FM® 94 Modified Epoxy Film

Description:

FM® 94 film adhesive is a 220°F (104°C) service temperature, modified epoxy film adhesive designed for bonding metallic and composite structures. FM® 94 adhesive offers a unique combination of high temperature performance, toughness and moisture resistance as demonstrated by its ability to bond to wet Nomex* honeycomb and retention of shear properties after prebond and postbond humidity exposures. FM® 94 adhesive is designed for applications demanding the best of both 220°F (104°C) service temperature and -67°F (-55°C) peel strength.

For composite and metal bonding applications, FM® 94 adhesive is formulated to exhibit superior elongation, toughness and shear strength properties. The controlled flow characteristics allow for its use in co-cured applications as well as bonding pre-cured structures. Also, FM® 94 adhesive provides excellent electrical insulation between metal and graphite composites, reducing the potential for galvanic corrosion.

FM® 94 film adhesive is manufactured as a supported adhesive with both knit and mat carriers, or as an unsupported film. When supported with a knit carrier, optimal mechanical properties can be obtained. The random mat provides superior handling characteristics. With the mat carrier, FM® 94 adhesive can be supplied in a one-side tacky (OST) version which helps reduce air entrapment when bonding large metal or composite parts.

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Features and benefits:

- **Demonstrates superior strength in bonding both metallic and composite structures.**
- **Provides structural performance from -67°F to 220°F (-55°C to 104°C)**
- **Offers exceptional elongation and toughness.**
- **Meets the requirements of military specification MMM-A-132B type I, class 2 and MIL-A-25463B, type I, class 2**
- **Higher temperature version of FM® 73 adhesive film.**

TECHNICAL DATA SHEET

Product description

Product	Nominal weight[1] psf (gsm)	Nominal thickness inches (mm)	Color	Carrier
FM 94K film adhesive	0.030 (146)	0.006 (0.15)	Green	Polyester knit
	0.045 (220)	0.007 (0.18)	Green	Polyester knit
	0.060 (293)	0.010 (0.25)	Green	Polyester knit
	0.080 (391)	0.012 (0.30)	Green	Polyester knit
FM 94M film adhesive	0.030 (146)	0.005 (0.13)	Green	Polyester mat
	0.060 (293)	0.010 (0.25)	Green	Polyester mat
FM 94M OST film adhesive	0.060 (293)	0.010 (0.25)	Green	Polyester mat
FM 94U film adhesive	0.030 (146)	0.005 (0.13)	Green	Unsupported

1 Weight tolerance equals nominal weight ± 0.005 psf (25 gsm)

Handling properties

Volatiles:	1.00% maximum
Shop life:	30 days at or below 85°F (30°C)
Shelf life:	Twelve months from date of shipment at recommended storage conditions
Recommended storage:	Store at or below 0°F (-18°C)

BR 6747-1 corrosion inhibiting primer description

Color:	Yellow
Solids:	20% ± 1% sprayable
Density:	8.7 lb/gal (1043 g/liter)
Shop life:	30 days at or below 90°F (32°C)
Shelf life:	Twelve months from date of shipment at recommended storage conditions
Recommended storage:	Store at 40°F (4.4°C) **DO NOT FREEZE**

The following products are recommended for use with FM® 94 film adhesives:

BR® 6747-1 corrosion inhibiting primer

FM® 490A foam adhesive

BR® 127 adhesive primer

Application notes

Preparation of aluminum

A clean, dry, grease-free surface is required for optimum performance. A recommended procedure for cleaning aluminum details is as follows:

1. Vapor degrease, alkaline clean, rinse and check for water break.
2. FPL etch per ASTM D-2651-79G
3. Phosphoric acid anodize per ASTM D3933

Primer application

Although not mandatory, BR® 6747-1 or BR® 127 corrosion inhibiting primers are recommended for use with FM® 94 film adhesive in bonding of aluminum details. These primers offer 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. Allow material to warm to room temperature prior to opening container; thoroughly mix before and agitate during application.
2. Spray or brush coat to a dry primer thickness of 0.0001 inch (0.0025 mm) nominal with a 0.0003 inch (0.005 mm) maximum thickness. For protective coating applications, increase primer thickness to 0.0004 to 0.0010 inch (0.0102 – 0.025 mm).
3. Air dry 30 minutes minimum prior to oven cure.
4. Oven cure 60 minutes at 250°F ± 10°F (120°C ± 6°C).

