

> FM[®] 377 ADHESIVE FILM

TECHNICAL DATA SHEET



DESCRIPTION

FM[®] 377 film adhesive is a 350°F (177°C) cure modified epoxy designed for continuous services at 350°F (177°C). FM 377 film adhesive provides outstanding durability in bonding metallic and non-metallic substrates, and in the co-cure or secondary bonding of composites structures. FM 377 adhesive exhibits excellent structural performance from -67°F to 350°F (-55°C to 177°C).

FM 377 adhesive is manufactured as a supported film with a knit carrier or as an unsupported film. The unsupported version can be easily reticulated on honeycomb core or perforated metal.

FEATURES & BENEFITS

- Designed for bonding metallic, non-metallic and sandwich structures
- Excellent combination of high peel strength and high 350°F (177°C) shear strength
- Designed for continuous service at 350°F (177°C)
- Superior performance in co-cure or secondary bonding of composite structures
- Easily reticulated on core or perforated metal for nacelle bonding applications
- 30 days shop life at 75°F (24°C)

SUGGESTED APPLICATIONS

- Bonding metallic, non-metallic and sandwich structures
- Co-cure and secondary bonding of composite structures

CHARACTERISTICS

Table 1 | Product Availability

Product Designation	Nominal Weight psf (gsm)	Nominal Thickness inches (mm)	Color	Carrier
FM 377U Film Adhesive	0.055 (269)	0.005 (0.13)	Grey	None
FM377S Film Adhesive	0.06 (293)	0.006 (0.15)	Grey	Knit
FM 377S Film Adhesive	0.08 (391)	0.010 (0.25)	Grey	Knit
FM377S Film Adhesive	0.095 (464)	0.013 (0.33)	Grey	Knit

Table 2 | Handling Properties

Volatiles	1% Maximum
Shop Life	30 days at or below 75°F (24°C)
Shelf Life	12 months from date of shipment at recommended storage conditions
Recommended Storage	Store at or below 0°F (-18°C)

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PROPERTIES

Table 3 | Mechanical Performance: Metal-to-Metal¹

Test Condition	FM 377S 0.06 psf (293 gsm)	FM 377S 0.08 psf (391 gsm)	FM 377S 0.095 psf (464 gsm)	FM 377U 0.055 psf (269 gsm)
Blister Shear, Psi (MPa) Tested at -67°F (-55°C) Tested at 75°F (24°C) Tested at 350°F (177°C)	3505 (24.2) 3920 (27.0) 2145 (14.8)	3585 (24.7) 3760 (25.9) 1970 (13.6)	3500 (24.2) 3730 (25.7) 1985 (13.7)	3700 (25.5) 3950 (27.3) 2025 (14.0)
Blister Shear after 1000 Hours at 350°F, Psi (MPa) Tested at 350°F (177°C)	2050 (14.1)	2110 (14.6)	2054 (14.2)	2085 (14.4)
Metal-to-Metal Climbing Drum Peel, in/lb/in (Nm/m) Tested at 75°F (24°C)	28 (125)	35 (156)	28 (125)	30 (133)
Creep Rupture Deformation at 300°F (149°C) under 800 psi (5.52 MPa) load for 192 hours, inch (mm)	0.0025 (0.064)	0.0002 (0.005)	--	0.001 (0.025)
Fatigue at 75°F (23°C) 10 ⁵ cycles at 1900 psi (13.1 MPa) 10 ⁷ cycles at 1250 psi (8.6 MPa)	No Failures No Failures	No Failures No Failures	No Failures No Failures	No Failures No Failures

Table 4 | Mechanical Performance: Honeycomb Specimens

Test Condition	FM 377S 0.08 psf (391 gsm)	FM 377S 0.095 psf (464 gsm)	FM 377U 0.055 psf (269 gsm)
Flatwise Tensile, psi (MPa) Tested at 75°F (24°C) Tested at 350°F (177°)	1210 (8.35) 485 (3.35)	1375 (9.49) 550 (3.79)	1250 (8.63) 410 (2.83)
Flatwise Tensile, psi (MPa) After 1000 hr aging at 350°F (177°C) Tested at 350°F (177°C)	490 (3.38)	560 (3.86)	460 (3.17)
Honeycomb Sandwich Peel, in-lb/3 in (Nm/m) Tested at 75°F (24°C)	60 (90)	90 (133)	35 (52)
Beam Shear, psi (MPa) Tested at 75°F (23°C)	800 (5.52)	830 (5.73)	835 (5.76)

