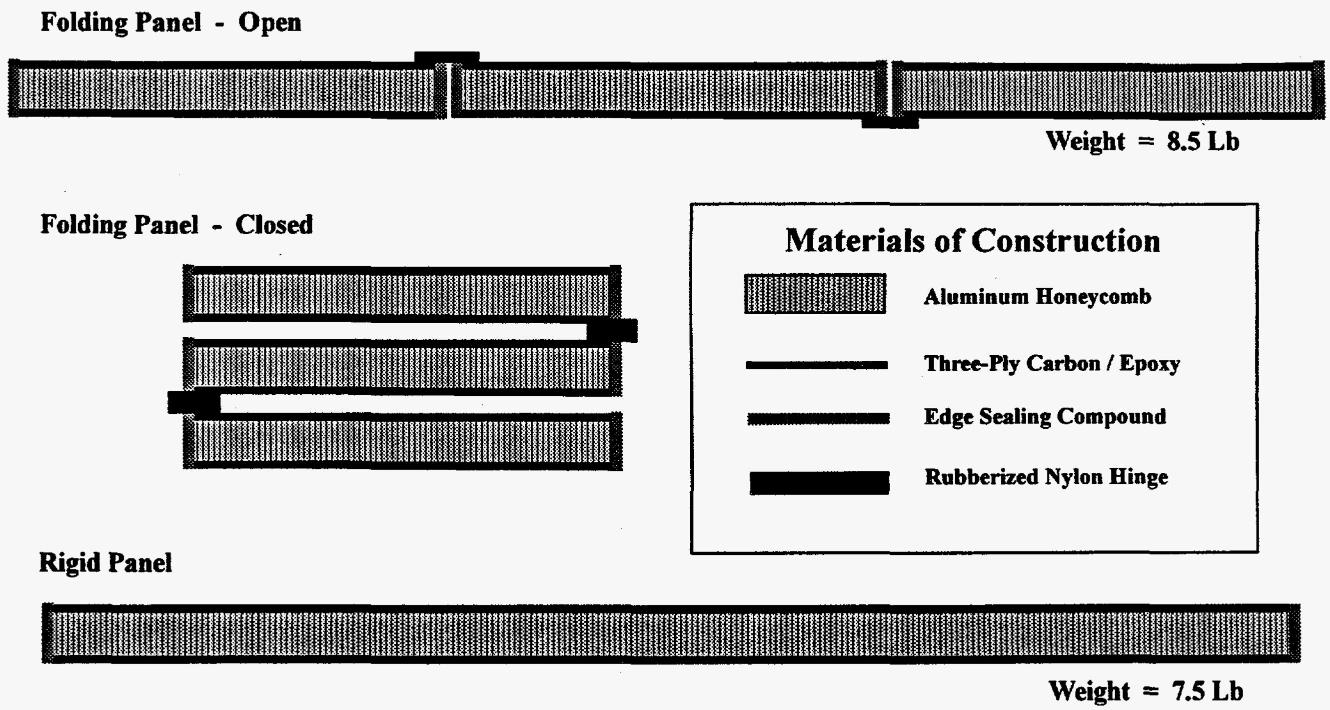
ORNL has been evaluating materials and lightweight structures for ballistic protection applications for nearly a decade. Ballistic shields incorporating a honeycomb core bonded to various materials as face sheets evolved as the best type of structure to resist over pressure loading from explosive detonations and projectile impingement from shrapnel or direct-fire weapons.

The lightweight composite cover is a sandwich structure that consists of face sheets bonded to a honeycomb core. Polymers incorporating several types of fiber reinforcement have been reviewed for use as face sheets in various ballistic protection fighting cover modifications. Performance characteristics of lightweight composite covers were evaluated using finite element analysis, presented in Appendix 1. The load bearing capability and over pressure resistance of the composite cover are maximized by increasing Young's modulus of the face sheets and increasing the Shear modulus of the core section. Carbon fiber reinforcement provides the highest Young's modulus in the face sheet materials. Optimizing the composite cover for minimum deflection and minimum weight drives the design to carbon fiber-reinforced face sheets, as shown in Figure 1.

Anticipated Static and Dynamic Load Deflections for
ORNL Lightweight Composite Fighting Cover - Preliminary Design

Constants	
Bending Deflection	0.01302
Shear Deflection	0.125
Lambda (1 - M^2)	0.9
Face Sheet - Carbon/Epoxy Prepreg (65% fiber fraction)	
Three-Ply Laminate - 0 / 90 / 0	
Young's Modulus (longitudinal)	13.0M psi
Young's Modulus (transverse)	7.0M psi
Core - Aluminum Honeycomb	
Shear Modulus	8.0K psi
Dimensions	
Facing Thickness (3 layers)	0.0156 in.
Section Thickness (core + facing)	0.5156 in.
Span	24 in.
Width	42 in.
Static Deflection	
Total Load (1.6 psi)	1575 lb.
Facing Deflection	0.1480 in.
Core Deflection	0.0273 in.
Total Deflection	0.1753 in.
Dynamic Deflection	
Total Load (26.6 psi)	31815 lb. (treat as static load)
Facing Deflection	2.9887 in.
Core Deflection	0.5509 in.
Total Deflection	3.5396 in.

Comparing the anticipated static deflections of fighting covers made with various materials options shows the degree of structural rigidity and weight savings that are obtained using carbon fiber reinforcement in the face sheets. Aluminum honeycomb is used as the core material in all options. Cover size is 12 $ft.^2$. Cover weight includes edge sealing compound, a low-density epoxy that prevents deformation of open cells at the outside edge of the honeycomb.



Designed and built for the U.S. Army Forces Command, Fort McPherson, by the U.S. Department of Energy Oak Ridge National Laboratory Engineering Technology Division

Figure 1. Conceptual Design for Lightweight Composite Fighting Covers

Face Sheet Reinforcement	Young's Modulus	Face Thickness	Core Height	Static Load Deflection	Cover Weight
Glass Fiber	2M psi	0.063 in.	1.5 in.	0.59 in.	13.2 lb.
Aluminum Metal	10M psi	0.063 in.	1.0 in.	0.58 in.	14.2 lb.
Aramid Fiber	19M psi	0.125 in.	1.0 in.	0.16 in.	13.5 lb.
Polyethylene Fiber	24M psi	0.125 in.	2.0 in.	0.07 in.	11.8 lb.
Carbon Fiber	33M psi	0.016 in.	0.5 in.	0.18 in.	5.5 lb.

2.3. Design Verification

Three-point bending tests were performed on composite panel specimens made with carbon fiber and a core thickness of 0.5 in. Specimens with surface dimensions of 10-in. by 1-in. were cut from 12-in. by 4-in. test panels. Each specimen was supported on two 1-in. diameter cylinders spaced 9.2-in. apart. Load was applied through a 1-in. diameter cylinder at mid-span using a hydraulic press. Deflection and load were monitored, along with strain on the tensile surface of the specimen.

Three specimens were of carbon fiber/0.5 in. core tested until failure. Failure was determined by evaluating the peak load sustained by each specimen. Failure mode was determined by examining the specimen after testing. The initial specimen suffered local deformation on the compression surface, directly under the mid-span cylinder. A 2-in. long spreader plate was used in the remaining tests.

Bending Test Results

Specimen	A	B	C
Peak Force (lb.)	80	128	120
Bending Moment (lb. in.)	---	230.4	216.0
Equiv. Uniform Load (psi)	---	21.7	20.4
Deflection (in.)	0.065	0.100	0.100
Deflection (calc.)	0.060	0.110	0.090
Failure Mode (observed)	Face Wrinkle	Core Buckle	Core Buckle

Quasi-isostatic uniform loads of 20-21 psi were predicted for specimens using equivalent bending moment at mid-span as the basis for calculations. It is interesting to note that both specimens tested with the spreader plate failed by buckling of one or more cell walls at a beam deflection of 0.100 in. The adhesive film used to join face layers to the core produced strong bonds that exceeded the shear strength of the core material. Damage to the three specimens is shown in Figure 2.

Based on these results, core thickness for the prototype lightweight composite cover was increased from 0.5 in. to 1.0 in. to increase the bending stiffness of the composite panel structure. Cell size and wall thickness of the honeycomb were modified to maintain equivalent weight for the core structure. The added section stiffness obtained by increasing the height of the core more than compensated for decreases in the specific stiffness of the materials and ensures that the composite structure will not deflect sufficiently under design loads to initiate failure by buckling of cell walls.

Anticipated Static and Dynamic Load Deflections for
ORNL Lightweight Composite Fighting Cover - Final Design

Constants	
Bending Deflection	0.01302
Shear Deflection	0.125
Lambda (1 - M^2)	0.9
Face Sheet - Carbon/Epoxy Prepreg (65% fiber fraction)	
Three-Ply Laminate	0°/90°/0°
Young's Modulus (longitudinal)	13.0M psi
Young's Modulus (transverse)	7.0M psi
Core - Aluminum Honeycomb	
Shear Modulus (span)	45.0K psi
Shear Modulus (cross)	1.5K psi
Dimensions	
Facing Thickness (3 layers)	0.0156 in.
Section Thickness (core + facing)	1.0156 in.
Span	24 in.
Width	36 in.
Static Deflection	
Total Load (1.6 psi)	1320 lb.
Facing Deflection	0.1066 in.
Core Deflection	0.0712 in.
Total Deflection	0.1778 in.

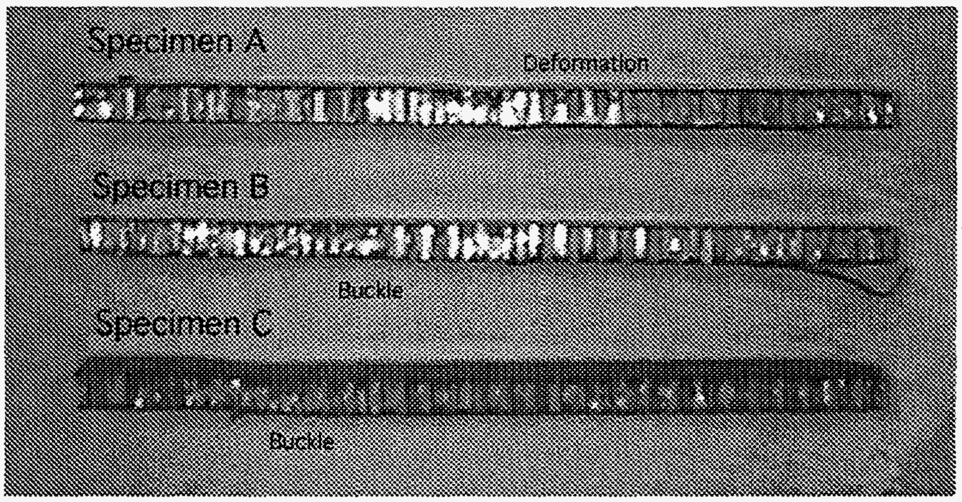


Figure 2. Design Verification Bending Test Specimens

Anticipated Static and Dynamic Load Deflections for
ORNL Lightweight Composite Fighting Cover - Final Design Continued

Dynamic Deflection	
Total Load (26.6 psi)	22920 lb. (treat as static load)
Facing Deflection	1.4791 in.
Core Deflection	0.0824 in.
Total Deflection	1.5615 in.

Face Sheet Reinforcement	Young's Modulus	Face Thickness	Core Height	Static Load Deflection	Cover Weight
Carbon Fiber	33M psi	0.016 in.	1.0 in.	0.18 in.	7.5 lb.

A somewhat less rigorous static load test was performed to confirm the predicted behavior of composite panel prototypes. A distributed load of 550 lb was placed on a 12 in. by 48 in. by 1 in. section of a lightweight folding composite cover, as shown in Figure 3. Beam deflection of 0.5 in. was observed at the midpoint of a 40-in. test span. The test panel is subjected to significantly higher compressive loading at the span supports, since the narrow edge of a 2x6 lumber beam provides only 18 in.^{2} of loading area at each support, versus an area of 72-144 in.^{2} for sandbags.

2.4. Processing Technology

Lightweight composite fighting covers are made in a six-step manufacturing process, including hinge attachment for folding covers. Face layers of three-ply carbon/epoxy are bonded to a core of aluminum honeycomb to form the basic composite cover structure. After resins in the structure have been cured, edges are trimmed to remove damaged or deformed honeycomb cells. The edges are then sealed with a low-density epoxy compound that fills in open cells to prevent their collapse in use. Individual panels in folding composite covers are then joined together with neoprene-coated nylon fabric hinges. The hinges are attached with an epoxy resin.

Step 1 - Prepreg Layup and Debulking

Carbon/epoxy composite face layers are made by laying up three plies of uniaxial prepreg tape. Ply orientations are 0°/90°/0°, using the long dimension of the panel as the reference axis. Excess air trapped between the plies is removed by applying a vacuum for 30 min.

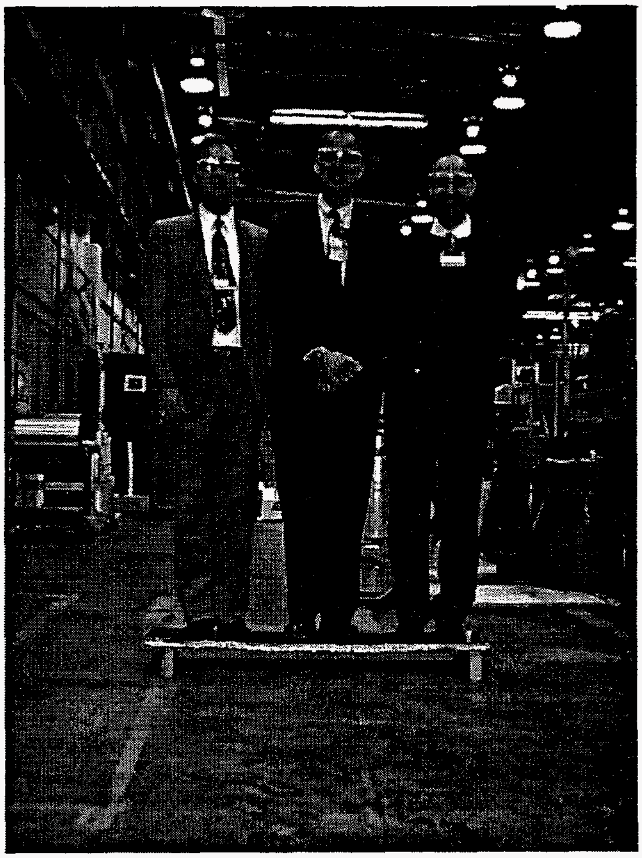


Figure 3. Design Verification Static Load Test Panel

Step 2 - Composite Structure Stack Assembly

Composite cover materials are assembled to form a flat panel structure that can be co-cured in one heat treatment. Folding panel section components are shown in Figure 4, along with a base plate and a completed panel. One three-ply facing layer is in the foreground, followed by a sheet of adhesive film that is placed atop the honeycomb core. Aluminum is used as a mold (base plate) for the panel structure. The entire stack assembly is shown schematically in Figure 5. It is built up as follows:

(1) base plate;
(2) release film;
(3) three-ply carbon/epoxy;
(4) adhesive film;
(5) honeycomb panel;
(6) adhesive film;
(7) three-ply carbon/epoxy;
(8) release film;
(9) caul plate;
(10) edge support frame;
(11) cheese cloth breather layer; and
(12) vacuum bag.

Note - It is of critical importance to the structural integrity of the composite cover that honeycomb cells are oriented with longitudinal direction (points) parallel to long dimension of the panel.

Note - The caul plate is required to prevent dimpling and wrinkling of the upper three-ply layer of carbon/epoxy. Air pressure resulting from the application of vacuum during the cure cycle is sufficient to deform the composite material unless it is protected with a caul plate. The plate must be flexible enough to conform to the contours of the base plate or mold.

Note - The edge support frame is required to prevent air pressure from acting on the sidewalls of the honeycomb layer during curing. Without edge support, air pressure deforms the honeycomb cells in the transverse direction. Use of the caul plate, alone, cannot prevent this deformation from occurring. The frame is made from aluminum angle stock 1.25 in. by 1.25 in. by 0.063 in. web. Frame dimensions (length, width, and height) need to be slightly larger than dimensions of the assembled panel components, but not extend below the bottom edge of the base plate.

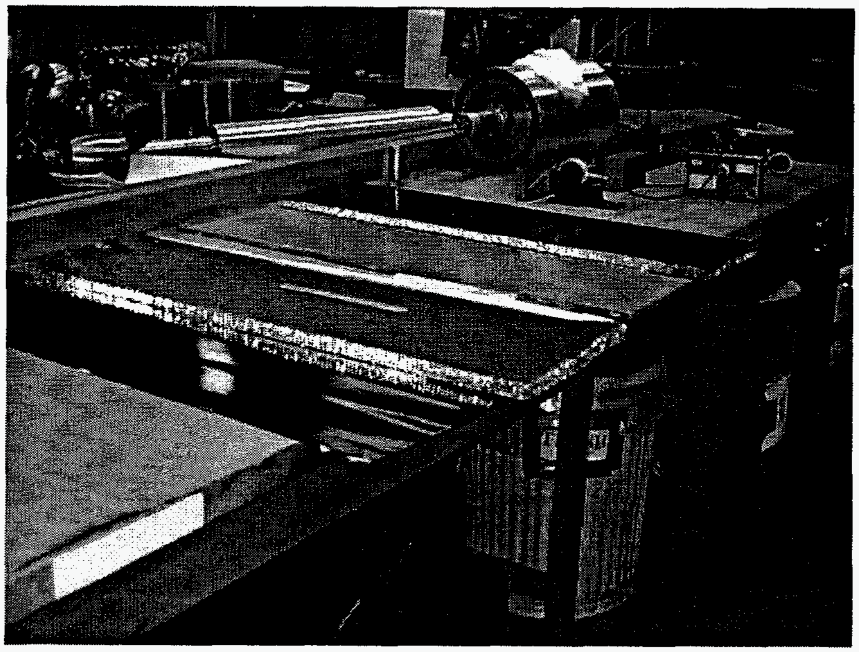


Figure 4. Composite Panel Layup Materials

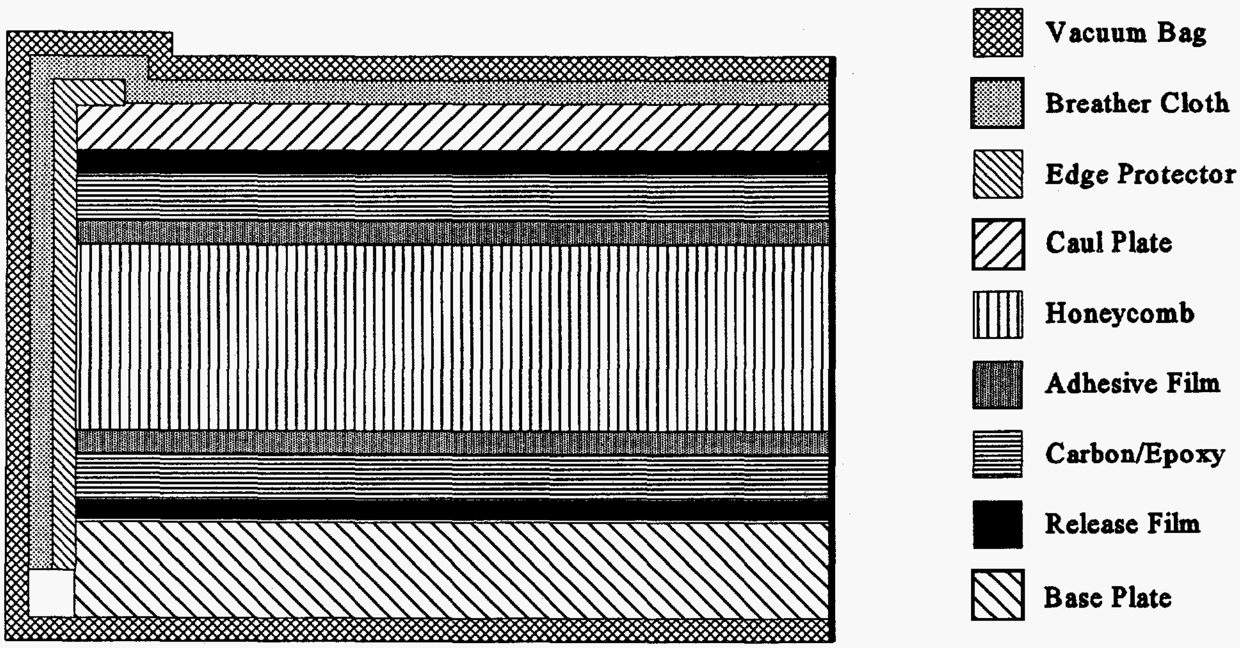


Figure 5. Composite Panel Stack Assembly

Step 3 - Vacuum-Assisted Oven Cure

The entire stack assembly, including the mold, is enclosed in a vacuum bag and placed in curing oven that is preheated to 100°F. Oven temperature is raised from 100°F to 250°F over a period of 25-35 min., then maintained at temperature for 120 min. Resins in the face layers and adhesive film layers bond the carbon fiber plies to each other and to the honeycomb, assisted by a combination of heat and air pressure. Vacuum is maintained throughout the cure cycle, including cool down from 250°F to 100°F.