Bonding procedure

Primer assemblies, which have been cured 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 adhesive film must be properly assembled. Patterns of FM® 94 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.

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

- Heat 3°F - 5°F (1.7 °C - 2.8°C)/ minute to 250°F (12°C)
- Apply 40 psi pressure
- Hold 60 minutes at 250°F ± 5°F (120°C ± 3°C)

Mechanical performance:
Typical average strength/aluminum substrates/BR® 6747-1 adhesive primer

Test and test condition		FM® 94K film adhesive 0.06 psf (293 gsm)		FM® 94 M film adhesive 0.06 psf (293 gsm)	
Wide area blister detection shear strength, psi (MPa) (ASTM D3165)					
-67°F	(-55°C)	5810	(40.1)	5215	(36.0)
75°F	(24°C)	5520	(38.1)	5195	(35.8)
180°F	(82°C)	3995	(27.5)	3695	(25.5)
220°F	(104°C)	3520	(24.3)	3410	(23.5)
250°F	(121°C)	2385	(16.4)	2490	(17.2)
Tensile shear, psi (MPa) (ASTM D1002)					
-67°F	(-55°C)	6510	(44.9)	6080	(41.9)
75°F	(24°C)	6760	(46.6)	6340	(43.7)
180°F	(82°C)	5040	(34.8)	4855	(33.5)
220°F	(104°C)	4235	(29.2)	3515	(24.2)
Metal-to-metal climbing drum peel, in-lb/in. (Nm/m) (ASTM D1781)					
75°F	(24°C)	85	(378)	80	(356)
200°F	(93°C)	70	(311)	78	(347)
220°F	(104°C)	65	(289)	75	(334))
Floating roller peel, pli, (N/mm) (ASTM D3167)					
-67°F	(-55°C)	65	(11.4)	52	(9.1)
75°F	(24°C)	74	(12.9)	70	(12.3)
180°F	(82°C)	75	(13.1)	70	(12.3)
220°F	(104°C)	60	(10.5)	60	(10.5)
Honeycomb sandwich peel, in-lb/3 in (Nm/m) (ASTM D1781)					
-67°F	(-55°C)	68	(101.0)	60	(89.0)
75°F	(24°C)	84	(125.0)	72	(107)
220°F	(104°C)	61	(90.4)	51	(75.6)
Flatwise tensile, psi (MPa) (ASTM C297)					
-67°F	(-55°C)	1655	(11.4)	1675	(11.6)
75°F	(24°C)	1190	(8.2)	1250	(8.6)
180°F	(82°C)	665	(4.6)	645	(4.5)
220°F	(104°C)	250	(1.7)	355	(2.5)

Core: Aluminum, 0.25 in (6.35 mm) cell, 7.9 pcf (0.126 g/cc), 5052

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Mechanical performance: FM® 94K 0.06 psf film adhesive after humidity, salt spray and solvent exposure. aluminum substrates/BR® 6747-1 adhesive primer

Test condition tensile shear, psi (MPa), (ASTM D1002)	Test temperature	Test results
-After 30 day exposure to salt spray per ASTM B117	75°F (23°C) 160°F (71°C)	6250 (43.1) 4975 (34.3)
-After 30 day exposure to 140°F (60°C),100% RH	75°F (23°C)	5950 (41.0)
-After 30 day exposure to Tap water at 75°F (24°C)	75°F (23°C) 160°F (71°C)	6210 (42.8) 5365 (37.0)
-After 30 day exposure to 180°F (82°C),100% RH	180°F (82°C)	4135 (28.5)
-After 7 day exposure to JP-4 at 75°F (24°C)	160°F (71°C)	5415 (37.3)
-After 7 day exposure to MIL-H-5606 fluid at 75°F (24°C)	160°F (71°C)	4690 (32.3)
-After 7 day exposure to MIL-L-7808 fluid at 75°F (24°C)	160°F (71°C)	4790 (33.0)