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Table 5 | Mechanical Performance: Durability Tests

Test Conditions	FM 377S 0.08 psf (391 gsm)	FM 377U 0.055 psf (269 gsm)	FM 377U 0.06 psf (293 gsm)
Crack Extension, lb/in (N)	6.1 (29)	4.6 (22)	5.2 (25)
Crack Extensions After 7 days immersion at 150°F (66°C), in lb/in (N)			
a) JP-4 (MIL-T-5624)	5.5 (26)	4.2 (20)	4.6 (22)
b) Hydraulic Fluid	4.0 (19)	3.6 (17)	4.0 (19)
c) Deicer Glycol (MIL-A-8243)	4.2 (20)	3.8 (18)	4.3 (20)
Crack Extension After 5 weeks in 100% RH at 140°F (60°C), lb/in (N)	4.1 (19)	3.9 (19)	4.5 (21)
Sustained Stress Loading at 140°F (60°C)/100% RH, 1100 psi (7.6 MPa)	No Failures in 90 days	No Failures in 90 days	No Failures in 90 days

Table 6 | Composite Substrates Bonding of Precured Thermoset Substrates and the Effect of Environmental Exposures

Precured Composite Substrate	Bonded Specimen Exposure	Lap Shear Strength, Psi (MPa) at 75°F (23°C)
CYCOM® 985 GH 3070 PW (Epoxy/Graphite)	None	3120 (21.53)
	30 days at 140°F (60°C)/100% RH	3035 (20.94)
	30 days salt spray	3255 (22.46)
HMF 5-322D/34C (Epoxy/Graphite)	None	3230 (22.29)
	30 days at 140°F (60°C)/100% RH	3055 (21.08)
	30 days salt spray at 95°F (35°C)	3410 (23.53)

Substrates: 7 plies cured at 350°F (177°C) for 90 minutes at 85 psi (0.76 MPa)

Substrate Surface Preparation: Hand sanded with 220 grit sandpaper, MEK wipe

Adhesive: FM 377 K (0.06 psf, 293 gsm)

Adhesive Cure Cycle: 4.5°F(2.5°C)/min to 350°F (177°C), 40 psi (0.28 MPa), hold 90 minutes at 350°F (177°C)

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Table 7 | Composite Substrates Cocure and Secondary Bonding of BMI/Graphite Structures

Substrate	Test Condition	Wide Area Lap Shear psi (MPa)
Rigidite [®] 5250-4 6K5H (BMI/Graphite Fabric) 8 plies procured at 375°F (190°C) for 6 hours, 40 psi (0.28 Mpa)	75°F (24°C)	3500 (24.19) (PLF)
	250°F (121°C)	2920 (20.15) (Coh)
	300°F (150°C)	2455 (16.90) (PLF)
	30 days exposure to 160°F (71°C) and 100% RH tested at 75°F (24°C)	3305 (22.80) (PLF)
Rigidite [®] 5250-4 6K5H (BMI/Graphite Fabric) 8 plies prepreg/FM 377/8 Plies prepreg cocured at 375°F (190°C) for 6 hours, 40 psi (0.28 Mpa)	75°F (24°C)	3005 (20.73) (PLF)
	250°F (121°C)	2490 (17.18) (PLF)
	300°F (150°C)	2160 (14.90) (Coh)
	30 days exposure to 160°F (71°C) and 100% RH tested at 75°F (24°C)	2705 (18.70) (PLF)

Adhesive: FM 377K (0.06 psf, 293 gsm)

Surface Preparation: For procured laminates a nylon peel ply was used

Failure Modes: Partial Laminate Failure (PLF); Cohesive in the adhesive (Coh)