Step 4 - Excess Stock Removal

Honeycomb materials are supplied in oversize sheets to allow removal of damaged or deformed edge cells following attachment to face layers. Composite panels are made with sufficient excess stock on each edge to ensure that all material in the usable portion of the panel contains face sheets bonded to correctly shaped core cells. Trimmed panels for a lightweight composite cover and one section of a folding cover are shown in Figure 6.

Machining experiments were performed to determine optimum cutting speed and feed rates for composite panels made with cores of 1-in. honeycomb. Cuts are made on a horizontal mill using a 6-in. diameter diamond wheel that is run at 500-600 rpm. The travel table on mill must have a working length of at least 54 in. Longitudinal cuts on the composite panel can be made at a feed rate of 1.0-1.5 in/min. Transverse cuts can be made at a feed rate of 0.7-1.0 in./min. Panels are marked near one longitudinal edge before cutting to ensure proper alignment with the composite structure.

Note - Milling bits or toothed saws cannot be used to cut the composite panels. These tools cause unacceptable damage to the carbon/epoxy face layers.

Step 5 - Composite Panel Edge Sealing

Open cells on edges of cut panels are filled in using a low-density potting compound that is designed for use with honeycomb panel structures. The resin has a lower density and a higher compressive strength than most epoxies. Resin is packed into open cells along the edges of each panel using a spatula. The surface of the resin is warmed using a heat gun to reduce its viscosity, then it is smoothed with the spatula. Panels are placed in curing oven that is preheated to 100°F. Oven temperature is raised from 100°F to 250°F over a period of 25-35 min., then maintained at temperature for 120 min. to cure the resin.

Step 6 - Hinge Attachment

Hinges for folding composite cover panels are made from neoprene-coated nylon fabric. The nylon is cut into strips 48-in. long by 4.5-in. wide. The rubber surface is cleaned in preparation for bonding by wiping it with a cloth soaked in toluene. A 2-in. wide strip at the edge of a composite panel is prepared by lightly abrading the surface with fine-grained sandpaper. Area adjacent to the strip is masked to prevent abrasion and catch excess adhesive.

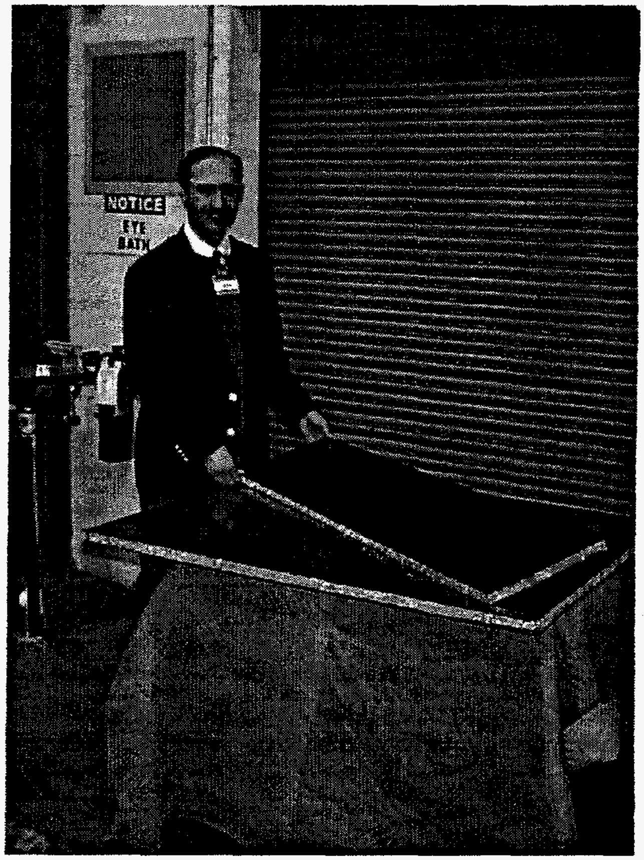


Figure 6. Composite Fighting Cover and Folding Cover Panel Section

When the surfaces of two panels and one hinge have been prepared, an epoxy paste is spread over the bonding areas of both panels and the hinge. The panels are positioned next to each other, and the hinge is placed on top of both panels. Release film, a strip of sheet metal, and weights are then placed on top of the hinge to help set the adhesive and force excess resin out of the bond area. Masking is removed after one hour. The resin system fully cures at room temperature over a period of seven days, however the panels can be handled after 16-20 hr. Weights are removed at that time, and the panels are placed in a curing oven set at 120°F for 2 hr. to accelerate the curing cycle for the adhesive.

Note - Nylon fabric with no coating was also tested for use as a hinge. The bonding adhesive soaked into the fabric, causing an unacceptable reduction in its flexibility. Qualitative peel tests were performed on coated and uncoated nylon fabric samples that were bonded to a carbon/epoxy composite surface. Peel characteristics and apparent bond strength were similar for the two hinge materials.

3. ENGINEERING PROTOTYPES

3.1. General Description

Ten lightweight composite fighting cover prototypes were built by ORNL for the U. S. Army. Surface dimensions of the baseline Army fighting cover are 51 in. by 42 in. The ORNL fighting cover prototypes are built with surface dimensions of 48 in. by 36 in. The slightly smaller size helps conserve materials and reduce costs for demonstration of the ORNL design concepts without degrading performance of the prototype in field tests.

Two kinds of lightweight composite fighting covers are prototyped, as shown in Figure 7 and Figure 8. The first kind is a single panel with dimensions of 36 in. by 46 in. by 1 in. Six of these panels were built for the Army. The second kind is a folding panel consisting of three sections that are connected with coated fabric hinges. Each section has dimensions of 12 in. by 48 in. by 1 in. Four of these panels were built for the Army.

The following discussions provide information on the materials, processes, and types of equipment used to build the lightweight composite fighting cover prototypes.

3.2. Materials

(1) Carbon Fiber Prepreg. The carbon/epoxy face sheets are potentially the costliest material in the composite panel. Commercial grade carbon fiber provides adequate strength and stiffness in the face layer, even in the minimum configuration of three-ply construction. Aerospace grades of carbon fiber offer 30-50% higher strength and stiffness, however the cost of these materials is 300-500% higher. Cut segments of prepreg tape are shown in Figure 9, along with a spool of carbon fiber tow for comparison. Fiber content of the prepreg is 5.3 oz./ft^2. Resin content is 35 wt.% Type 8804 epoxy.

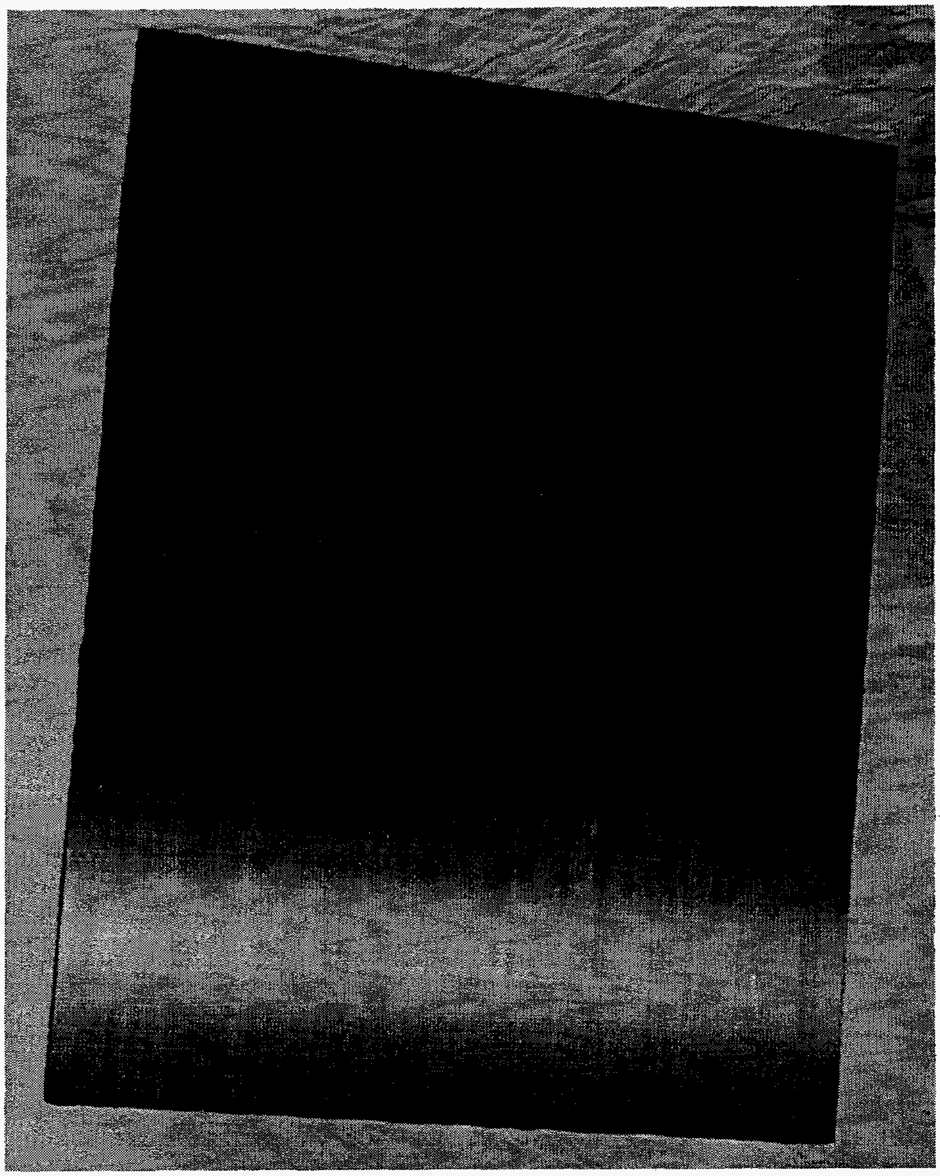


Figure 7. Lightweight Composite Fighting Cover

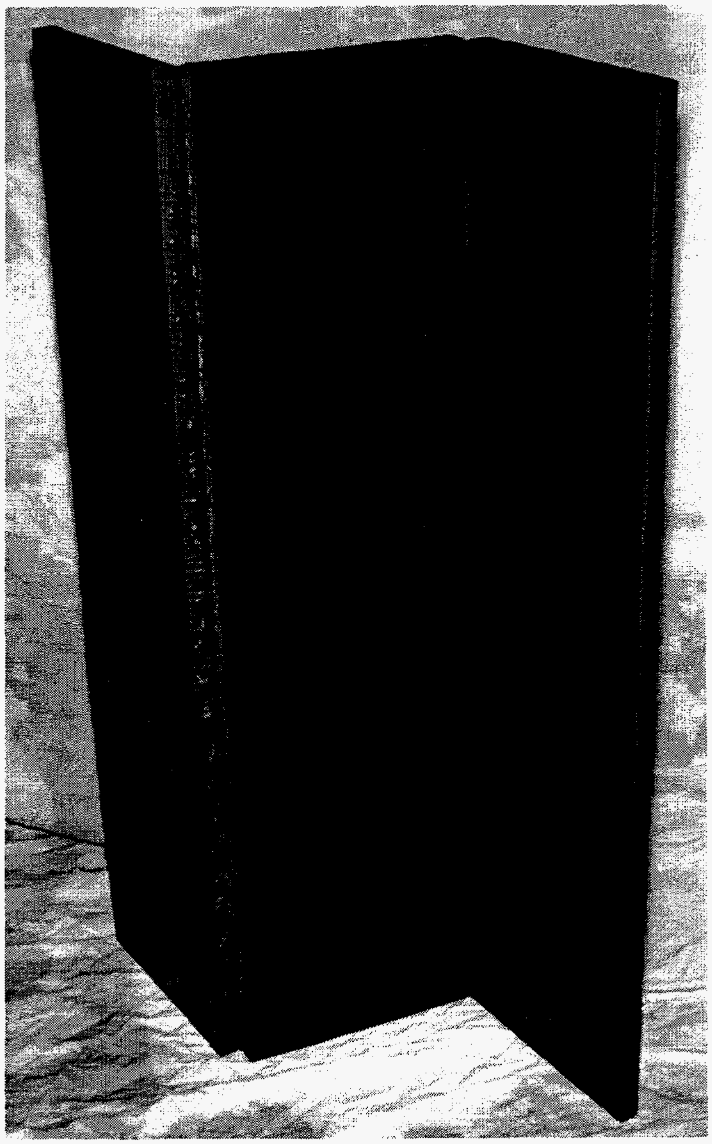


Figure 8. Folding Lightweight Composite Fighting Cover

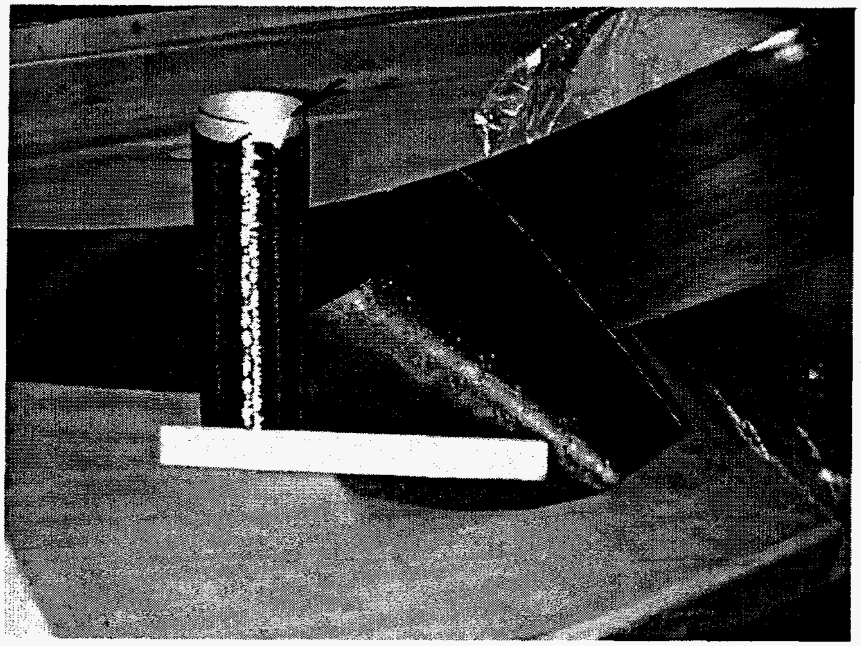


Figure 9. Carbon/Epoxy Prepreg Tape

(2) Aluminum Honeycomb. Honeycomb structures are available in various polymers, fiber-reinforced polymers, and metals. Aluminum provides the most shear strength per unit weight, and it suffers the least environmental degradation. Pre-cut honeycomb sheets are used in the prototypes to facilitate handling in laboratory settings. They still required post-fabrication trimming to obtain final panel dimensions. The honeycomb material used in prototypes is made using aluminum alloy 5052. Cell size is 0.188 in. (wall to wall). Foil gauge is 0.0007 in. There are no perforations in the foil, as this would seriously degrade its resistance to buckling.

(3) Structural Adhesive Film. Epoxy film adhesive is used to bond face sheets to the honeycomb core. The adhesive must have similar curing characteristics as the resin used in the prepreg material. Several film thicknesses are available. Nominal film thickness of 0.010 in. is used to ensure development of an adequate bonding web between the face sheets and the core.

(4) Edge Sealing Compound. The epoxy compound used to seal exposed edges of the composite panel also serves a structural function. Incomplete honeycomb cells at the edges of a panel are more susceptible to buckling or crushing. The cured resin has sufficient compressive strength to support the panel structure at this location.

(5) Neoprene-Coated Nylon Fabric. Commercial material is used in this application.

(6) Adhesive Paste. This epoxy adhesive is used to develop bonds that will resist the most of the stresses that might cause hinges to peel from panels.

The approximate amounts and small-quantity procurement costs of materials used in each type of composite cover are shown in the following tables. Costs are typical for each type of material used, without regard to the manufacturer. Additional manufacturer technical information about specific materials is provided in Appendix 2.

Materials Used in ORNL Lightweight Composite Fighting Cover

Size: 36 in. by 46 in. by 1 in.

Component	Commercial Material	Amount per Cover Weight	Amount per Cover Cost
Carbon Fiber Prepreg	Fortafil 3(C)/8804	3.66 lb.	$85
Aluminum Honeycomb	Plascore 5052	1.90 lb.	$122
Structural Adhesive Film	Scotch-Weld AF163-2M	1.37 lb.	$65
Edge Sealing Compound	Cyanamid BR-624	0.46 lb.	$13
	Total	7.39 lb.	$285

Materials Used in ORNL Folding Lightweight Composite Fighting Cover

Size: 36 in. by 48 in. by 1 in. (open)
12 in. by 48 in. by 3 in. (closed)

Component	Commercial Material	Amount per Cover Weight	Cost
Carbon Fiber Prepreg	Fortafil 3(C)/8804	3.85 lb.	$89
Aluminum Honeycomb	Plascore 5052	2.00 lb.	$100
Structural Adhesive Film	Scotch-Weld AF163-2M	1.44 lb.	$68
Edge Sealing Compound	Cyanamid BR-624	0.76 lb.	$20
Neoprene-Coated Nylon Fabric	no specification	0.30 lb.	$3
Structural Adhesive Paste	Hysol EA-9330	0.08 lb.	$1
	Total	8.43 lb.	$281

3.3. Manufacturing Materials and Equipment

Base Plate	Aluminum plate stock (for ease in handling), nominal 0.5 in. thick.
Caul Plate	Any suitable metal sheet stock, nominal 0.063 in. gauge.
Edge Support	Any suitable metal angle stock, with web lengths of 1.125 in. to 1.1375 in.