Mechanical performance: FM® 94K 0.06 psf film adhesive/ effect of cure cycle - aluminum substrates/BR® 6747-1 adhesive primer

Test	Test temperature	TEST RESULTS		
		Cured 60'@ 250°F (121°C)	Cured 60' @ 300°F (149°C)	Cured 60' @ 350°F (177°C)
Tensile shear, psi (MPa), ASTM D1002	75°F (24°C) 180°F (82°C)	6250 (43.1) 4600 (31.7)	6100 (42.1) 4550 (31.4)	6000 (41.4) 4350 (30.0)
Honeycomb sandwich Peel, in-lb/3 in.(Nm/m) ASTM D1781	-67°F (-55°C) 75°F (24°C) 180°F (82°C)	75 (111) 85 (126) 80 (119)	78 (116) 90 (133) 80 (119)	80 (119) 90 (133) 85 (126)

Cure Cycles: Heat-up rates
for 250°F (121°C) cure, 3°F (1.6°C)/min, 40 psi (0.28 MPa)
for 300°F (149°C) cure, 3.7°F (2.1°C)/min, 40 psi (0.28 MPa)
for 350°F (177°C) cure, 4.6°F (2.6°C)/min, 40 psi (0.28 MPa)

Core: Aluminum 0.187 in (4.76 mm) cell, 5.7 pcf (0.09 g/cc), 0.625 in (15.9 mm) thick, 5052

TECHNICAL DATA SHEET

Durability data: FM® 94 M 0.06 psf adhesive film
BR® 6747 water based primer - aluminum substrates
BR® 6747-1 adhesive primer

Test (ASTM D3433)	TEST RESULTS
1) Crack extension, G1a, lb./in (N)	12.0 (53.3)
2) Crack extension after 5 wk exposure to 140°F (60°C)/100% RH, G1scc, lb/in (N)	6.0 (26.7)
3) Crack extension after 15 wk exposure to 140°F (60°C)/100% RH, G1scc, lb/in (N)	6.0 (26.7)
4) Crack extension after 7 day exposure to JP4 @ 75°F (24°C), lb/in (N)	8.5 (37.8)
5) Crack extension after 7 day exposure to hydraulic fluid @ 75°F (24°C), lb/in (N)	7.1 (31.6)
6) Fatigue (ASTM D3166-93) max stress 2600 psi, (17.94 MPa) R-ratio: 0.1 Frequency: 30 HZ	> 10^7 Cycles, no failure
7) Creep (MMM-A-132), 1600 psi (11.03 MPa) for 192 hours @ 75°F (24°C)	No creep
8) Creep (MMM-A-132), 1500 psi (10.34 MPa) for 192 hours @ 180°F (82°C)	No Creep
9) RAAB specimens (1 hour loaded and 15 min. unloaded)	No failure up to 3000 cycle

Effect of out-time on mechanical properties
FM® 94K 0.06 psf adhesive film/ BR® 6747-1 adhesive primer

Test	TEST RESULTS					
	Control	**15 days @ 75°F(24°C)**	**15 days @ 90°F(32°C)**	**30 days @ 75°F(24°C)**	**30 days @ 90°F(32°C)**	**60 days @ 75°F(24°C)**
Tensile shear, psi (MPa) @ 75°F (24°C)	6500 (44.8)	6415 (44.2)	6285 (43.3)	6320 (43.6)	6405 (44.2)	6555 (45.2)
Honeycomb sandwich peel, in-lb/3 in, (N m/m) @ 75°F (24°C)	80 (119)	80 (119)	72 (107)	75 (111)	64 (95)	69 (102)
Floating roller Peel, pli, (N m/m) @ 75°F (24°C)	80 (14.0)	---	---	72 (12.6)	72 (12.6)	75 (13.1)