Table 8 | Effect of 75°F (24°C) Storage on the Performance of FM 377 Adhesive Film

Adhesive Film	Prebond Film Exposure at 75°F (24°C), days	Test Results				
		Wide Area Lap Shear, psi (MPa)			Metal-to-Metal Drum Peel, in- lb/in (Nm/m) 75°F (24°C)	Honeycomb Sandwich Peel, in-lb/3in (Nm/m) 75°F (24°C)
		-67°F (-55°C)	75°F (24°C)	350°F (177°C)		
FM 377 unsupported 0.055 psf, 269 gsm	0	3800 (26.2)	4025 (27.7)	1950 (13.5)	32 (142)	33 (50)
	14	3730 (25.7)	3940 (27.2)	2095 (14.5)	29 (129)	35 (53)
	28	3725 (25.7)	3895 (26.9)	2045 (14.1)	28 (124)	30 (45)
	63	3635 (25.1)	3610 (24.9)	1900 (13.1)	29 (129)	36 (54)
FM 377 supported 0.08 psf, 391 gsm	0	3595 (24.8)	3835 (26.5)	2050 (14.1)	35 (155)	29 (74)
	14	3685 (25.4)	3780 (26.1)	1950 (13.5)	36 (160)	53 (80)
	28	3845 (26.5)	3870 (26.7)	1845 (12.7)	37 (164)	16 (69)
	63	3695 (25.5)	3700 (25.5)	1900 (12.1)	37 (164)	44 (66)

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Table 9 | KGR-1 Stress Strain Data for FM 377 Adhesive Film, 0.08 psf (390 gsm) with BR[®] 6747 Corrosion Inhibiting Primer (f = Shear Stress, psi (MPa), Σ = Shear Strain, in/in, G = Shear Modulus, psi (MPa))

Test Temperature	Linear Limit (LL)			Knee (KN)		Ultimate Failure (UL)	
	f	Σ	G	f	Σ	f	Σ
-67°F (-55°C)	1460 (10.1)	0.0055	268,400 (1852)	8115 (56)	0.0827	9530 (65.8)	0.1927
75°F (23°C)	2070 (14.3)	0.0122	171,500 (1183)	6040 (41.7)	0.0736	6880 (47.50)	0.2310
300°F(150°C)	950 (6.6)	0.0167	59,200 (408)	2040 (14.1)	0.0597	2770 (19.1)	0.3226