Any suitable commercial products can be used for the following manufacturing items, based on the preferences of the fabricator and the availability of resources:

Release Film	Cheese Cloth	Vacuum Bag	Bag Sealer
Vacuum Pump	Curing Oven	Horizontal Mill or Water-Jet Cutter	

3.4. Prototypes Fabrication

Ten prototype lightweight covers were built using composite manufacturing steps described in the Technical Approach. The six lightweight composite covers each required about eight hours of effort to build and finish. The four folding lightweight composite covers each required about 12 hours of effort to build, finish, and assemble. Approximately 50 % of the total effort expended for each version of the composite cover was expended in trimming excess stock from honeycomb sheets and from cured panels.

ORNL Lightweight Composite Fighting Cover

Size: 36 in. by 46 in. by 1 in.

Process Step	Description	Time (Hr)
1	Prepreg Layup and Debulking	1
2	Composite Panel Stack Assembly	1
3	Vacuum-Assisted Oven Cure	1
4	Excess Stock Removal	4
5	Composite Panel Edge Sealing	1
	Total	8

ORNL Folding Lightweight Composite Fighting Cover

Size: 36 in. by 48 in. by 1 in. (open)
12 in. by 48 in. by 3 in. (closed)

Process Step	Description	Time (Hr)
1	Prepreg Layup and Debulking	1
2	Composite Panel Stack Assembly	1
3	Vacuum-Assisted Oven Cure	1
4	Excess Stock Removal	6
5	Composite Panel Edge Sealing	2
6	Hinge Attachment	1
	Total	12

Fabrication costs of the ten first-of-a-kind prototypes are in the range of $1000-2000/unit. This cost can be reduced by several routes: (1) The cost basic materials in small-quantity orders is high. In some cases, the minimum order quantity is several times the amount actually needed. Material costs for high-volume production quantities should be 25-30% less. (2) Existing processes and equipment were adapted to produce prototypes. Labor and materials can be used more efficiently by tailoring manufacturing processes to build the cover structures. For example, the ability to use trimmed versus untrimmed honeycomb material would lower unit cost for this component from ≥$100 per cover to ≤$10. (3) Final trimming of panel edges is a labor-intensive step. Use of a water-jet cutter would be somewhat faster. Additional testing is also needed to determine if the static and dynamic loads on the cover require perfect cell structure up to the edge or if there is an acceptable zone of imperfect cells near the edge that would allow fabrication with no final edge trimming.

4. CONCLUSIONS

Lightweight fighting covers were designed and built from composite materials. Weighing only eight pounds, the composite covers have structural characteristics that should meet Army needs for static and dynamic loading-bearing capability under battlefield conditions. Design and analysis philosophies for multiple-layer lightweight ballistic shielding concepts are valid for development and evaluation of soldier fighting cover mechanical properties and failure modes.

5. RECOMMENDATIONS

Future demonstrations of lightweight composite fighting cover technology should examine methods for minimizing manufacturing costs while maintaining the functional quality of the cover. In addition, research is needed to modify the design of cover structures to maximize their utility in the construction of both in-ground and above-ground protective structures and to evaluate the costs and benefits of enhancing ballistic protection capabilities within the cover structure.

6. ACKNOWLEDGMENTS

The authors wish to recognize the important contributions made by the following researchers in the development and prototyping of lightweight soldier fighting covers:

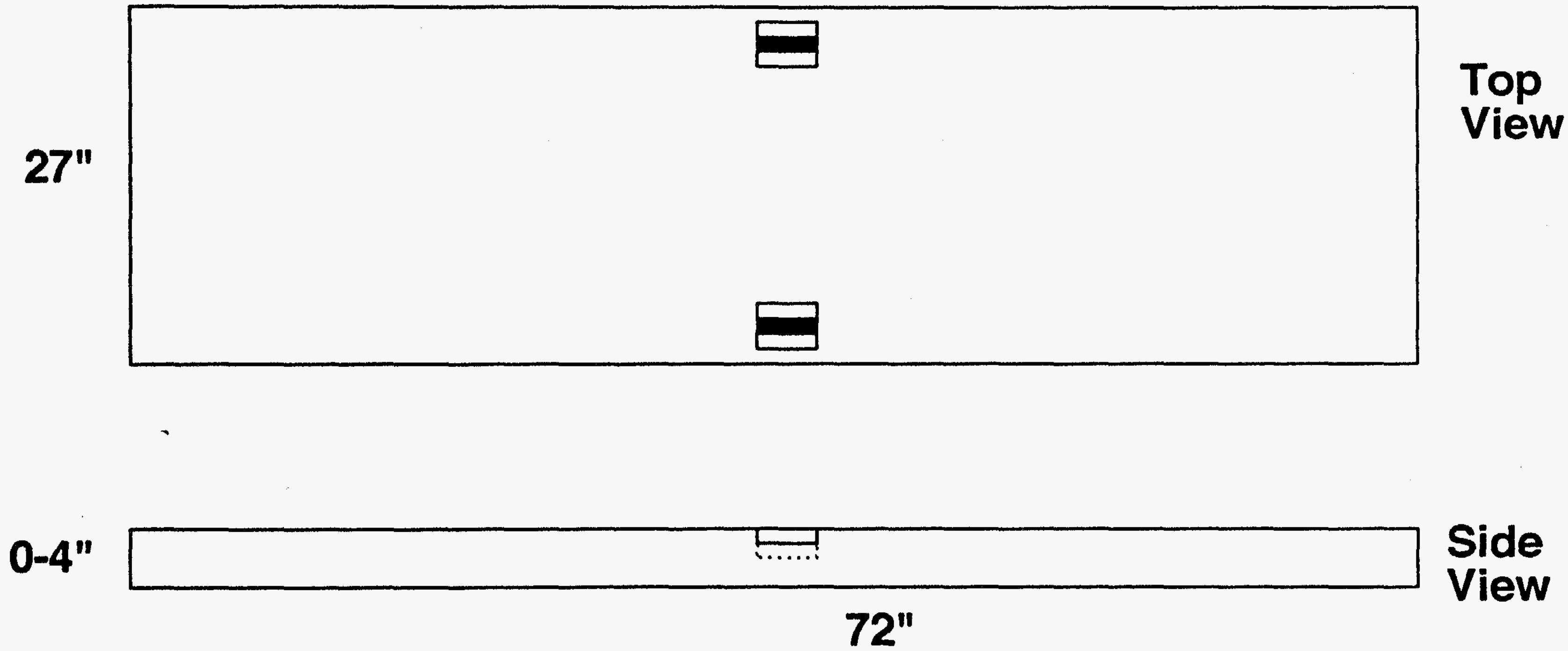
D. Skidmore and R. D. Lomax for developing and demonstrating processing technologies for lightweight covers and serving as lead technologists for building prototypes;

R. L. Battiste and T. D. Godwin for instrumenting composite specimens and performing flexure tests; and

C. L. Knaff and R. W. Starr for support in building prototype covers for the Army.

APPENDIX A. FINITE ELEMENT ANALYSIS OF LIGHTWEIGHT SOLDIER FIGHTING COVER

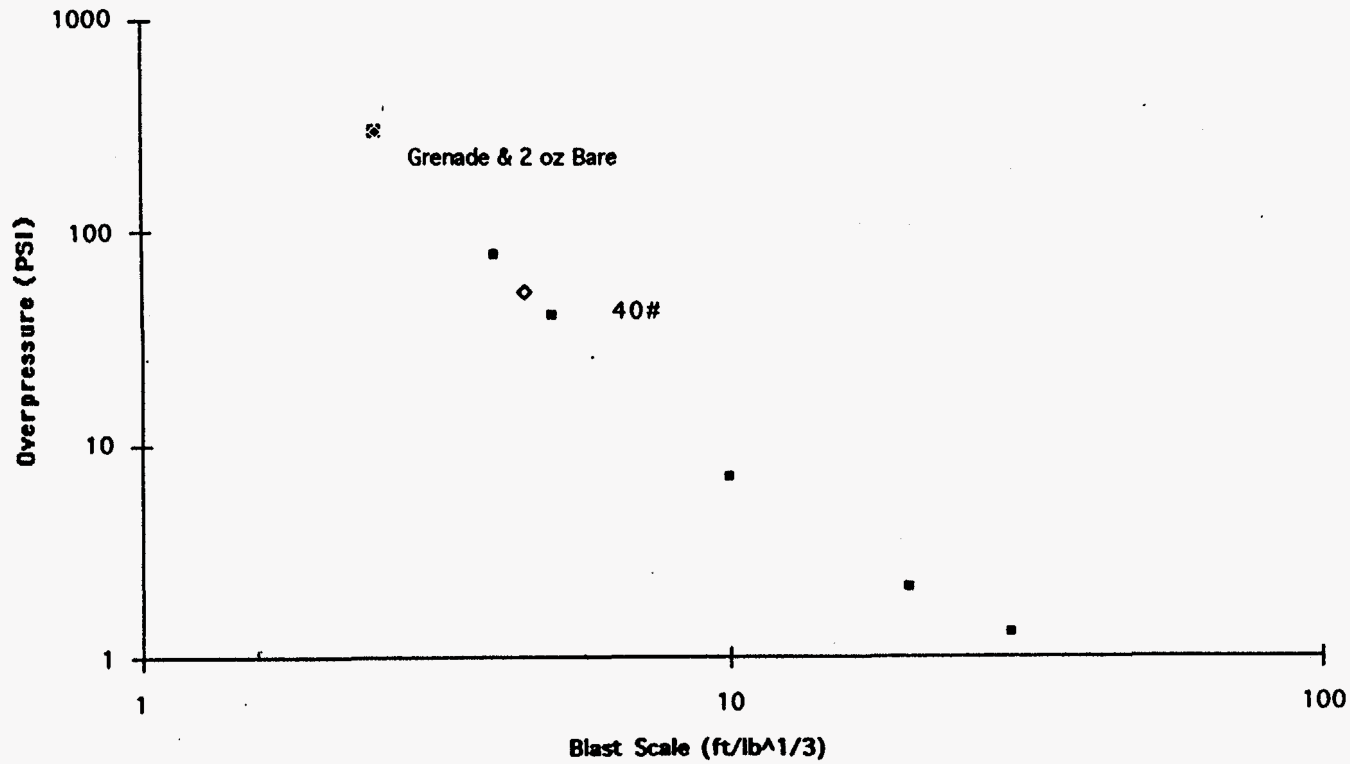
Fighting Cover



This design was selected for further evaluation.
Parts of this design are the subject of a patent application filed with US Patent Office Nov. 12, 1992.

*ET/*ornl

Peak Overpressure Estimate



Reference: G. F. Kinney, K. J. Graham, Explosive Shocks in Air, Springer-Verlag, Berlin p. 92 (1985)

Grenade, 2 ounce C-4, and 40 lb C-3 placed on scaling chart. No pressure measurements were made.

ET/ornl

Material Data and Calculations
Fighting Cover - 3 Layer Model

G10 Fiberglass/Aluminum Honeycomb Construction

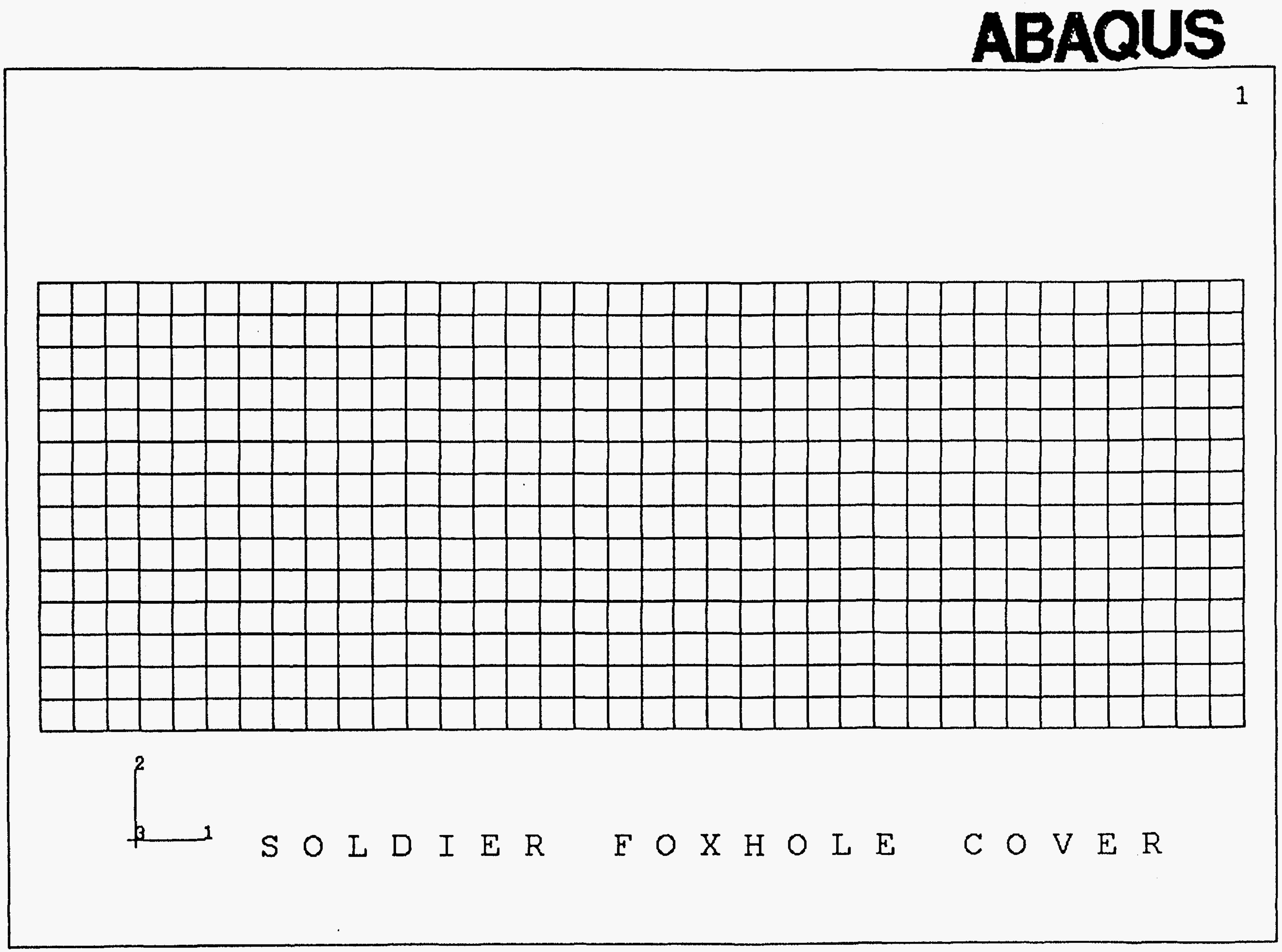
Material	Glass (G10)	Honeycomb
E_{11} (psi)	2.2M	60.0K
E_{22} (psi)	2.7M	60.0K
G (psi)	1.2M	6.5K
N	0.13	0.001
Layer (in.)	0.063	1.5

Static Load Conditions

Bending Stress	(psi)	16.4K
Deflection	(in.)	0.587

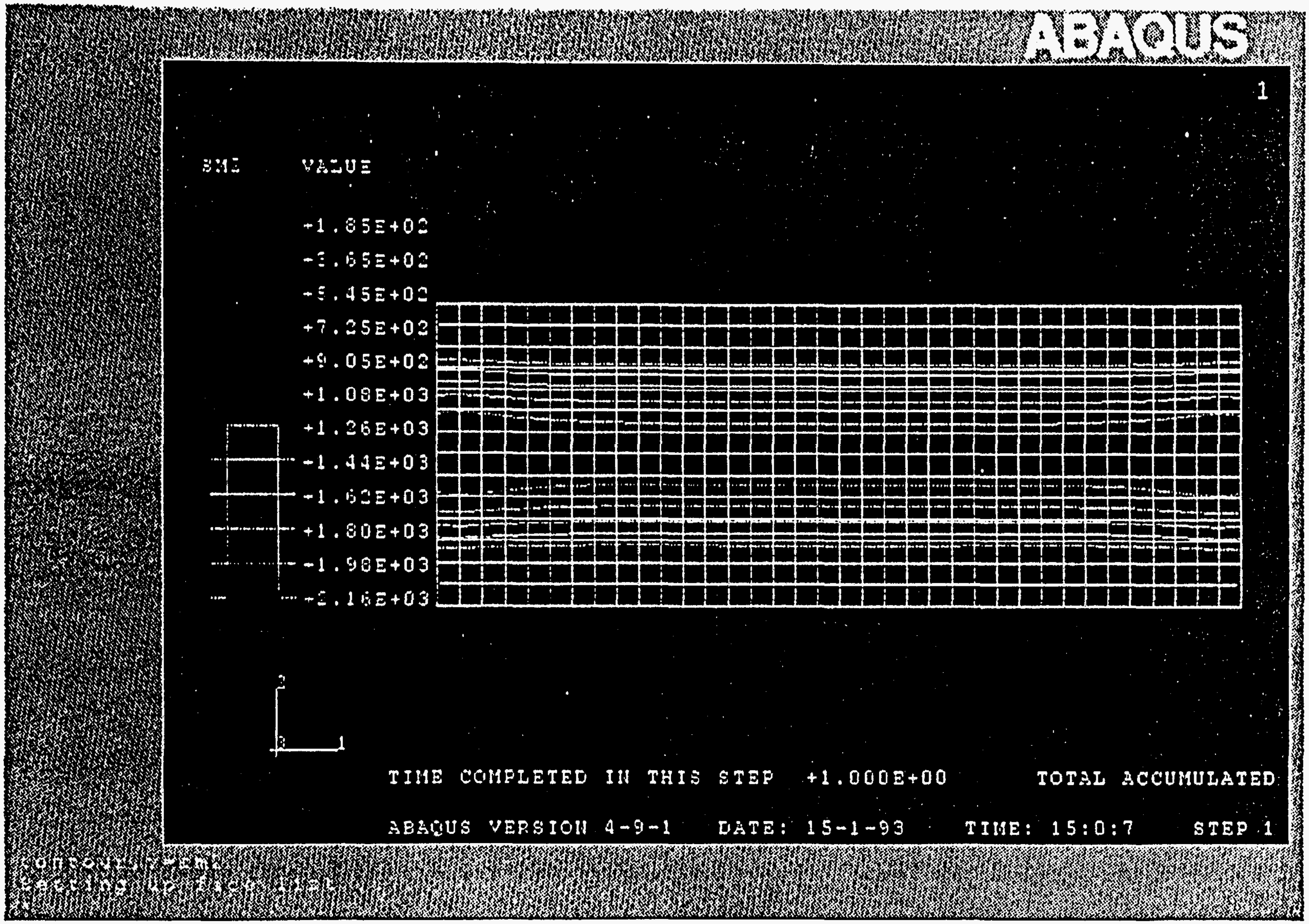
Dynamic Load Conditions

Face Bending Stress	(psi)	22.4K
Core Shear Stress	(psi)	200.0
Face Dimpling Stress	(psi)	200.0K
Face Wrinkling Stress	(psi)	67.4K
Deflection	(in.)	2.5