Substrate: Aluminum 2024 T3
Core: Aluminum, 0.187 in (4.76 mm) cell, 5.7 pcf (0.09 g/cc), 0.625 in (15.9 mm) thick, 5052

Effect of humidity, wet nomex bonding with FM® 94 M 0.06 psf adhesive

Nomex core exposure	Test temp	Flatwise tensile (psi) Mpa	Failure mode
Immersed in water for 24 hrs at 140°F (60°C) then bonded within 2 hrs	75°F (24°C)	610 (4.2)	100% core
	160°F (71°C)	540 (3.7)	100% core

Nomex core: 3.18 mm cell (0.125 in), 0.128 g/cc (8 pcf) density
Face sheets: Aluminum 2024T3, 0.063 in (1.6 mm) thick, primed with BR® 6747-1 primer

Mechanical performance:
Composite substrates cocure data with FM® 94M 0.06 psf adhesive film

Test	Exposure conditions	Test results
1) 75°F (24°C) tensile shear FM® 94 M cocured with CYCOM® 985 3K-70P (BMS 8-212 prepreg), psi (MPa)	None	3710 (25.6)
	30 days @ 71°C (160°F)/100% RH	4200 (29.0)
2) 180°F (82°C) tensile shear FM® 94 M cocured with CYCOM® 985 3K70P (BMS 8-212 prepreg), psi (MPa)	None	2850 (19.7)
	30 days @ 71°C (160°F)/100% RH	3040 (21.0)
3) 75°F (24°C) flatwise tensile strength FM 94 M cocured with BMS 8-79 prepreg (epoxy/glass), BMS 8-124 core (Type 1, class 1), psi (MPa)	None	1115 (7.7)
4) 75°F (24°C) honeycomb sandwich peel, FM® 94 M cocured with BMS 8-79 prepreg (epoxy glass), BMS 8-124 core (Type 1, Class 1) in-lb/3 in (Nm/m)	None	62 (92)

Panel layup: 8 plies of prepreg/FM® 94 Adhesive/8 plies of prepreg
Cure cycle: For CYCOM® 985, the heat up rate was 3°F (1.7°C)/min to 350°F(177°C), 40 psi (0.28 MPa), hold 2 hours at 350°F (177°C)
For BMS 8-79 prepreg, the heat up rate was 3°F (1.7°C)/min to 250°F (121°C), 40 psi (0.28 MPa), hold 2 hours at 250°F (121°C)

Secondary bonding of epoxy/graphite substrates FM® 94M (0.06 psf) adhesive film

Test	TEST RESULTS		
	75°F	160°F	180°F
Tensile shear psi,(MPa) CYCOM® 985 3K 70P, 0.1 in thick	3450 (23.8)	3000 (20.7)	2570 (17.7)
Flatwise tensile, psi, (MPa) CYCOM® 950-1 3K 70P 3 plies Composite surface preparation: nylon peel ply	442 (3.0) (Core failure)	-----	446 (3.1) (Core failure)

Adhesive cure cycle: 3°F/min to 250°F, 60 min @ 250°F, 40 psi
Core: HRH, 0.125 in (3.175 mm) cell, 4.0 pcf (0.064 g/cc)