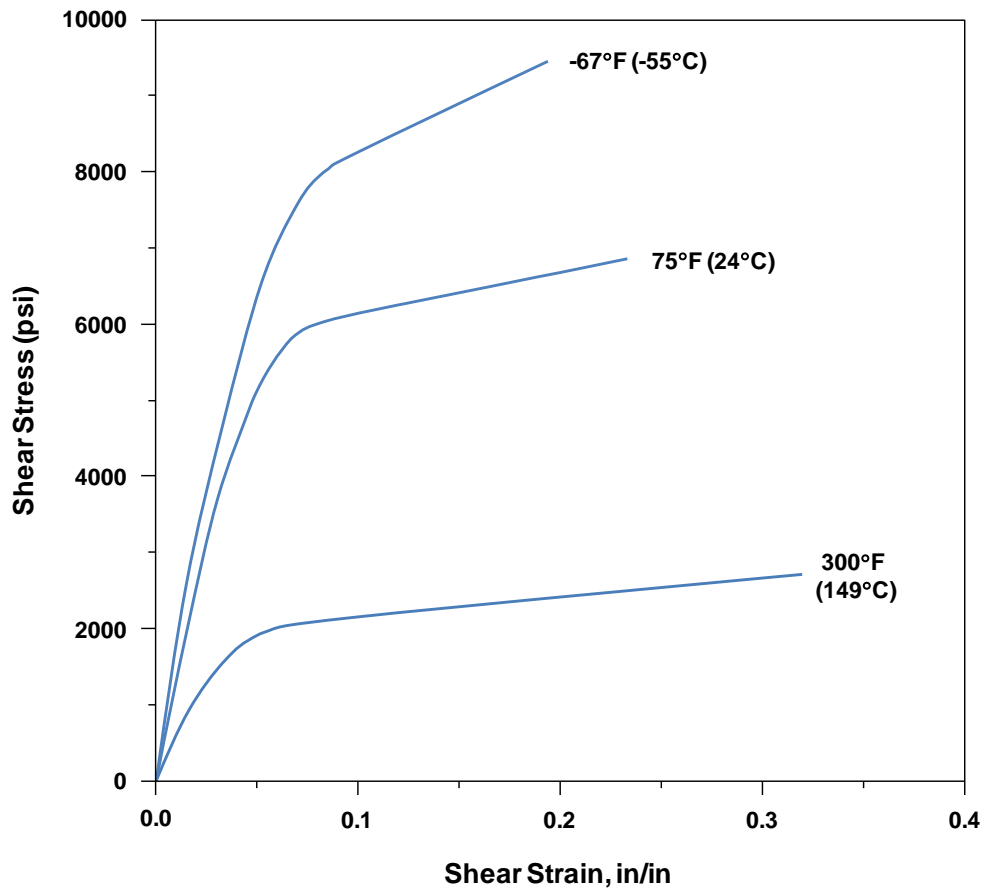


Figure 1 | Shear stress versus shear strain for FM 377 adhesive film

MATERIALS AND PROCEDURES

1. Substrates/Test Methods

- a. Lap Shear: 2024-T3 bare aluminum, 0.063 in. (1.6mm) thick, MMA-A-132A
- b. Metal-to-Metal Peel: 2024-T3 clad, 0.02 in (0.5mm) and 0.04 in (1.0mm) thick, ASTM D 1781
- c. Honeycomb Peel: ASTM D 1781
 - i. Core: 0.25 in cell, 7.9 psf, 0.625 in (15.9mm) thick (BMS 4-4, Type 4-40N)
 - ii. Face Sheets: Supported – 2024-T3 clad, 0.02 in (0.5 mm) thick, Unsupported – 0.025 in (0.63mm) thick, BMS 7-209 perforated plate, 15 – 20 POA, 0.035 – 0.045 inch (0.89 – 1.14mm) hole diameter
- d. Flatwise Tensile and Short Beam Shear
 - i. Core: 0.25 in (6.35mm) cell, 7.9 pcf, 0.126 g/cc 0.625 in (15.9mm) thick (BMS 4-4, Type 4-40N), MIL-A-25463B
 - ii. Face Sheets: Supported – 2024-T3 Clad, 0.063 in (1.6mm) thick, Unsupported – 0.063 in (1.6mm) thick, BMS 7-209 perforated plate, 26 POA, 0.080 ± 0.004 inch (2.0 ± 0.1mm) diameter
- e. Crack Extension: 2024-T3 bare aluminum 0.50 in (12.7mm) thick, tested per Boeing BSS 7208, 7211 and 7212 test methods

2. Metal Substrates

Surface Preparation: FPL etch (ASTM D-2651-79 G) followed by phosphoric acid anodization (ASTM D 3933)

3. Adhesive Cure Cycle

3.0 – 3.2°F (1.7°C)/minute heat-up to 350°F (177°C), 40 psi (0.28 MPa), hold 90 minutes at 350°F (177°C) or as otherwise stated

4. Unsupported Adhesive

The unsupported grade adhesive was reticulated on the perforated face sheets for all honeycomb specimens

5. Primer

BR[®] 6747-1 water-based primer, primer thickness 0.15 to 0.4 mils, (3.8 to 10mm) cured 60 minutes at 270°F (132°C).

PRIMER APPLICATION

Although not mandatory, BR 6747-1 water-based corrosion inhibiting primer is recommended for use with FM 377 film adhesives in the bonding of aluminum details. BR 6747-1 primer offers superior durability and resistance to hostile environments within the bond line and also may be used as a protective coating outside the bonded areas.