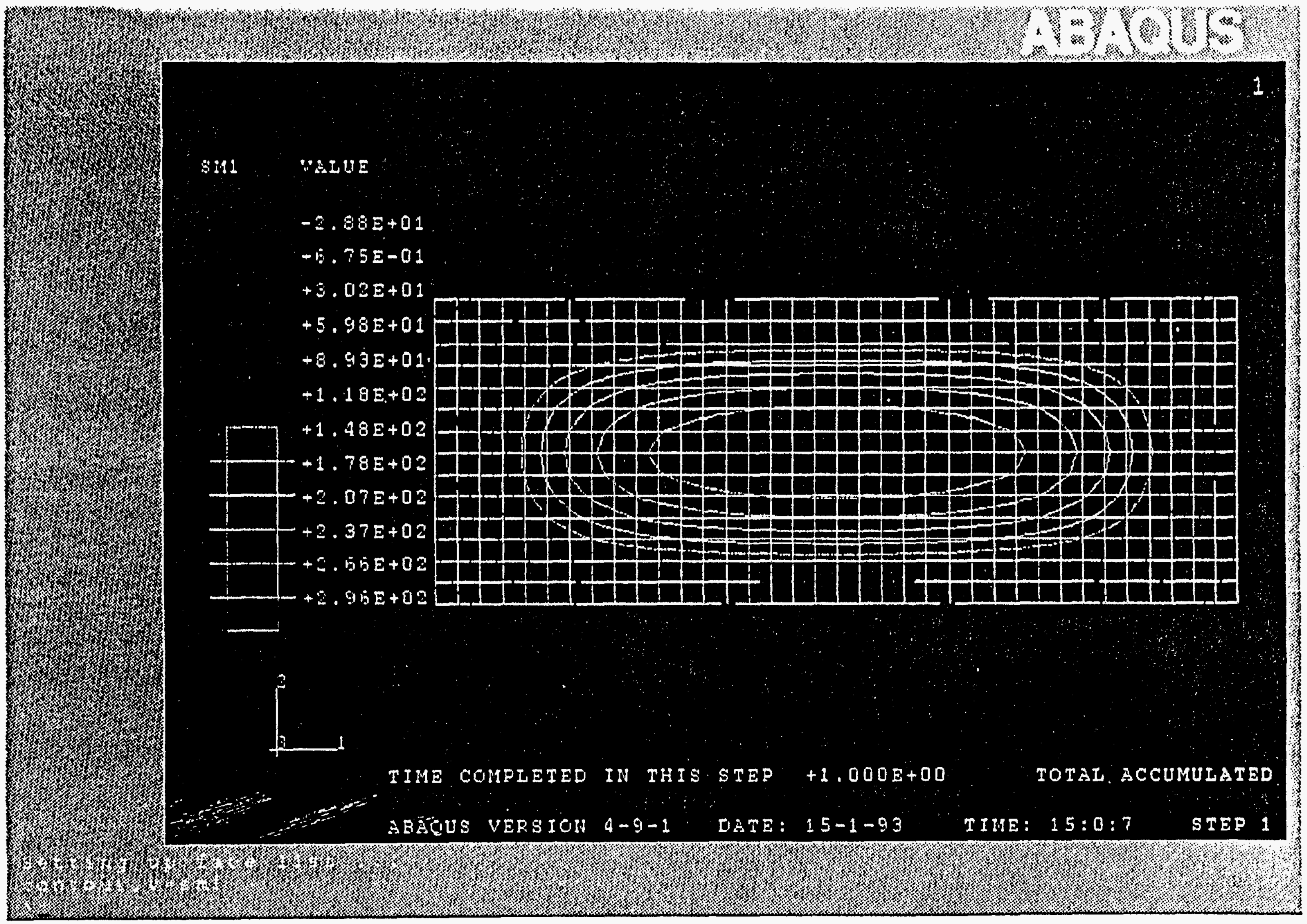
Finite Element Model of The Soldier Foxhole Cover With 3 Layers, The Two Outer Layers are 1/16" G-10 With The Middle Layer Being 1 1/2" Honeycomb.

Jan 18, 1993 11:24:18



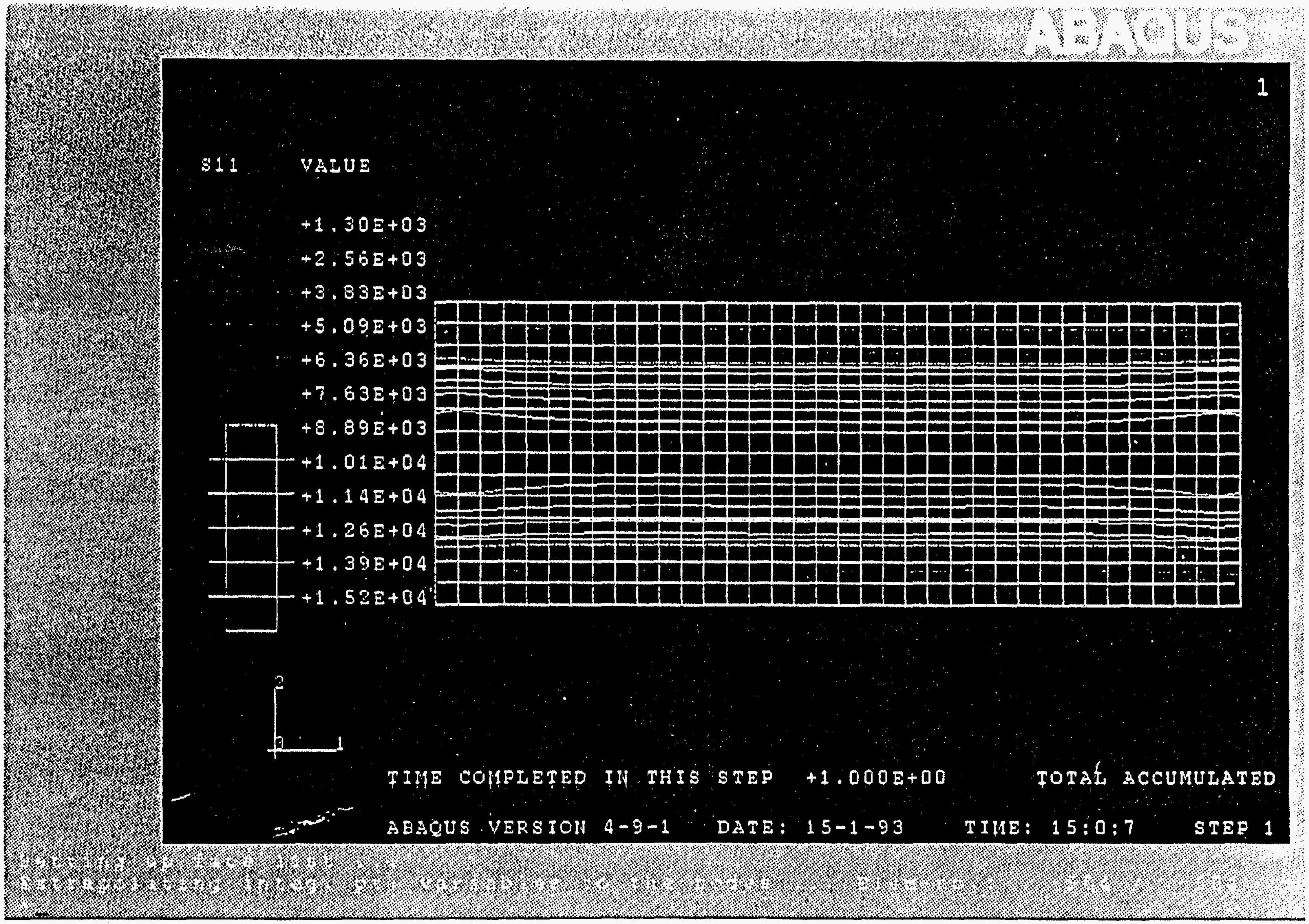
Calculated Bending Moment in The Width or Short Span Direction for The 3 Layer Configuration.

Jan 18, 1993 12:24:50



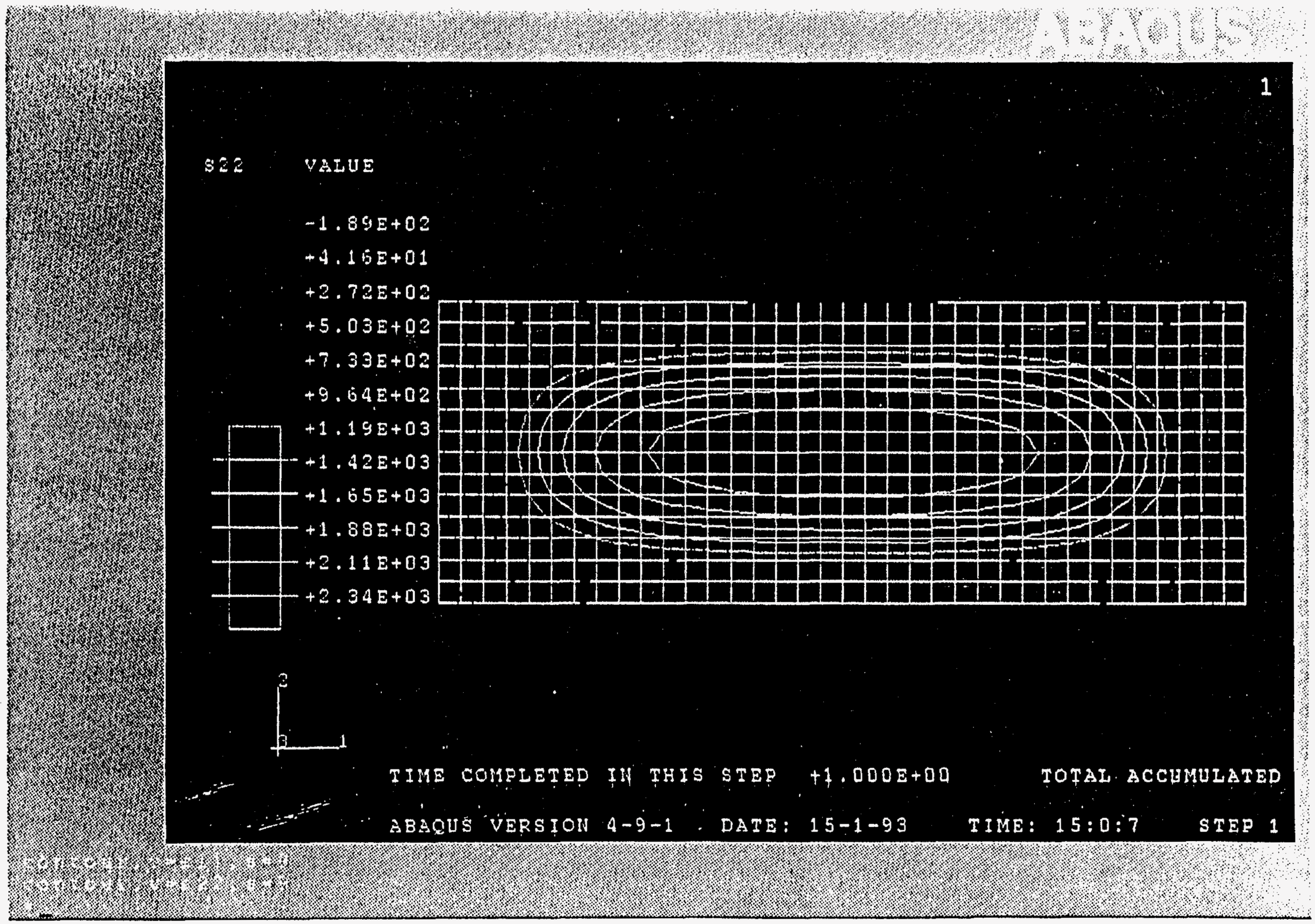
Calculated Bending Moment in The Length or Long Span Direction for The 3 Layer Configuration.

Jan 18, 1993 13:54:18



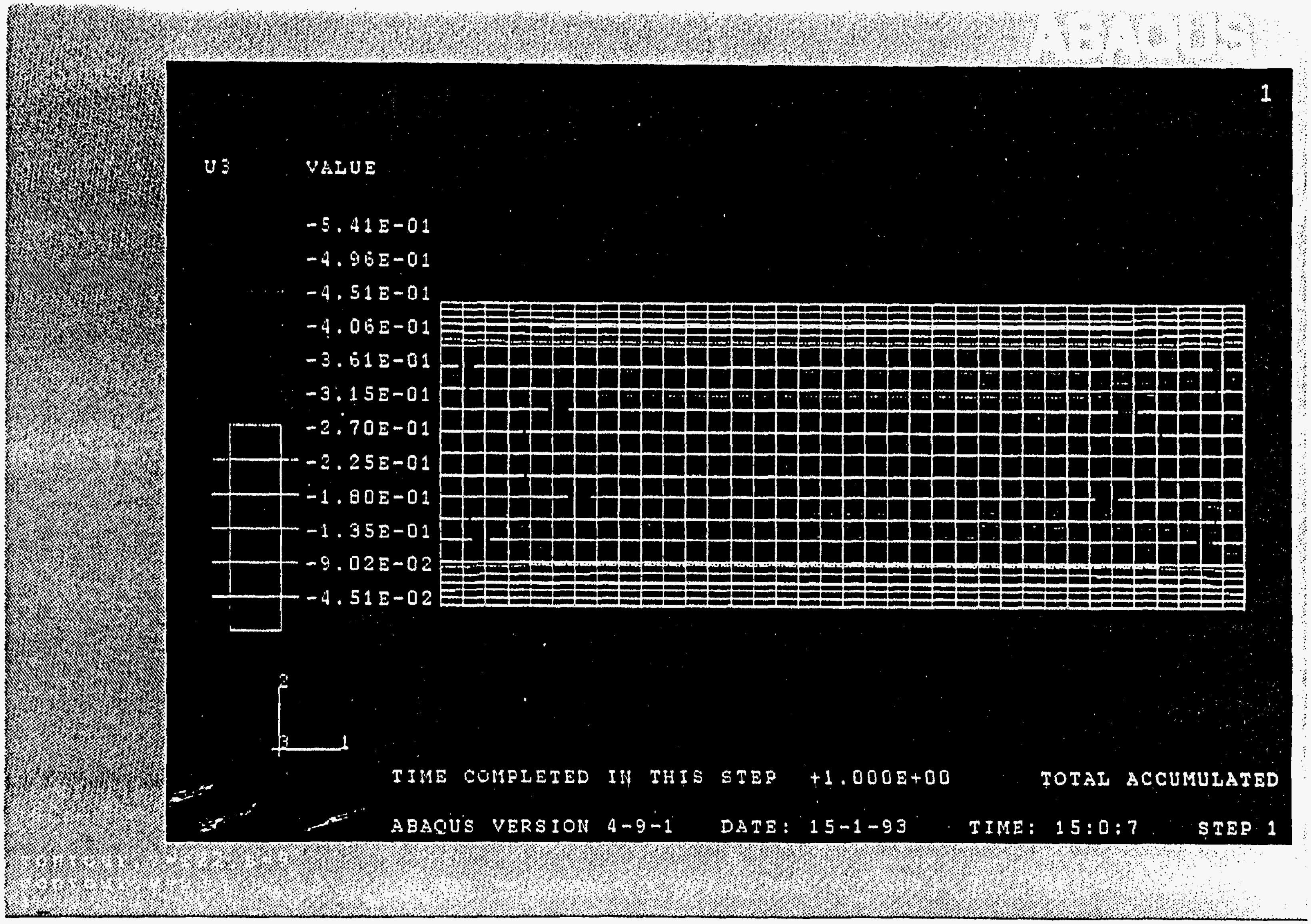
Calculated Bending Stress in The Short Span Direction for The 3 Layer Configuration.

Jan 18, 1993 14:01:12

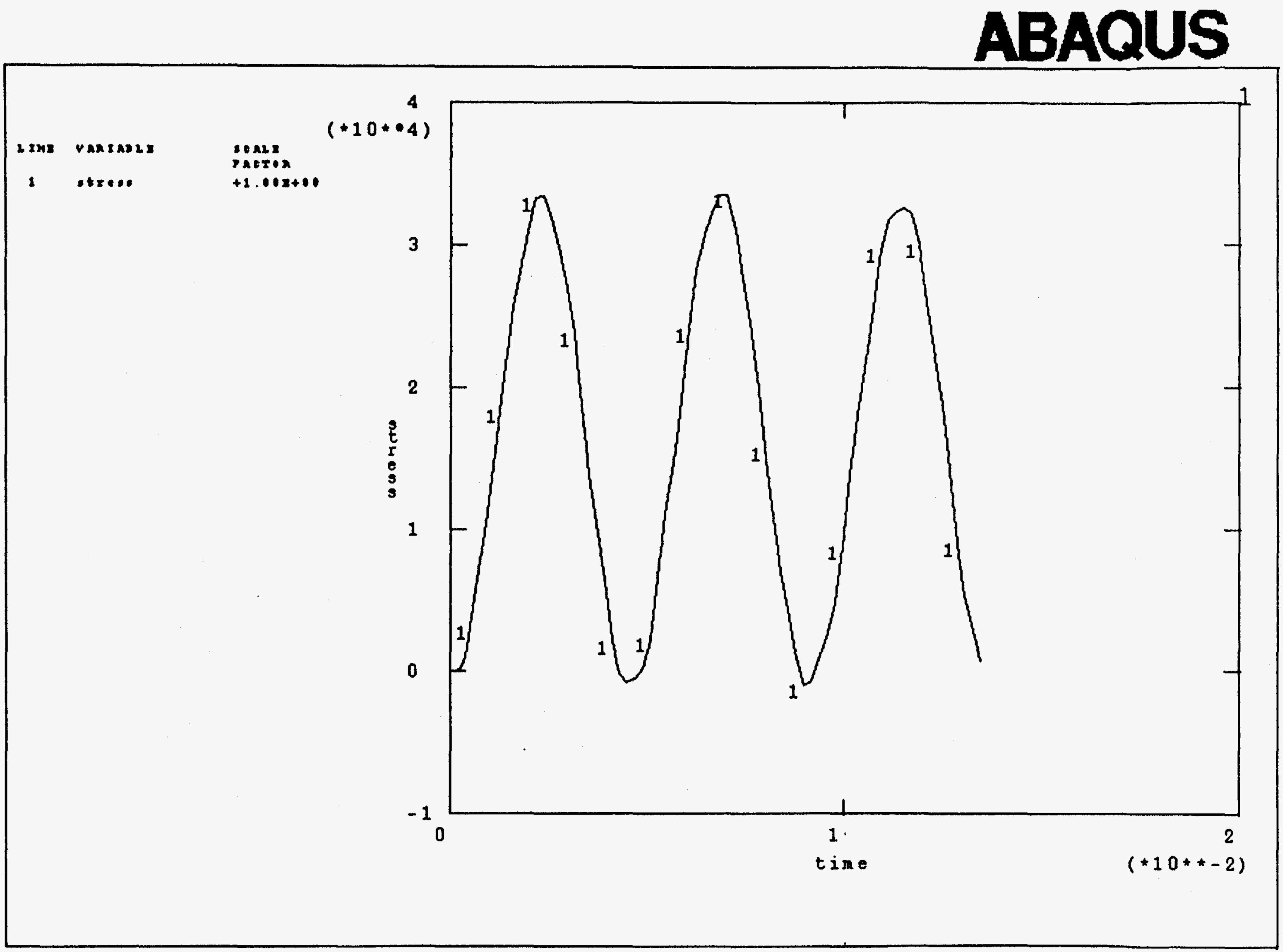


Calculated Bending Stress in The Long Span Direction for The 3 Layer Configuration.