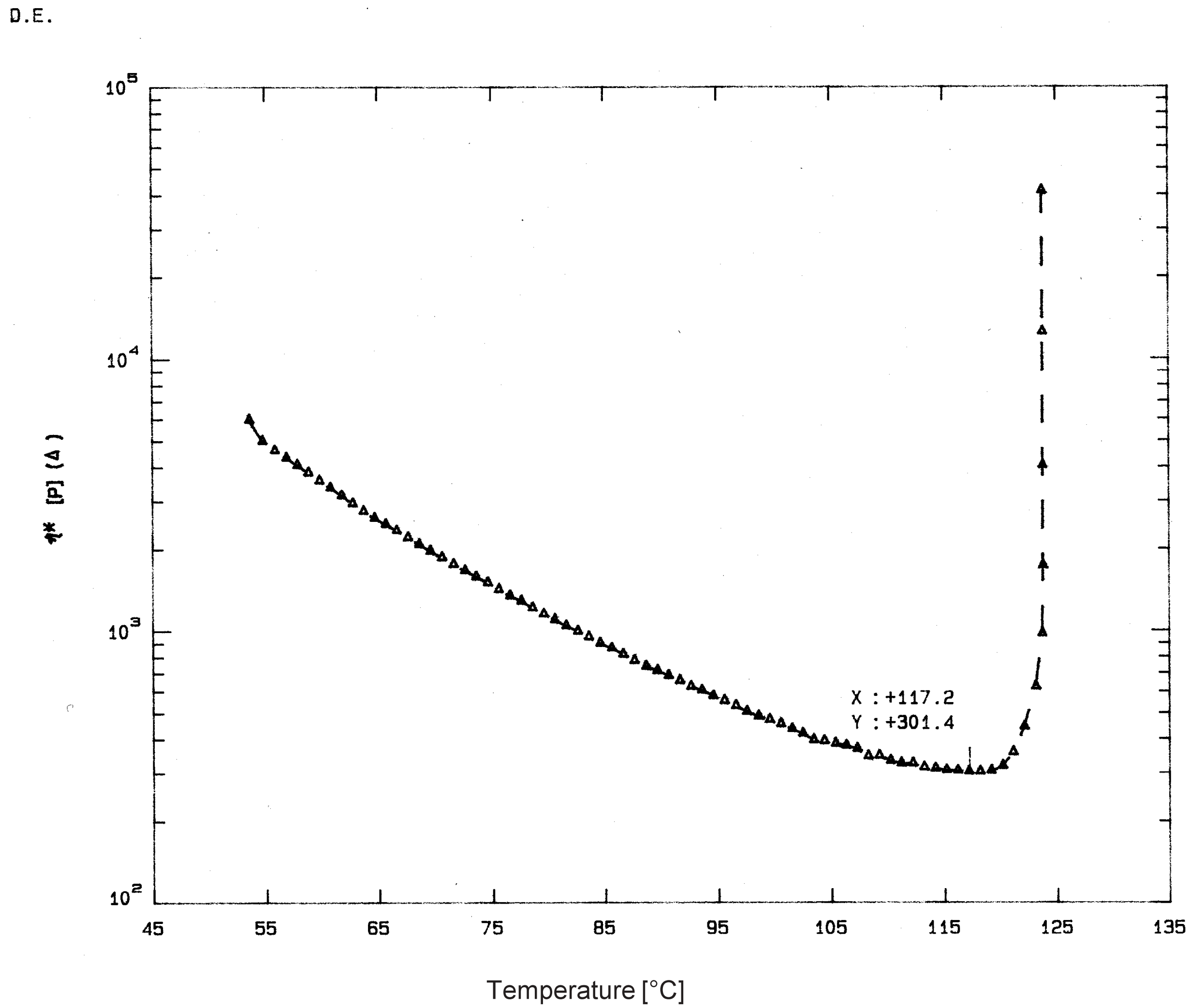
KGR-1 stress strain data for FM® 94 0.06 psf film adhesive, with BR® 6747-1 corrosion inhibiting primer

f = Shear stress, psi (MPa) $\Re$ = Shear strain, in/in **G** = Shear modulus, psi (MPa)

	Linear limit (LL)			Knee (KN)		Ultimate failure (UL)	
Test Temp.	**f**	$\Re$	**G**	**f**	$\Re$	**f**	$\Re$
–67°F (-55°C)	3620 (25.0)	0.0238	153,100 (1056)	8760 (60.4)	0.1053	10140 (70.0)	0.5398
75°F (24°C)	2820 (19.5)	0.0237	119,300 (823)	46400 (32.0)	0.0738	6990 (48.2)	0.1934
180°F (82°C)	1060 (7.3)	0.0220	45,100 (311)	1910 (13.2)	0.0722	5620 (38.8)	1.7834

Rheology data

FM® 94K .08 PSF roll 2 batch 113 (1°C / min ramp)



Health and safety information

Refer to Material Safety Data Sheet and product labels.

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