1. Spray or brush coat to a dry primer thickness of 0.00015 to 0.0004 inch (3.8 to 10mm) maximum. For protective coating applications, increase primer thickness to 0.0004 to 0.0010 inch (0.0102 to 0.025mm).
2. Air dry 30 minutes minimum prior to oven cure
3. Oven cure 60 minutes at 240°F (115°C) to 300°F (144°C)

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BONDING PROCEDURE

Primed assemblies which have been dried and wrapped with a protective covering such as Kraft paper may be stored at 75°F (24°C) for six months and longer without fear of degradation of the final bond. Before bonding, detail parts and film adhesive must be properly assembled. Patterns of FM 377 film adhesive should be cut as required before removal of the protective covering which is easily stripped from the film at room temperature. Apply the film adhesive smoothly to the parts. FM 377 adhesive has sufficient tack and does not require the use of heat-gun or tack table.

After assembly of the details, apply pressure and cure, using the standard cure cycle below:

Heat up in 60 – 90 minutes to 350°F (177°C). Hold 90 minutes at 350°F (177°C) with 40 ± 5 psi (0.28 ± 0.03 MPa)

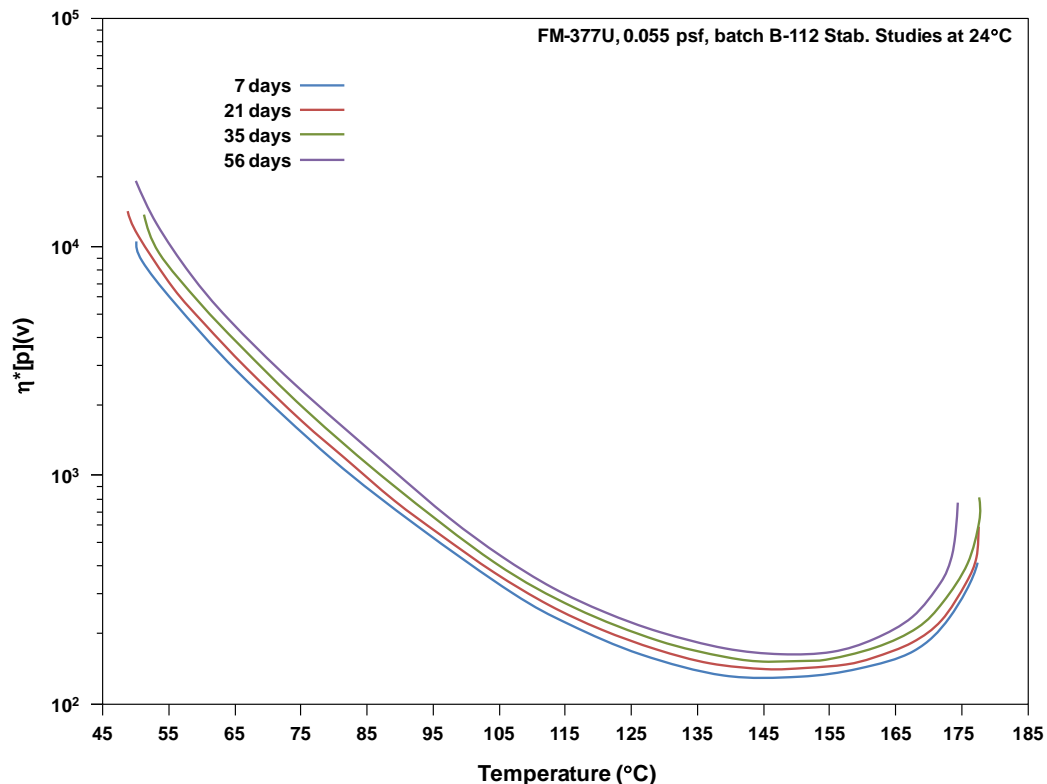


Figure 2 | FM 377 adhesive film rheology data

PRODUCT HANDLING AND SAFETY

Cytec Engineered Materials recommends wearing clean, impervious gloves when working with adhesives to reduce skin contact and to avoid contamination of the product.

Materials Safety Data Sheets (MSDS) and product labels are available upon request and can be obtained from any Cytec Engineered Materials Office.

DISPOSAL OF SCRAP MATERIAL

Disposal of scrap material should be in accordance with local, state, and federal regulations.

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