Jan 18, 1993 14:08:23



Calculated Deflection across The Foxhole for The 3 Layer Configuration.



Dynamic Analysis Showing Maximum Stress Calculated During The Assumed Pressure Pulse Application for The 3 Layer Configuration.

*

APPENDIX B. TECHNICAL DATA FOR SOLDIER FIGHTING COVER MATERIALS

Carbon Fiber Prepreg

Aluminum Honeycomb

Structural Adhesive Film

Edge Sealing Compound

Neoprene-Coated Nylon Fabric

Structural Adhesive

FORTAFIL CARBON FIBERS
Continuous in Quality. Economical by Design.

Fortafil 3C-150/35% 8804

AKZO

Technical Data Sheet 921C

FORTAFIL 3(C) UNIDIRECTIONAL CARBON FIBER PREPREGS

Fortafil 3(C) carbon fibers are available in unidirectional, pre-impregnated forms based on 250°F epoxy systems. A wide range of combinations are offered with various resin contents, fiber areal weights, with or without glass scrim backings, and a selection of widths. Product types are offered that address differing resin tack requirements, resin flows, and resin gel time characteristics. Fortafil prepregs are ideally suited for composite part fabrication techniques such as vacuum bag/autoclave molding, high and low pressure matched metal die compression molding and shrink tape consolidation of mandrel wrapped material.

Resin Systems	
Type	250°F
Resin System Designations	See below
Cure Conditions	1 hour @ 250°F
Volatile Content	Less than 0.2%
Shelf Life @ RT	30 Days (minimum)
Shelf Life @ 0°F	12 Months (minimum)
Prepreg Characteristics	
Width	12" or 24"
Fiber Type	F3(C) 50K
Fiber Areal Weight (FAW) Range	120 - 190 g/m^2
Resin Content Range	35 - 41%
Backings Available	None or 108 glass scrim

Resin Designations		8601	9117 (8804)
Gel Times °F	250	12.5	12.5
	275	6.0	7.2
	300	3.1	5.0
Glass Transition Temperature (T_g),°F		310	270
Resin Flow (w/bleeder) Avg. Wt.		7.6%	10.3%
Viscosity (during heat-up)		High	Low
Tack		Intermediate	Intermediate
Typical Laminate Properties (150 FAW, scrimless, unidirectional 60% fiber volume)			
Tensile Strength		290 ksi	290 ksi
Tensile Modulus		19 Msi	19 Msi
Flexural Strength		280 ksi	240 ksi
Flexural Modulus		18 Msi	18 Msi
Shear Strength (short beam)		13.5 ksi	12.5 ksi
Cured Ply Thickness		5.6 x 10^{-3}in. (0.14 mm)	

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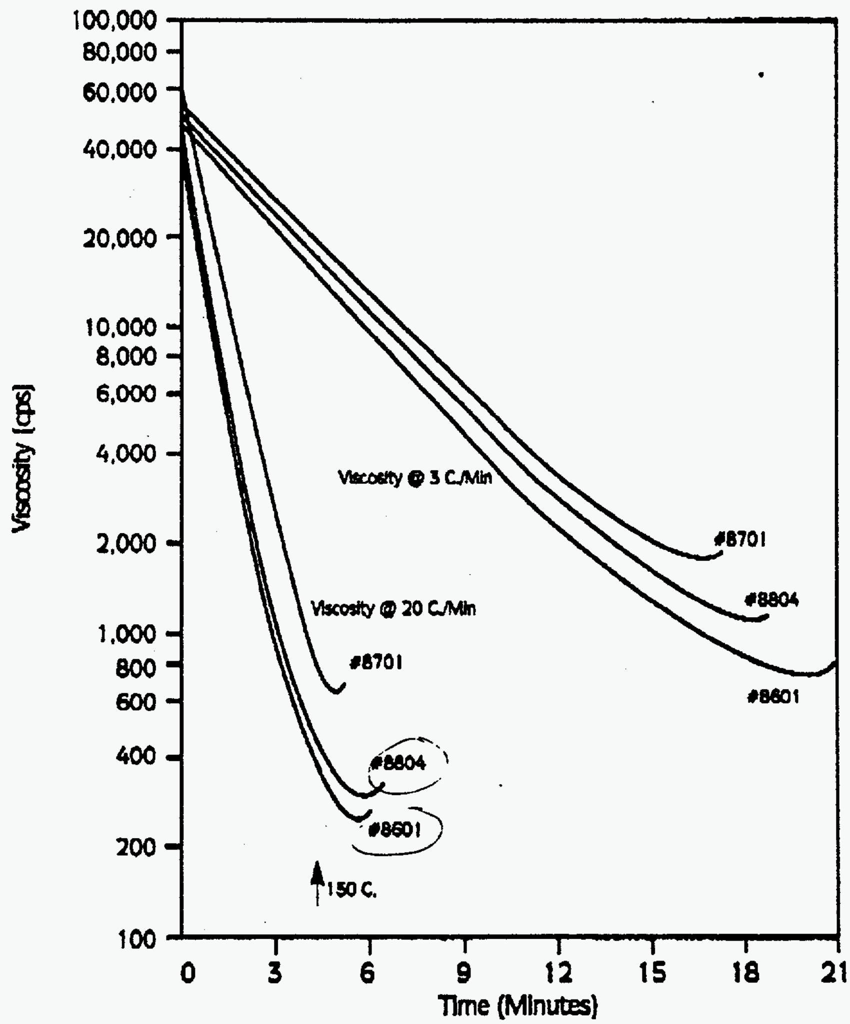
Technical Data Sheet 902C3

FORTAFIL® 3(C) UNIDIRECTIONAL CARBON FIBER PREPREGS

VISCOSITY VERSUS HEAT-UP RATE



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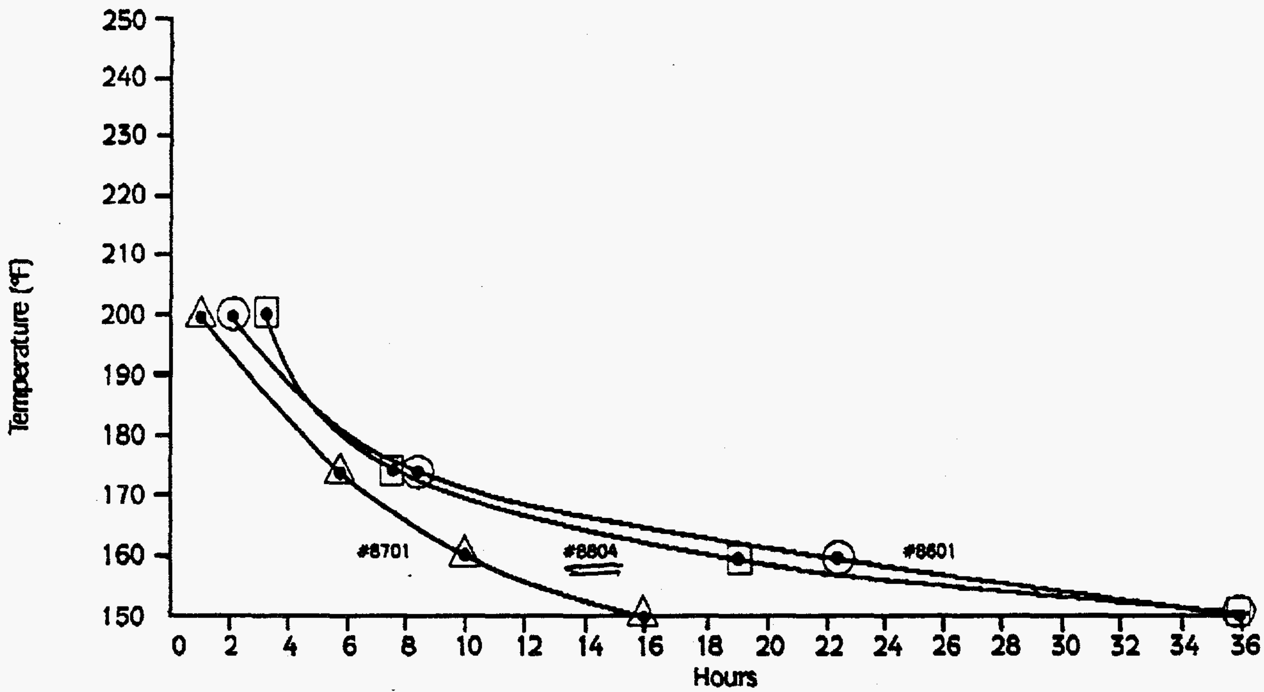
Technical Data Sheet 902C1

FORTAFIL® PREPREGS — ALTERNATIVE CONDITIONS FOR COMPLETE CURING*

The 250°F. epoxies are recommended to be cured at 250°F. for 1 hour. However, a complete cure can be effected for all Fortafil® prepreg grades at reduced temperatures using extended time periods as shown in the plot below. These are without regard to fiber and resin consolidation in the part or resin flow and loss. The use of temperatures higher than 250°F. with shortened cure times should be avoided.



*Minimum times required at each temperature to achieve a Barcol hardness of 65 (typical after 1 hour at 250°F.).

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Technical Data Sheet 902C2

FORTAFIL® 3(C) UNIDIRECTIONAL CARBON FIBER PREPREGS

PREPREG COMPONENT & SUMMARY WEIGHTS/YIELDS

Type \ Areal Weight		120 FAW		130 FAW		140 FAW		145 FAW		150 FAW		165 FAW		190 FAW	
Scrim	Resin Content (%)	Total g/m²	Yield ft²/lb.	Total g/m²	Yield ft²/lb.	Total g/m²	Yield ft²/lb.	Total g/m²	Yield ft²/lb.	Total g/m²	Yield ft²/lb.	Total g/m²	Yield ft²/lb.	Total g/m²	Yield ft²/lb.
Scrim-less	32	176.5	27.66	191.2	25.53	205.8	23.72	213.2	22.90	220.6	22.13	242.6	20.12	279.4	17.47
	34	181.8	26.86	197.0	24.78	212.1	23.02	219.7	22.22	227.3	21.48	250.0	19.53	287.9	16.96
	36	187.5	26.04	203.1	24.04	218.7	22.32	226.6	21.55	234.4	20.83	257.8	18.94	296.9	16.44
	38	193.5	25.23	209.7	23.28	225.8	21.62	233.9	20.87	241.9	20.18	266.1	18.35	306.4	15.94
	40	200.0	24.41	216.7	22.53	233.3	20.93	241.7	20.20	250.0	19.53	275.0	17.75	316.7	15.42
	42	206.9	23.60	224.1	21.79	241.4	20.23	250.0	19.53	258.6	18.88	284.5	17.16	327.6	14.90
104 Scrim	32	205.4	23.77	220.1	22.18	234.8	20.79	242.1	20.17	249.5	19.57	271.6	17.98	308.3	15.84
	34	211.6	23.07	226.7	21.53	241.9	20.18	249.5	19.57	257.1	18.99	279.8	17.45	317.7	15.37
	36	218.2	22.37	233.8	20.88	249.5	19.57	257.3	18.98	265.1	18.42	288.5	16.92	327.6	14.90
	38	225.2	21.68	241.4	20.22	257.5	18.96	265.6	18.38	273.6	17.84	297.8	16.39	338.2	14.44
	40	232.8	20.97	249.4	19.58	266.1	18.35	274.4	17.79	282.8	17.26	307.8	15.86	349.4	13.97
	42	240.8	20.28	258.0	18.92	275.3	17.73	283.9	17.20	292.5	16.69	318.4	15.33	361.5	13.51
108 Scrim	32	247.8	19.70	262.5	18.60	277.2	17.61	284.5	17.16	291.9	16.73	313.9	15.55	350.7	13.92
	34	255.3	19.12	270.4	18.06	285.6	17.09	293.1	16.66	300.7	16.24	323.4	15.10	361.3	13.51
	36	263.2	18.55	278.9	17.51	294.5	16.58	302.3	16.15	310.1	15.74	333.6	14.64	372.6	13.10
	38	271.7	17.97	287.9	16.96	304.0	16.06	312.1	15.64	320.1	15.25	344.3	14.18	384.6	12.70
	40	280.8	17.39	297.5	16.41	314.1	15.54	322.5	15.14	330.8	14.76	355.8	13.72	397.5	12.28
	42	290.5	16.81	307.7	15.87	324.9	15.03	333.6	14.63	342.2	14.27	368.1	13.26	411.2	11.87

NOTES:
- Yield does not include paper weight.
- To convert g/m² to g/ft² multiply the g/m² value by 0.0929.
- Paper areal weight (average of Daubert & Akrosil) is 101.8 g/m² (48.0 ft²/lb).

	GLASS SCRIM			
	Weight		Thickness	
Type	oz/yd²	g/m²	inches	mm
104	0.58	19.66	0.0012	0.0305
106	0.73	24.75	0.0015	0.0381
108	1.43	48.48	0.0023	0.0584

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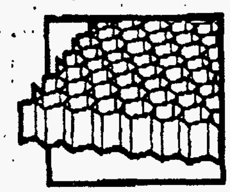
PLASCORE

Aluminum Honeycomb Cores



PAMG 5052 Aluminum Honeycomb

Description:

PAMG 5052 aluminum honeycomb is a lightweight core material which offers superior strength and corrosion resistance over commercial grade aluminum core. PAMG 5052 core is made from 5052 aluminum alloy foil and meets all the requirements of MIL-C-7438.

Features:

- Elevated Use Temperatures
- High Thermal Conductivity
- Flame Resistant
- Excellent Moisture and Corrosion Resistance
- Fungi Resistant
- Low Weight / High Strength

Applications:

PAMG 5052 honeycomb uses include aircraft floors, aircraft leading and trailing edges, missile wings, fan casings, fuel cells, fuselage components, helicopter rotor blades, and navy bulkhead joiner panels. PAMG 5052 aluminum honeycomb is suitable for applications where materials conforming to MIL-C-7438 are required.

Availability:

PAMG 5052 honeycomb is available in four forms: unexpanded blocks, unexpanded block slices, untrimmed expanded sheets and cut to size expanded sheets. PAMG 5052 core is also available with or without cell perforations to facilitate cell venting for certain applications.

Sheet Length (W):	150" max	
Sheet Width (L):	60" max	
Tolerances:	Length:	± .032"*
	Width:	± .032"*
	Thickness:	± .005"
	Density:	± 10%
	Cell size:	± 10%

*Varies with cell size

Special dimensions, cell sizes, tolerances and mechanical properties can be provided.

Structural data on reverse side.

PAMG 5052 Honeycomb Typical Property Values:

Plascore Honeycomb Designation			Bare Compressive		Plate Shear			
Cell Size	Foil Gauge	Nominal Density PCF	Strength PSI	Modulus KSI	Strength PSI "L"	Strength PSI "W"	Modulus KSI "L"	Modulus KSI "W"
1/8	.0007	3.1	270	75	210	130	45	22
1/8	.001	4.5	520	150	340	220	70	31
1/8	.0015	6.1	870	240	505	320	98	41
1/8	.002	8.1	1400	350	725	455	135	54
3/16	.001	3.1	270	75	210	130	45	22
3/16	.0015	4.4	500	145	330	215	68	30
3/16	.002	5.7	770	220	460	300	90	38
3/16	.0025	6.9	1080	285	590	375	114	46
3/16	.003	8.1	1400	350	725	455	135	54
1/4	.0007	1.6	85	20	85	50	21	11
1/4	.001	2.3	165	45	140	85	32	16
1/4	.0015	3.4	320	90	235	150	50	24
1/4	.002	4.3	480	140	320	210	66	29
1/4	.0025	5.2	670	190	410	265	82	35
1/4	.003	6.0	850	235	495	315	96	40
1/4	.004	7.9	1360	340	700	440	130	52
3/8	.0007	1.0	30	10	45	30	12	7
3/8	.0015	2.3	165	45	140	85	32	16
3/8	.002	3.0	260	70	200	125	43	21
3/8	.0025	3.7	370	105	260	170	55	26
3/8	.003	4.2	460	135	310	200	65	29
3/8	.004	5.4	720	200	430	280	86	36

7/16 2.0

How to Specify Plascore Honeycomb Cores:

Plascore PAMG 5052 aluminum honeycomb is specified by using product parameters in the following manner:

PAMG-Density-Cell Size-Foil Thickness-Perforated-Alloy

Example: PAMG-3.0-3/8-.002-P-5052

- PAMG designates Aluminum Military Grade
- 3.0 is nominal density in pounds per cubic foot
- 3/8 is the cell size in inches
- "P" indicates that the cell walls are to be perforated. If no perforation is desired omit the "P".
- 5052 designates the alloy of the foil
- .002 designates the foil thickness in inches

PLASCORE®

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Scotch-Weld
BRAND

Aerospace
Technical Data

Issue No. 1
March, 1986
Supercedes previous
product data

Structural Adhesive Film AF-163-2

Introduction:

Scotch-Weld Brand AF-163-2 designates a family of thermosetting modified epoxy structural adhesives in film form which are available in a variety of weights with or without a supporting carrier. AF-163-2 films are designed for both solid panel and honeycomb sandwich constructions. These products offer the following advantageous properties.

1. High bond strengths from −67°F. to 250°F.
2. High fracture toughness and peel strengths.
3. Excellent resistance to high moisture environments before and after curing.
4. Short cure times as low as 225°F. (90 min).
5. Freedom from volatile by-products during cure which permits low pressure bonding.
6. Vacuum cure capability.
7. Bond line heat up rates as low as 1°F./minute can be tolerated.
8. X-ray opaque resin system allows use of x-ray NDT methods.
9. Improved shop open time and long shelf life.
10. Limited self-extinguishing characteristics.

Description:

The following AF-163-2 products are included in this data sheet:

Product	Weight Lbs./Ft.^{2}	Color	Nominal Thickness - mils	Base
AF-163-2K	0.045	Yellow	7.5	Modified Epoxy
AF-163-2K	0.06	Red	9.5	Modified Epoxy
AF-163-2K	0.085	Blue	13	Modified Epoxy
AF-163-2M	0.045	Yellow	7.5	Modified Epoxy
AF-163-2M	0.06	Red	9.5	Modified Epoxy
AF-163-2M	0.085	Blue	13	Modified Epoxy
AF-163-2OST	0.03	Green	5.5	Modified Epoxy
AF-163-2OST	0.06	Red	9.5	Modified Epoxy
AF-163-2U	0.03	Red	5.5	Modified Epoxy
AF-163-2U	0.06	Red	9.5	Modified Epoxy

Code: K = knit supporting carrier
M = non-woven supporting carrier
OST = one side tacky with non-woven carrier on low tack surface
U = unsupported film

Contents:

Product Performance:

The following results have been obtained by 3M Laboratories under the conditions specified with test specimens prepared using the general methods described in the product application section.

I Typical Cured Free Film Properties:

A. Glass Transition Temperature — unsupported

Method: Dupont 1090 DMA at 5°C./minute

Cure: 60 minutes at 250°F.

dry: 108°C (226°F.)

*wet: 82°C (180°F.)

*after 14 day immersion in water at 70°C.

B. Tensile Strength and Modulus — unsupported

Cured: Free Film Strips approx. ¼" x 3" x .01" Thick

Cure: 90 minutes at 235°F.

Temperature	Ultimate Strength - PSI	Modulus PSI
−67°F.	11,000	2.3×10^5
75°F.	7,000	1.6×10^5
180°F.	3,000	6×10^4

C. 75°F. Bulk Modulus, Shear Modulus, and Poisson's Ratio — knit supported

17 ply laminate ~ 0.1 inches thick (ASTM D-3039) cure — 60 minutes at 250°F.

Modulus of Elasticity	161×10^3 psi
Poisson's Ratio	0.34
Shear Modulus	60×10^3 psi

D. Self-extinguishing Characteristics: knit supported.

Method: FAR 25.853 — **Sample:** ¼" x ½" x 4"

Cure: 60 minutes at 250°F.

Sample Orientation	Flame Exposure Time (Seconds)	Self-Extinguishing Time (Seconds)
1. 4" length horizontal and ½" dimension vertical	15	0.5
2. Same as (1)	60	3.7
3. 4" length vertical	15	6.3
4. Same as (3)	60	70

Product Performance (cont):

II **Typical Cured Bond Properties**

A. **75°F. Fracture Toughness — (AC & S method C-295)**

Cure Cycle: 235°F. — 90 minutes — 35 psi — 5°F./min.

Primer: EC-3960

Metal: 2024 T-3 Bare ½" thick aluminum Phosphoric Acid Anodize

		AF-163-2K .06	AF-163-2OST.03	AF-163-2OST.06
G_{IC}	$\frac{\text{IN LBS}}{\text{IN}^2}$	25	22	21
G_{IA}	$\frac{\text{IN LBS}}{\text{IN}^2}$	15	13	13

B. **Thick Adherend Shear Properties — (AC & S method C-288)**

Cure Cycle: 270°F. — 60 minutes — 40psi — 1°F./min.

Adherends: 2024 T-3 Bare 0.25 inch thick aluminum — FPL etched

Primer: EC-3924B

Test Temp.	Ultimate Shear - PSI	Ultimate Elong. In.	Yield Stress - PSI	Yield Elong. In.	Shear Modulus - PSI
75°F.	6950	.0052	5255	.00074	63,685
180°F.	5780	.0114	3075	.00079	26,495

C. **Metal to Metal Wide Area Blister Detection Shear Strength — PSI (AC & S method C-2232)**

Cure: 235°F. — 90 minutes — 35 psi — 5°F./min.

Primer: EC-3960 **Metal:** 2024 T-3 Bare .063" thick — FPL etched

	AF-163-2OST		AF-163-2M	AF-163-2K	
	Wt. .03	Wt. .06	Wt. .06	Wt. .06	Wt. .085
−67°F.	5500	4800	5200	5400	5100
75°F.	5400	5400	5100	5100	5000
180°F.	3700	3800	3700	3500	3400
250°F.	2400	2400	2400	2400	2200

D. **Metal to Metal Overlap Shear Strength — PSI (AC & S method C-244)**

Cure Cycle: 250°F. — 60 minutes — 20 psi — 1°F./minute

Primer: EC-3917 **Metal:** 2024 T-3 ALCLAD .063" thick — unsealed Chromic Acid Anodized

	AF-163-2OST	AF-163-2M	AF-163-2K	
	Wt. .03	Wt. .06	Wt. .06	Wt. .085
−67°F.	5400	6400	6200	5100
75°F.	5200	5700	5800	5400
180°F.	3200	3600	3800	3800

Product Performance (cont):

E. Metal to Metal Blister Detection Shear (AC & S method C-265)

Cure Cycle: 270°F. — 60 minutes — 40 psi — 1°F./minute rise rate

Primer: EC-3924B

Metal: 2024 T-3 Bare 0.063 inches thick — FPL etched

Test Temperature	AF-163-2K Wt. .06	AF-163-2M Wt. .06
-67°F.*	6900	7000 psi
75°F.	5100	5000 psi
180°F.	3600	3600 psi

*Used ¼ inch overlap instead of ½ inch overlap used for 75°F. and 180°F. testing.

F. Metal to Metal T-Peel Strength — PIW (AC & S method C-252)

Cure Cycle: 250°F. — 60 minutes — 20 psig — 1°F./minute rise rate

Primer: EC-3917 **Metal:** 2024 T-3 clad .020" thick aluminum unsealed Chromic Acid Anodized

Peel Rate: 20 inches/minute

	AF-163-2OST	AF-163-2M	AF-163-2K	
Test Temperature	Wt. .03	Wt. .06	Wt. .06	Wt. .085
-67°F.	25	25	33	29
75°F.	29	44	45	41
180°F.	24	40	38	35
250°F.	20	30	28	20

G. Metal to Metal Floating Roller (Bell) Peel Strength — PIW (AC & S method C-260)

1. **Cure Cycle:** 270°F. — 60 minutes — 50 psi — 1°F./minute rise rate

   Primer: EC-3924B

   Metal: 2024T-3 Bare FPL etched .025" to .063" aluminum

   Peel Rate: 6 inches/minute

Test Temperature	AF-163-2K .06	AF-163-2M .06
-67°F.	78 piw	58 piw
75°F.	78 piw	79 piw
180°F.	76 piw	76 piw

2. **Cure:** 250°F. — 60 min. — 30 psig — 5°F./minute rise rate

   Primer: EC-3924B

   Metal: 7075 T6 CLAD Chromic Acid Anodize
   .025" to .063" Aluminum

   Peel Rate: 6 inches/minute

	AF-163-2M		AF-163-2K
Test Temperature	Wt. .045	Wt. .085	Wt. .045
-67°F.	57	55	—
75°F.	55	63	55
160°F.	46	45	—

H. Metal to Metal Climbing Drum Peel Strength-In. Lbs./In. — (AC & S method C-2222)

Cure Cycle: 235°F. — 90 minutes — 35 psig — 5°F./minute rise rate

Primer: EC-3960 **Metal:** 2024 T-3 Clad aluminum .020 inch to .040 inch FPL etched

Peel Rate: 3 inches/minute (cross head travel)

Test Temperature: 75 ± 5°F.

Adhesive	Peel Strength-In. Lbs./In.
AF-163-2OST.03	70
AF-163-2OST.06	75
AF-163-2K .06	80
AF-163-2M .06	80

I. Metal to Honeycomb Climbing Drum Peel Strength — (AC & S method C-245)

1. **Cure Cycle:** 250°F. — 60 minutes — 20 psi — 1°F./min

Primer for Skins: EC-3917

Skins: 2024 T3 0.020 inches thick aluminum — Chromic Acid Anodized

Core: ¼" cell — ½" thick — 4 mil foil — 5052 alloy — non perforated

Test Rate: 1.0 inches/minute (cross head)

	Strength-In. Lbs./In.	
Test Temperature	AF-163-2K Wt. .06	AF-163-2M Wt. .06
−67°F.	20	17
75°F.	23	26
180°F.	18	19
250°F.	9	9

2. **Cure Cycle:** 250°F. — 60 minutes — 30 psi — 5°F./minute

Primer: EC-3924B

Skins and Core: as per (1) above

Test Rate: 1.0 Inches/minute (cross head)

	Strength-In. Lbs./In.		
Test Temperature	AF-163-2K Wt. .045	AF-163-2M Wt. .045	AF-163-2M Wt. .085
−67°F.	—	15	33
75°F.	15	15	39
160°F.	—	12	34

3. **Cure Cycle:** 235°F. — 90 min. — 35 psi — 5°F./minute

Primer: EC-3960

Skins: 2024 T-3 0.020 inch aluminum — FPL etched

Core: as per (1) above

Test Rate: 3 inches/minute (cross head)

Adhesive	75°F. Peel Strength-In. Lbs./In.
AF-163-2K .06	22
AF-163-2K .085	35
AF-163-2M .06	24
AF-163-2M .085	35
AF-163-2OST.06	20

4. **Cure Cycle:** 270°F. — 60 min. — 50 psi — 1°F./min.
   Primer: EC-3924B
   Skins: as (3) above
   Core: 3/16" cell — ½" thick — 5052 alloy — non perforated
   Test Rate: 1.0 inches/minute (cross head)

	Strength-In. Lbs./In. AF-163-2U		AF-163-2K
Test Temperature	**Wt. .03**	**Wt. .06**	**Wt. .06**
−67°F.	—	—	33
75°F.	15	36	31
180°F.	—	—	24

J. **Metal to Honeycomb Flatwise Tensile — (AC & S method C-251)**

1. **Cure Cycle:** 250°F. — 60 minutes — 20 psig — 1°F./min. rise rate
   Primer for Skins: EC-3917
   Metal: Skins: 2024 T-3 aluminum — Chromic Acid Anodized
   Core: ¼" cell — ½" thick — 4 mil foil — 5052 alloy — non perforated

	Strength — PSI AF-163-2K	
Test Temperature	**Wt. .06**	**Wt. .085**
−67°F.	1700	1800
75°F.	1200	1400
180°F.	700	825
250°F.	260	290

2. **Cure cycle:** 250°F. — 60 minutes — 30 psig — 5°F./minute rise rate
   Primer for Skins: EC-3924B
   Metal & Core: same as (1) above

	Strength — PSI AF-163-2M		
Test Temperature	**Wt. .045**	**Wt. .06**	**Wt. .085**
−67°F.	1400	—	1900
75°F.	935	1150	1500
160°F.	625	750	990

3. **Cure Cycle:** 235°F. — 90 minutes — 35 psi — 5°F./min. rise rate
   Primer for Skins: EC-3960
   Metal: Skins; 2024 T-3 aluminum — FPL etched
   Core: same as (1) above

	Strength — PSI				
	AF-163-2U		AF-163-2K		AF-163-2OST
Test Temperature	**Wt. .03**	**Wt. .06**	**Wt. .06**	**Wt. .085**	**Wt. .06**
75°F.	800	1200	1150	1350	1150
180°F.	500	700	650	800	625
250°F.	—	—	250	275	250

K. Metal to Honeycomb Beam Flexure Strength — LBS. — (AC & S method C-250)

Cure Cycle: 250°F. — 60 minutes — 30 psi — 5°F./minute rise rate

Primer: EC-3924B

Metal: 2024 T-3 Bare 0.063 inch thick aluminum — Chromic Acid Anodized

Core: ¼ inch cell — ½ inch thick — 5052 Alloy — 4 mil foil — non perforated

	AF-163-2M		
Test Temperature	**Wt. .045**	**Wt. .06**	**Wt. .085**
−67°F.	3050	3150	3200
75°F.	2850	3160	3200
160°F.	2100	2600	2860

L. Typical Metal to Metal Fatigue Resistance:

1. **Wide Area Blister Shear Type Specimens** — C-2232 Type

   Cure Cycle: 235°F. — 90 minutes — 35 psi — 5°F./minute rise rate

   Primer: EC-3960 **Metal:** 2024 T-3 Bare .063 inch thick aluminum — FPL etched

   Max. Stress: 1500 psi Stress Ratio: 0.1 **Rate:** 1800 cycles/minute

   Test Temperature: 75 ± 5°F.

   Results: Under these conditions AF-163-2 films have yielded greater than 10^7 cycles without adhesive failure

2. **Double Lap Strap** 6, 4 Titanium Specimens

   Cure Cycle: 250°F. — 60 minutes — 20 psig — 1°F./minute rise rate

   Primer: EC-3917 **Adhesive:** AF-163-2K Wt. .06

   Metal: 6, 4 Titanium alloy — phosphate fluoride etched
   Center Adherends 1 inch x 4⅝ inches x 0.125 inches
   Straps 1 inch x 1⅝ inches x .063 inches

   Stress Ratio = 0.1 Rate = 1800 cycles/minute Test temp. = 75°F. ± 5°F.

   Shear Area — 1.5 square inches

Max. Stress (PSI)	**Avg. Life (Cycles)**
4500	1.58×10^4
4000	5.28×10^4
3500	4.75×10^5
3000	2.67×10^6
2200	NF — 1.03×10^7

NF = No failure, test discontinued.

M. Typical Creep Resistance

1. **Metal to Metal Wide Area Shear Specimens — C-2232 Type**

   Cure Cycle: 235°F. — 90 minutes — 35 psig — 5°F./minute rise rate

   Primer: EC-3960

   Metal: 2024 T-3 Bare .063" thick aluminum — FPL etched

	Creep after 192 hours in inches	
Adhesive	**75°F. — 1600 psi**	**180°F. — 800 psi**
AF-163-2K .06	Less than 0.0003	≤ .0012
.085	Less than 0.0003	≤ .0015
AF-163-2OST .03	Less than 0.0003	Less than 0.0003
.06	Less than 0.0003	Less than 0.0003

2. **Metal to Metal Overlap Shear Specimens — C-245 Type**
Cure Cycle: 250°F. — 60 minutes — 30 psi — 5°F./min rise rate
Primer: EC-3924B
Metal: 7075 T-6 Clad .063" thick aluminum — Chromic Acid Anodized

	Creep after 192 hours in inches	
Adhesive	**75°F. — 1600 psi**	**160°F. — 1200 psi**
AF-163-2M .085	Less than 0.0003	Less than 0.0003

3. **Metal to Honeycomb Creep Deflection in Flexure — (Mil-A-25463 method)**
Cure Cycle: 250°F. — 60 minutes — 30 psig — 5°F./minute rise rate
Primer: EC-3924B
Metal: 2024 T-3 Bare 0.063 inch thick aluminum — Chromic Acid Anodized
Core: ¼ inch cell — ½ inch thick — 5052 Alloy — 4 mil foil — non perforated

	Deflection after 192 hours in inches					
	75°F. Test		160°F. Test		180°F. Test	
Adhesive (Stress)	**970 Lbs.**	**1500 Lbs.**	**970 Lbs.**	**1500 Lbs.**	**970 Lbs.**	**1500 Lbs.**
AF-163-2M						
Wt. .045	.0005	—	.003	—	.005	—
Wt. .085	—	0.0011	—	.006	—	.017

N. **Typical Bond Strengths on Other Substrates**
Adhesive: AF-163-2M Wt. .045
Primer: EC-3924B
Cure Cycle: 250°F. — 60 minutes — 30 psig — 5°F./minute

Substrate	**AC & S Method C-244 L/T = 8 Shear - PSI 75°F.**	**180°F.**	**AC & S Method C-260 6 inches per minute Floating Roller Bell Peel - PIW 75°F.**
7075 T6 Clad FPL- Etch	.063" Thick Metal 6050	3500	.025" Thick Metal Peel Skin 65
6, 4 Titanium Phosphate Fluoride Etch	0.063" Thick Metal 6825	3650	.014" Thick Metal Peel Skin 45
301 Stainless Steel HNO_3 - HF Etch	0.060" Thick Metal 6260	3750	0.020" Thick Metal Peel Skin 60
Epoxy FRP ("Scotchply" Brand Type 116)	0.150 Thick Skin		—
Abrade & degrease - unprimed	*4300	*2300	—

*Interlaminar adherend failure

III **Typical Performance after Environmental Exposure**

A. **Metal to Metal Overlap Shear Strength — PSI** — (AC & S method C-244)
Cure Cycle: 250°F. — 60 minutes — 30 psig — 5°F./minute rise rate
Primer: EC-3924B
Metal: 7075 T-6 Clad 0.063" thick — Chromic Acid Anodized

Adhesive: AF-163-2M Wt. .085

Specimens: Precut to 1 inch width prior to exposure

Environmental Exposure	75°F. Lap Shear Strength (PSI)
1. Control (No Exposure)	6345
2. 7 day immersion in JP-4	6570
3. 7 day immersion in Mil-F-5566	6365
4. 7 day immersion in Mil-H-5606	6465
5. 7 day immersion in Type III Hydrocarbon	6510
6. 30 day water immersion	5860
7. 30 day 5% Salt Spray Exposure	5930
8. *Cyclic Humidity Exposure a) 15 Cycles	6245
b) 30 Cycles	5510
c) 45 Cycles	5655

*Each Cycle: 16 hours @ 125°F. at 95-100% RH followed by 8 hours at −67°F.

B. Metal to Metal Blister Detection Shear — (AC & S method C-265)

Cure Cycle: 270°F. — 40psi — 60 minutes — 1°F./minute rise rate

Primer: EC-3924B

Metal: 2024 T-3 Base .063" thick aluminum — FPL etch

Adhesive: AF-163-2K Wt. .06

Specimens: Precut to 1.0 inch width and notched prior to exposure

Environmental Exposure	75°F. Shear Strength (PSI)
1. Control (No Exposure)	5095
2. 7 day immersion in JP-4	5065
3. 7 day immersion in Mil-4-5606	5050
4. 7 day immersion in Mil-L-7808	5005
5. 30 day Exp. 120°F. — 95 to 100% RH	4980
6. 30 day Exp. to 5% Salt Spray	5030

C. Metal to Metal Floating Roller (Bell) Peel — (AC & S method C-260)

Cure Cycle: (same as above)

Primer: EC-3924B

Metal: 2024 T-3 Bare .025" Thick to .063" thick aluminum — FPL etched

Adhesive: AF-163-2K Wt. .06

Specimens: Precut to 1 inch wide before exposure

Peel Rate: 6 inches/minute

Environmental Exposure	75°F. Peel Strength (PIW)
1. Control (No Exposure)	82
2. 7 day immersion in JP-4	83
3. 7 day immersion in Mil-H-5606	85
4. 7 day immersion in Mil-L-7808	84
5. 30 day Exposure 120°F. and 95 to 100% RH	80
6. 30 day 5% Salt Spray Exposure	82

D. Metal to Metal Wide Area Blister Detection Shear — PSI — (AC & S method C-2232)

Cure Cycle: 235°F. — 90 minutes — 35 psi — 5°F./minute rise rate

Primer: EC-3960

Metal: 2024 T-3 Bare 0.063 inches thick — FPL etched

Specimens: Precut to 1.0 inch width and notched prior to exposure

Environmental Exposure	75°F. Shear Strength — PSI AF-163-2OST Wt. .03	AF-163-2OST Wt. .06	AF-163-2K Wt. .06	AF-163-2K Wt. .085
1. Control (No Exposure)	5405	5280	5105	5115
2. 7 day JP-4 minimum (75°F.)	5345	5255	5225	5079
3. 7 day Type III Hydrocarbon immersion (75°F.)	5340	5315	5255	5160
4. 7 day Skydrol 500B immersion (150°F.)	5400	5470	5214	5135
5. 30 day 5% Salt Spray	5330	5105	4865	4635
6. 30 day 120°F. — 95-100% RH	5360	5200	4940	4735

E. Metal to Metal GIscc — Crack Extension at 140°F. and 95-100% RH — (AC & S method C-295)

Cure Cycle: 235°F. — 90 min. — 35 psig — 5°F./min. rise rate

Primer: EC-3960

Metal: 2024 T-3 Bare 0.5 inch thick aluminum — phosphoric acid anodized

Specimen: DCB specimen precut to 1.0 inch width prior to exposure

Exposure	GIscc — In. Lbs./In.² AF-163-2OST		AF-163-2K	
Time (hours)	Wt. .03	Wt. .06	Wt. .06	Wt. .085
2500 hours	6.4	7.5	7.2	8.5

F. Metal to Honeycomb Beam Flexure Strength (Lbs) — (AC & S method C-250)

Cure Cycle: 250°F. — 60 minutes — 30 psi — 5°F./min

Primer for Skins: EC-3924B

Metal Skins: 2024 T-3 Bare 0.063 inches thick aluminum — Chromic Acid Anodized

Core: ¼ inch cell — ½ inch thick — 4 mil foil — 5052 Alloy — non perforated

Adhesive: AF-163-2M Wt. .045

Environmental Exposure	75°F. Flexural Strength — Lbs.
1. Control (No Exposure)	2850
2. 30 day immersion in Type III Hydrocarbon	2800
3. 30 day 5% Salt Spray	2800
4. *Cyclic Exposure — 45 Cycles	2900

G. Metal to Honeycomb Flatwise Tensile Strength — PSI — (AC & S method C-251) conditions as per (F) above

Environmental Exposure	75°F. Flatwise Tensile Strength — PSI
1. Control (No Exposure)	935
2. *Cyclic Exposure: 15 Cycles	865
45 Cycles	870

*Each Cycle: 16 hours at 125°F. and 95-100% RH followed by 8 hours at −67°F.

Product Performance (cont):

IV Typical Performance after Open Time at 90°F. and 75% RH

Cure Cycle: 250°F. — 60 minutes — 30 psig — 5°F./min. rise rate

Primer: EC-3924B **Metal Skin Prep:** Chromic Acid Anodize

Core: ¼" cell — ½" thick — 4 mil foil — 5052 Alloy — non-perforated

Exposure Method: Adhesive applied to Primed Skin with liners removed and exposed open face

A. 75°F. Overlap Shear on 7075 T-6 Clad .063 inch thick aluminum — (AC & S method C-244)

Exposure Time	AF-163-2M Wt. .045
0	6300 psi
7 days	6400 psi
15 days	6500 psi

B. Floating Roller (Bell) Peel on 7075 T-6 Clad .025" to .063" aluminum — (AC & S method C-260)

	AF-163-2M Wt. .045		
Exposure Time	−67°F. Test	75°F. Test	160°F. Test
0	57 piw	55 piw	46 piw
7 days	55 piw	61 piw	50 piw
15 days	59 piw	55 piw	44 piw

C. 75°F. Honeycomb Peel 2024 T-3 Bare .020 Aluminum Skins — (AC & S method C-245)

	AF-163-2M	
Exposure Time	Wt. .045	Wt. .085
0	15 In. Lbs./In.	39 In. Lbs./In.
7 days	15 In. Lbs./In.	31 In. Lbs./In.
15 days	11 In. Lbs./In.	26 In. Lbs./In.

D. 75°F. Honeycomb Flatwise Tensile 2024 T-3 Bare Aluminum Skins — (AC & S method C-251)

	AF-163-2M	
Exposure Time	Wt. .045	Wt. .085
0	935 psi	1500 psi
7 days	1050 psi	1600 psi
15 days	1000 psi	1570 psi

V Typical Metal to Metal 200°F. Cure Performance:

Cure Cycle: 200°F. ± 5°F. — 50 psi — 1°F./min rise rate

Primer: EC-3924B

	AF-163-2K Wt. .06		
Cure Time	Blister Detection Shear (AC & S method C-265)		Floating Roller (Bell) Peel (AC & S method C-260)
	75°F. Test	180°F. Test	75°F. Test
A. 2 hours	4120 psi	1750 psi	68 piw
B. 4 hours	4580 psi	2880 psi	76 piw
C. 6 hours	4700 psi	3280 psi	77 piw

Product Performance (cont):

VI Typical Vacuum Cure Performance

Cure: 250°F. — 60 minutes — 5°F./min rise rate

Primer: EC-3960

Overlap Shear: (AC & S method C-244) — 2024 T-3 .063" thick aluminum

Honeycomb Peel: (AC & S method C-245) — ¼" cell Core — 2024 T-3 .020" thick aluminum skins

Peel Rate: 3 inches/minute (cross head travel)

	AF-163-2K .06		**AF-163-2M .06**		**AF-163-2OST .03**
Pressure (Vacuum)	**Overlap Shear 75°F. PSI**	**Honeycomb Peel 75°F. In Lbs/3 In.**	**Overlap Shear 75°F. PSI**	**Honeycomb Peel 75°F. In Lbs/3 In.**	**Overlap Shear °F. PSI**
A. 25 psig positive pressure	5700	77	6200	74	5600
B. 9-11 Inches Hg	5700	65	6000	75	5200
C. 16-18 Inches Hg	3800	54	6000	67	5500
D. 24-26 Inches Hg	3300	45	4800	59	5200

VII Effect of rise rate on Typical Metal to Metal Properties

Primer: EC-3917 **Metal Prep:** Chromic Acid Anodize

Metal: (AC & S method C-252) T-Peel 2024 T-3 Clad 0.020 inch aluminum
(AC & S method C-244) OL Shear 2024 T-3 Clad 0.063 inch aluminum

T-Peel Rate: 20 inches/minute

Adhesive: AF-163-2K Wt. .06

Cure Temp. **Cure Time** **Cure Pressure** **Rise Rate**	**250°F.** **60 min.** **20 psig** **1°F./min.**	**250°F.** **60 min.** **20 psig** **8°F./min.**	**250°F.** **60 min.** **50 psig** **20°F./min.**
75°F. Overlap Shear	5760 psi	5840 psi	5640 psi
75°F. T-Peel	45 piw	46 piw	45 piw

Product Application:

Note: While this information is provided as a general application guideline based upon typical conditions, it is recognized that no two applications are identical due to differing assemblies, methods of heat and pressure application, production equipment and other limitations. It is therefore suggested that experiments be run, within the actual constraints imposed, to determine optimum conditions for your specific application and to determine suitability of product for particular intended use.

I. Surface Preparation

A thoroughly cleaned, dry, grease-free surface is essential for maximum performance. Cleaning methods which will produce a break free water film on metal surfaces are generally satisfactory.

A. Aluminum: Phosphoric acid anodize (AC & S method C-2780), Chromic acid anodize with or without a chromate seal (AC & S methods C-2801 or C-2782) are preferred for maximum joint durability in moist environments. Optimized FPL Etch has also demonstrated improved durability performance.

Optimized FPL Etch — 3M Company (AC & S method C-2803)

1. Vapor degrease — perchloroethylene condensing vapors for 5-10 minutes
2. Alkaline degrease — Oakite 164 solution 9-11 oz./gallon of water at 190°F. ± 10°F. for 10 to 20 minutes. Rinse immediately in large quantities of cold running water (AC & S method C-2802)
3. Acid Etch — Immerse panels in the following solution for 10 minutes at 150 ± 5°F.:

Sodium dichromate ($Na_2Cr_2O_7 \cdot 2H_2O$)	4.1-4.9 oz./gallon
Sulfuric Acid 66°Be	38.5-41.5 oz./gallon
2024 T-3 aluminum (dissolved)	0.2 oz./gal. minimum
Tap Water	Balance

4. Rinse immediately in large quantities of clear running tap water.
5. Dry — Air dry approximately 15 minutes followed by a force dry at 150°F. ± 10°F. for 10 minutes
6. Current theory suggests that both surface structure and chemistry play a significant role in determining the strength and permanence of bonded structure. It is therefore advisable to bond or prime freshly cleaned surfaces as early as possible after preparing to avoid contamination and/or mechanical damage.

B. Aluminum Honeycomb Core

1. Vapor degrease in condensing vapors of perchloroethylene or soak in clean aliphatic naphtha (conforming to TT-N-95A) for five minutes at room temperature. Dry 10 minutes at 150°F. ± 5°F.
2. Optional — Immerse in etching solution above for 2 minutes at 150°F. ± 5°F. Rinse, air dry and force dry in a similar manner to skins.

Product Application:(cont.)

C. Titanium CP or 6Al 4V Both *Turco 5578 and improved phosphate fluoride processing have been used successfully with AF-163-2 Systems.

*Turco 5578 process

1. Vapor hone 140 grit in water — rinse thoroughly with clear running tap water.
2. Degrease — solvent or alkaline process.
3. Immerse for 15 minutes at 185 ± 5°F. in the following bath:
   *Turco 5578 — 420 grams
   Distilled water — Balance to make 1 liter
4. Immerse for 1 minute in 170°F. ± 5°F. distilled water.
5. Spray rinse for 5 minutes in hot tap water ~ 130°F.
6. Air dry for 10 to 20 minutes.
7. Force dry for 15 minutes at 150°F.
8. It is advisable to bond or prime freshly cleaned surfaces within four hours.

*Turco Products division of Purex.

D. Stainless Steel — 301 Type

1. Vapor hone 140 grit in water.
2. Rinse thoroughly in clear running tap water.
3. Alkaline degrease — see A2 procedure above.
4. Rinse thoroughly in clear running tap water.
5. Immerse for 10 minutes at 75°F. ± 5°F. in the following bath:

Nitric Acid 42° Be	30-50 oz./gallon
Hydrofluoric Acid 70%	3-5 oz./gallon
Distilled Water	Balance

6. Rinse thoroughly in clear running tap water.
7. Air dry for 10-20 minutes.
8. Force dry for 15 minutes at 150°F.
9. Bond or prime within four hours after preparing.

E. Cured fiberglass or carbon fiber reinforced epoxy resin based reinforced plastic.

1. Abrade with 180 grit paper or "Scotch-Brite" Brand scrub pad (do not cut through resin into reinforcing fibers).
2. Degrease using acetone or methylethyl ketone using an unsized cheezecloth pad.
3. Air dry for two hours minimum.

Product Application:(cont.)

II Primers

For most applications, use of a corrosion inhibiting primer is suggested to obtain maximum bond durability in moist, corrosive environments. 3M corrosion inhibiting primers EC-3924B, EC-3960, EC-3980 and EC-3917 have all been successfully used with AF-163-2 films. Because of its characteristics which allow both spray and brush application methods, EC-3924B is normally suggested for use with AF-163-2 films. For suggested application techniques, refer to the respective primer data sheets.

III Primer Coverage

For the primers noted above, the optimum mechanical property test performance with AF-163-2 will normally be found with a uniform primer coverage in the 1000-3000 mg/m^2 range (dry weight). This is approximately 0.1 mils as measured by an Isometer*. As the primer weight is increased a gradual decrease in low temperature peel strength will be found along with increasing levels of cohesive fracture in the primer layer (exception: properly controlled 180° T-Peel does not normally show this effect). Where specific tests and required strength levels are involved, a few simple experiments with varied primer coverage will be required to establish an allowable primer coverage range. Further applications can then be controlled by correlating color or thickness standards for the acceptable range.

*Foerster Instruments Inc.

IV Primer Dry

The following cycle is suggested for these primers when used with AF-163-2 films:

Air dry: 60 minutes followed by a
Force dry: 60 minutes at 250 to 300°F.

Normally optimum performances will be found at the higher end of the force dry temperature range when used with AF-163-2 films.

Note: Use of these primers without a force dry is not recommended in conjunction with AF-163-2 films and is subject to very strict limitations. Consult with your 3M representative if further information is required.

V Adhesive Film Application

Care should be taken during application to avoid contamination of the adhesive and substrates by any substance which will interfere with the wetting action of the adhesive.

Layup:

A. AF-163-2U, M, or K Films

1. Cut a portion of film sufficient for the assembly from the stock roll with protective liner(s) in place.
2. If the film has one protective liner, place the exposed adhesive against the substrate using the liner as a protective cover. If two liners are present, remove one and follow as above.
3. Position film and rub out all air between the adhesive and the substrate. Use of a rubber roller will facilitate this process.
4. Remove protective liner.
5. Complete assembly being careful to avoid trapping air and cure.

B. AF-163-2OST Films

OST films are designed to facilitate the removal of air from large area solid panel construction. Application of vacuum to the assembly prior to and during the initial heat cycle is normally required (see cure conditions below).

1. Cut a portion of film sufficient for the application with the liner in place.
2. Remove the protective liner and apply the high tack side of the film against the substrate (high tack side is adjacent to the liner).
3. Position the film and rub out all air between the adhesive and the substrate (use of a rubber roller will facilitate this process).
4. Complete assembly and cure.

VI Cure Conditions & Characteristics

AF-163-2 films are designed to provide short cure times in the 225°F. to 300°F. temperature range. While performance outside this cure temperature range has not been fully investigated, limited results suggest that cure temperatures as high as 350°F. may be used as well as longer cure times at 200°F. (6 hrs.) to obtain useful performance.

A. Weight Loss During Cure: Less than 1% (AC & S method C-273)
(60 min. at 250°F.)

B. Gel Time: The following times are typically required to convert the AF-163-2 resin system to a low strength, rubbery solid on a pre-heated stage.

Temperature	Gel Time
200°F.	103 minutes
225°F.	47.5 minutes
250°F.	20.5 minutes
275°F.	10 minutes
300°F.	5.5 minutes

C. Flow During Cure: (AC & S method C-261)

The following levels are typical averages for AF-163-2 films using a cure of 235°F. — 30 minutes — 35 psi — 5°F./minute.

Adhesive	% Flow (area increase)
AF-163-2OST Wt. .03	225%
AF-163-2K Wt. .06	350%
AF-163-2M Wt. .06	400%
AF-163-2K Wt. .085	450%

D. Cure Time and Temperature

1. For temperatures from 250°F. to 300°F., a cure time of 60 minutes at temperature is suggested.
2. For temperatures between 225°F. and 250°F., a cure time of 90 minutes at temperature is suggested.

Following cure, it is suggested that pressure be maintained until the assembly has been cooled to 150°F. or below.

E. Heat up rate

Bond line temperature rise rates between 1°F./minute and 20°F./minute have been used successfully with AF-163-2 films. It must be noted that hot entry cures at 300°F. and above can be expected to produce reduced performance due to the presence of resultant bond line porosity.

Product Application: (cont.)

F. Cure Pressure

1. Positive Pressure Cures

During cure, pressure is required to keep parts in alignment and to overcome distortions and thermal expansion of the adherends. When bonding honeycomb assemblies with non-perforated core, pressure is required to overcome the thermal expansion of air in the honeycomb cells. Positive pressures between 20 and 80 psi have been used successfully with AF-163-2 film. For very small area bonds, however, pressures at the higher end of this range may produce excessive squeeze out and adhesive bond line starvation. For large solid panel constructions which are autoclave cured, application of vacuum for 15 to 20 minutes prior to application of heat and pressure is suggested to assist in removing any residual air trapped in the assembly. Normally, the vacuum is released following application of positive pressure. For problem assemblies, maintain the vacuum during the heatup cycle to about 130°F to further assist in providing void free bonds.

Note: When using AF-163-2OST films it is essential that these suggested vacuum application steps be included to gain the full effect of the air removal potential of the OST construction.

2. Vacuum Curing

AF-163-2 films can be successfully cured using vacuum cure techniques. For performance comparable to positive pressure cures, AF-163-2K films should be cured using a vacuum level in the range of 8-12 inches of mercury. Higher vacuum levels yield excessive porosity and corresponding strength reductions. AF-163-2M and OST versions have shown a high level of performance retention across the 10-25 inches of mercury vacuum level range.

Storage:

Storage Stability — Storage at 0°F. or below is recommended for Scotch-Weld Brand Adhesive AF-163-2 films to obtain maximum storage life.

Caution: AF-163-2 films should be permitted to thoroughly warm to room temperature before being used in order to prevent moisture condensation. (Do not open protective container prior to reaching ambient conditions).

Precautionary Information:

See Material Safety Data Sheet for precautions during use.

Important Notice to Purchaser:

All statements, technical information and recommendations contained herein are based on tests we believe to be reliable, but the accuracy or completeness thereof is not guaranteed, and the following is made in lieu of all warranties, express or implied:

Seller's and manufacturer's only obligation shall be to replace such quantity of the product proved to be defective. Neither seller nor manufacturer shall be liable for any injury, loss or damage, direct or consequential, arising out of the use or the inability to use the product. Before using, user shall determine the suitability of the product for his intended use, and user assumes all risk and liability whatsoever in connection therewith.

No statement or recommendation not contained herein shall have any force or effect unless in an agreement signed by officers of seller and manufacturer.

BR® 624

Potting Compound

BR 624 potting compound is a one-part, low-density material formulated for use in insert or edge filling of honeycomb sandwich construction. It is a thermosetting, modified epoxy system, serviceable over a temperature range of −70 °F to 350 °F (−57 °C to 175 °C).

BR 624 potting compound is thixotropic and cure cycles may be varied over a broad range; cure temperatures as low as 225 °F (105 °C) and as high as 350 °F (175 °C) have been used successfully. Multiple cure cycles at temperatures up to 350 °C (175 °C) will not impair its use as a structural material.

Product Description

Form	Thixotropic paste	Storage	Store at or below 0 °F (−18 °C)
Color	Dark maroon	Density range (cured)	37 to 47 lb/ft³ (.592 to .752 gm/cc)
Specific gravity	Approximately 0.65	Shop life	30 days below 75 °F (24 °C)
Shelf life	Six months from date of shipment at recommended storage		

Curing Procedure

BR 624 potting compound may be applied with caulking guns or spatula-like tools. Warming to temperatures up to 110 °F (43 °C) will facilitate filling of honeycomb cells.

The recommended cure cycle is 30 to 60 minutes heat-up to 250 °F (120 °C); 60 minutes hold at 250° ± 5 °F (120° ± 3 °C). If slight expansion is objectionable, restraint during cure is suggested. After cure, BR 624 can be sanded or machined, as required.

CYANAMID

American Cyanamid Company
Polymer Products Division
Engineered Materials Department
[illegible]

BPT-0618

Table I
Typical Strength Properties of BR 624 Potting Compound

Density lb/cu ft (gm/cc)	Compressive Strength at 0.2% offset psi (MPa)	Testing Temperature °F (°C)
43.12 (.69)	10,463 (73.16)	75 (24)
47.00 (.75)	10,800 (74.48)	75 (24)
45.65 (.73)	9,850 (67.93)	75 (24)
42.27 (.68)	5,428 (37.43)	180 (82)
46.31 (.74)	3,800 (26.21)	180 (82)
46.80 (.75)	4,435 (30.59)	180 (82)

Material — Core—8.1-1/8-.002-5052N, 1" t (3.175 mm-.050 mm-5052N, 25.4 mmt)

Cure Cycle — BR 624 potting compound troweled into core, taking care not to entrap air bubbles
Press rate to 250°F (120°C); 60 minutes at 250°F (120°C);
Restrained under 40 psi (.276 MPa).
Specimens machined to 1-1/2 inches (38.10 mm) diameter

Table II
Core Shear as a Function of Splicing Core with BR 624 Potting Compound

Splice Material	Variable	R.T. Flexure Load-lb (Load-N)	Type Failure
None	Control	3050 (13.567)	Core shear
		3020 (13.434)	Core shear
BR 624 potting compound	Core spliced	3030 (13.480)	Core shear
		2940 (13.078)	Core shear

Materials — Faces—.064" (1.63 mm) 2024-T3 Alclad
Core—7.9-1/4-.004-5052N, 1/2" t (6.25 mm-.102 mm-5052N, 12.7 mmt)
Panels bonded with FM® 123-2 adhesive film, .085 psf (.42 kg/m²)

Cure Cycle — 60 minutes to 225°F (105°C); 90 minutes at 225°F (105°C);
40 psi (.276 MPa)

Table III
Compressive Strength vs. Heat Aging at 350°F (175°C)

Test Temperature	Control psi (MPa)	1000 Hours psi (MPa)	2000 Hours psi (MPa)
75°F (24°C)	10,970 (75.66)	8,800 (60.69)	9,155 (63.14)
350°F (175°C)	1,755 (12.11)	1,900 (13.10)	2,230 (15.38)

Material — Specimens machined to 1-1/2 inches (38.10 mm) diameter
Core—8.1-1/8-.002-5052N, 1" t (3.175 mm-.050 mm-5052N, 25.4 mmt)

Cure Cycle — Press rate to 250°F (120°C); 60 minutes at 250°F (120°C);
Restrained under 40 psi (.276 MPa).

Warning
Contains an epoxy resin. May cause allergic skin reaction. Avoid prolonged or repeated contact with skin. Wash thoroughly after handling.

First Aid
In case of contact, immediately wash skin with soap and plenty of water.

Ventilation Required
Use mechanical exhaust ventilation when heat curing resin system.

Detailed Handling Instructions
Refer to Material Safety Data Sheets and product labels.

Important Notice
The information and statements herein are believed to be reliable but are not to be construed as a warranty or representation for which we assume legal responsibility. Users should undertake sufficient verification and testing to determine the suitability for their own particular purpose of any information or products referred to herein. NO WARRANTY OF FITNESS FOR A PARTICULAR PURPOSE IS MADE. Nothing herein is to be taken as permission, inducement or recommendation to practice any patented invention without a license.

CYANAMID

American Cyanamid Company
Polymer Products Division
Engineered Materials Department
Aerospace Products
[illegible]

Nylon and Polyester Fabrics

Nylon

COLORED POLYURETHANE COATED NYLON FABRIC

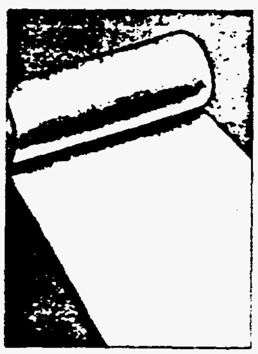
Tear-resistant nylon with a tough polyurethane coating makes great truck covers, outdoor curtains, equipment covers, and canopies. Fabric is lightweight, flexible in cold temperatures, and has high resistance to abrasion. Resists oils, solvents, chemicals, mildew, and rot. Will not stretch or shrink. Weight is 13 ounces per square yard. Thickness is .025".
Width is 61¼" and maximum continuous length is 150 yds.

Color	No.	NET/LIN. YD. 1-9	10-Up
Red	8809K11	$10.60	$8.83
White	8809K12	10.60	8.83
Blue	8809K13	10.60	8.83
Black	8809K14	10.60	8.83
Green	8809K15	10.60	8.83

✱ ➔ NEOPRENE COATED NYLON FABRIC

A good, strong, all-around fabric for asphalt covers, equipment covers, and truck covers. Also makes a good flexible duct connector. The neoprene coating gives excellent resistance to deterioration caused by exposure to asphalt, oils, solvents, gases, grease, mildew, and ultraviolet rays. The heavy fabric resists tearing and punching.
Fabric is easy to handle at low temperatures. Furnished with black neoprene coating on both sides or with black neoprene on one side and aluminum on the other side.
Weight is 16 ounces per square yard. Thickness is .025".
Width is 60" and maximum continuous length is 100 yds.

Description	No.	NET/LIN. YD. 1-9	10-Up
Neoprene Both Sides	8811K11	$12.94	$10.83
Neoprene/Aluminum	8811K12	13.72	11.43



LIGHT WEIGHT COLORED VINYL LAMINATED NYLON FABRIC

Flexible fabric is excellent for light duty tarpaulins, windscreens, bags, air structure liners, aprons, and vests. Fabric resists abrasion, weather, water, and rot. Has high tensile strength and resists tearing.
Fabric conforms to MIL-C-43006F Type 2 and is fire retardant. Weight is 10 ounces per square yard. Thickness is .012". **Width is 54" and maximum continuous length is 100 yds.**

Color	No.	NET/LIN. YD. 1-9	10-Up
Red	87735K83	$6.83	$5.31
White	87735K84	6.83	5.31
Beige	87735K85	6.83	5.31
Yellow	87735K86	6.83	5.31
Black	87735K87	6.83	5.31

MEDIUM WEIGHT COLORED VINYL LAMINATED NYLON FABRIC

Oil-resistant fabric is ideal for indoor and outdoor curtains, equipment and floor covers, spray booth curtains, draft protection, and privacy barriers.
Fabric resists acids, alkalies, and mildew and is tear and abrasion resistant. Not recommended for use as truck covers. Fabric is flame retardant. Weight is 13 ounces per square yard. Thickness is .022". **Width is 60" and maximum continuous length is 100 yards.**

Color	No.	NET/LIN. YD. 1-24	25-Up
Red	8810K11	$8.05	$6.44
White	8810K12	8.05	6.44
Blue	8810K13	8.05	6.44

Polyester

MEDIUM WEIGHT COLORED VINYL LAMINATED POLYESTER FABRIC

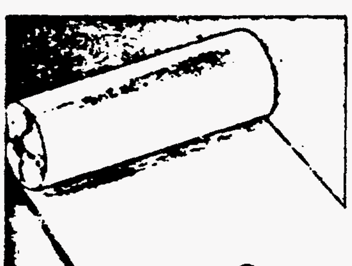
Whether it's inside or outside, you've got it covered with this vinyl laminated polyester fabric. Ideal for tarpaulins, windscreens, and drop cloths. Excellent as outdoor protective covers for equipment and vehicles. Fabric has high tear and tensile strength. Resists abrasion and rot. Material is fire retardant.
Olive drab fabric is a little heavier, with a camouflage pattern. Use for equipment bags, windscreens, and coverings.

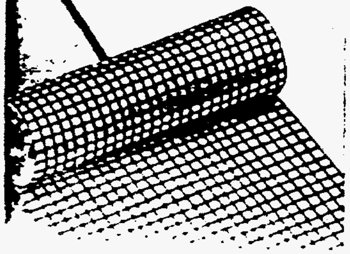
Color	No.	NET/LIN. YD. 1-9	10-Up
14 OZ./SQ. YD.—62" WIDE AND .017" THICK			
Maximum continuous length is 75 yards			
Red	87615K73	$8.03	$6.24
White	87615K74	8.03	6.24
Beige	87615K75	8.03	6.24
Yellow	87615K76	8.03	6.24
Black	87615K77	8.03	6.24
Orange	87615K78	8.03	6.24
18 OZ./SQ. YD.—54" WIDE AND .021" THICK			
Maximum continuous length is 50 yards			
Olive Drab Camouflage	87615K88	$9.90	$7.92

HEAVY WEIGHT COLORED VINYL COATED POLYESTER FABRIC

This excellent general purpose outdoor covering is ideal for tarps, curtains, and equipment covers. Waterproof material will not rot. Fabric is not flame retardant. Weight is 18 oz. per square yard. Thickness is .024".
Width is 61" and maximum continuous length is 100 yards.

Color	No.	NET LIN./YD. 1-9	10-Up
Red	8843K11	$9.98	$8.32
White	8843K12	9.98	8.32
Blue	8843K13	9.98	8.32
Black	8843K14	9.98	8.32





A. ALUMINIZED VINYL LAMINATED POLYESTER FABRIC

Cloth reflects heat to where it's needed . . . saves on energy costs.
Use this unique fabric for insulating curtains, drop ceilings, thermal barriers, reflective covers and tarpaulins.
Fabric is made of aluminum foil laminated to polyester, then laminated to vinyl. Fabric is waterproof and resistant to abrasion and rot.
Use indoors as well as outdoors in humid and damp environments. Color of non-aluminum side is white.
Width is 54".

Thick.	Oz./Sq. Yd.	Max. Contin. Lg., Yds.	No.	NET/LIN. YD. 1-9	10-Up
.012"	10	100	87605K67	$7.48	$5.98
.022"	18	50	87605K68	10.18	8.14

B. OPEN MESH COLORED VINYL COATED POLYESTER FABRIC

Here's a super lightweight, see-through mesh fabric that still has plenty of strength for outdoor use. Excellent for pedestrian traffic barriers, divider curtains, truck covers, windscreens, safety apparel, utility bags, and landscaping tie-downs. The material has good dimensional stability and is abrasion resistant. It's also resistant to tearing and rot.
[illegible]
Thickness is .020", except camouflage, which is .014" thick. **Width is 62" and maximum continuous length is 100 yards.**

Colors	No.	NET LIN. YD. 1-9	10-Up
Red	87655K93	$5.31	$4.13
White	87655K94	5.31	4.13
[illegible]	87655K95	5.31	4.13

HYSOL

Aerospace Products

EA 9330

STRUCTURAL ADHESIVES

DESCRIPTION

Hysol® EA 9330 is a two component paste adhesive which is easily mixed and has high peel strength. This room temperature cure system has good environmental resistance and bonds to a variety of substrates.

FEATURES

- Two Component
- Room Temperature Cure
- Tolerant of Bondline Thickness Variations
- High Peel Strength
- Excellent Environmental Resistance

UNCURED ADHESIVE PROPERTIES

	Part A	Part B	Mixed
Color	Cream	Amber	Cream
Viscosity 77°F Brookfield, HBT	2000 Poise Spdl 5 @ 10 RPM	15 Poise Spdl 1 @ 20 RPM	
Viscosity, 25°C Brookfield, HBT	200 Pa•s Spdl 5 @ 1.05 rad/sec	1.5 Pa•s Spdl 1 @ 2.09 rad/sec	
Density (g/ml)	1.20	1.03	1.15
Shelf Life @ < 40°F/4°C (from date @ < 77°F/25°C of shipment) @ < 90°F/33°C	1 year 1 year 1 year	1 year 1 year 1 year	
This material will normally be shipped at ambient conditions, which will not alter our standard warranty, provided that the material is placed into its intended storage upon receipt. Premium shipment is available upon request.			

HANDLING

Mixing • This product requires mixing two components together just prior to application to the parts to be bonded. Complete mixing is necessary. The temperature of the separate components prior to mixing is not critical, but should be close to room temperature (77°F/25°C).

Mix Ratio	Part A	Part B
By Weight	100	33

Note: Volume measurement is not recommended for structural applications unless special precautions are taken to assure proper ratios.

Pot Life (100 gm mass) 60 minutes
Method • ASTM D 2471 in water bath.

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APPLICATION

Mixing – Combine Part A and Part B in the correct ratio and mix thoroughly. THIS IS IMPORTANT! Heat buildup during or after mixing is normal. Do not mix quantities greater than 1 pound as dangerous heat buildup can occur causing uncontrolled decomposition of the mixed adhesive. TOXIC FUMES CAN OCCUR, RESULTING IN PERSONAL INJURY. Mixing smaller quantities will minimize the heat buildup.

Applying – Bonding surfaces should be clean, dry and properly prepared. For optimum surface preparation consult the Hysol Surface Preparation Guide. The bonded parts should be held in contact until the adhesive is set. Handling strength for this adhesive will occur in 29 hours at 77°F/25°C, after which the support tooling or pressure used during cure may be removed. Since full bond strength has not yet been attained, load application should be small at this time.

Curing – Hysol EA 9330 may be cured for 5-7 days at 77°F/25°C to achieve normal performance. Accelerated cures up to 200°F/93°C (for small masses only) may be used as an alternative. For example, 2 housr at 180°F/82°C will give complete cure.

Cleanup – It is important to remove excess adhesive from the work area and application equipment before it hardens. Denatured alcohol and many common industrial solvents are suitable for removing uncured adhesive. Consult with your supplier's information pertaining to the safe and proper use of solvents.

BOND STRENGTH PERFORMANCE

Tensile Lap Shear Strength

Tensile lap shear strength tested per ASTM D 1002 after curing as shown below. Adherends are 2024-T3 clad aluminum treated with chromic acid etch.

Test Temperature, °F/°C	Typical Results (PSI/MPa) Cured 7 days@77°F/25°C	Cured 2 hrs@180°F/82°C	Cured 1 hr@250°F/121°C
-67/-55	5,000/34.5	6,000/41.4	6,000/41.4
77/25	5,000/34.5	6,000/41.4	6,300/43.5
180/82	1,000/ 6.9	1,100/ 7.6	1,200/ 2.3

Effect of Surface Preparation on Tensile Lap Shear at 77°F/25°C. Substrates are 2024-T3 clad aluminum:

Surface Preparation	Cured 7 days@77°F/25°C	Cured 2 hrs@180°F/82°C	Cured 1 hr@250°F/121°C
MEK Wiped	3,900/26.9	4,300/29.7	5,600/38.6
Sand Blasted	4,400/30.4	5,100/35.2	5,200/35.9
Wire Brushed	4,100/28.3	4,500/31.0	5,300/36.6

After Exposure to the following conditions*:	Cured 7 days@77°F/25°C	Cured 2 hrs@180°F/82°C	Cured 1 hr@250°F/121°C
Control, 77°F/25°C	5,500/37.9	6,300/43.5	6,500/44.8
77°F/25°C Water-30 days	3,700/25.5	4,400/30.4	4,400/30.3
120°F/49°C-100%RH-30 days	4,300/29.7	4,100/28.3	3,900/26.9
Anti-icing FI-7 days	5,500/37.9	6,200/42.8	6,000/41.4
Hydraulic Oil-7 days	5,600/38.6	6,400/44.1	6,600/45.5
JP-4 Fuel-7 days	5,800/40.0	6,100/42.1	6,300/43.5
Salt Spray-105°F/41°C-30 days	3,500/24.1	3,500/24.1	3,700/25.5
Skydrol 500-7 days	5,700/39.3	6,100/42.1	6,300/43.5
TT-S-735-7 days	5,300/36.6	5,900/40.7	5,800/40.0

*Test temperature on all exposure tests is 77°F/25°C

Effect of Primer on Tensile Lap Shear properties:

Test Temperature, °F/°C	None	Primer EA 9202(A)	EA 9202(B)
-67/-55	5,300/36.6	5,600/38.6	5,400/37.2
77/25	5,500/37.9	5,100/35.2	5,600/38.6
180/82	1,000/ 6.9	1,500/10.3	1,900/13.1

Primer Thickness:	0.3mils/.008mm
Primer Flash:	1 hr@77°F/25°C
Primer Bake: (A)	1 hr@250°F/121°C
(B)	1 hr@325°F/163°C
Adhesive Cure:	7 days@77°F/25°C

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Effect of Bondline Thickness on Tensile Lap Shear at 77°F/25°C (Cure: 7 days@77°F/25°C):

Bondline Thickness (Mils/mm)	Typical Results (PSI/MPa)
4/0.10	5,200/35.9
10/0.25	5,000/34.5
20/0.51	4,500/31.0
30/0.76	4,500/31.0
40/1.02	4,400/30.3
50/1.27	4,100/28.3

Peel Strength

T Peel strength tested per ASTM D 1876 after curing as shown below. Adherends are 2024-T3 clad aluminum treated with chromic acid etch.

Test Temperature, °F/°C	Typical Results (PLI/NLM)		
	Cured 7 days@77°F/25°C	Cured 2 hrs@180°F/82°C	Cured 1 hr@250°F/121°C
77/25	35/155	46/204	46/204

Bell Peel Strength

Test Temperature, °F/°C	Typical Results (PLI/NLM)		
	Cured 7 days@77°F/25°C	Cured 2 hrs@180°F/82°C	Cured 1 hr@250°F/121°C
77/25	92/407	97/429	106/469

Metal to Metal Climbing Drum Peel

Test Temperature, °F/°C	Typical Results (PLI/NLM)		
	Cured 7 days@77°F/25°C	Cured 2 hrs@180°F/82°C	Cured 1 hr@250°F/121°C
77/25	58/257	99/438	92/407

Service Temperature

Service temperature is defined as that temperature at which this adhesive still retains 1000 PSI/6.9 MPa using test method ASTM D 1002 and is 180°F/82°C.

Bulk Resin Properties

Tensile Properties – tested using 0.125 inch/0.317cm castings per ASTM D 638. Specimens were cured 7 days at 77°F/25°C.

	Typical Results
Tensile Strength, PSI @ 77°F/25°C	5,600/38.6
Tensile Modulus, PSI @ 77°F/25°C	384,000/2.65
Elongation at Break, % @ 77°F/25°C	2.4
Barcol Hardness @ 77°F/25°C, #935 Impressor	65
T_g	135°F/57°C
Shear Modulus KSI/MPa	140/965
Poisson's Ratio	0.41

Compressive Properties – tested using 0.5 inch/1.27cm castings per ASTM D 695.

Compressive Strength, PSI @ 77°F/MPa @ 25°C	7,700/53.1
Compressive Modulus, PSI @ 77°F/GPa @ 25°C	253,000/1.74

Electrical Properties – tested per ASTM D 149, D 150.

	100 Hz	1 KHz	10 KHz	100 KHz
Dielectric Constant	4.50	4.38	4.23	3.96
Dissipation Factor	0.025	0.020	0.032	0.056

Volume Resistivity at 77°F/25°C, 500 Volts, 1.0 minute electrification 1.59 x 10^{14} Ohms-CM

Surface Resistivity at 77°F/25°C, 500 Volts, 1.0 minute electrification 1.59 x 10^{14} Ohms

EA 9330 4 of 4

HANDLING PRECAUTIONS

Before using this product, read the Material Safety Data Sheets carefully.

For industrial use only.

General:
Use these products with adequate ventilation. Do not get in eyes or on skin. Avoid breathing the vapors. Wash thoroughly with soap and water after handling. Empty containers retain product residue and vapors so obey all precautions when handling empty containers.

PART A
WARNING! The uncured adhesive causes eye irritation and may cause skin irritation or allergic dermatitis. Contains epoxy resins.

PART B
DANGER! Causes severe skin and eye burns. Vapors may be irritating to the respiratory tract.

AVAILABILITY

This Hysol Aerospace Product is available from Dexter Aerospace Materials Division, 2850 Willow Pass Road, P.O. Box 312, Pittsburg, CA 94565-0031. Telephone 510/458-8000. FAX 510/458-8030.

Revised 3/92

DEXTER
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THE DEXTER CORPORATION

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