

AEROSPACE MATERIAL SPECIFICATION

Carbon Fiber Fabric and Epoxy Resin Wet Lay-Up Repair Material Part 5 - Material Specification: Carbon Fiber Fabrics, Plain Weave, 193 g/m², and Epoxy Resin

RATIONALE

AMS 2980/5 has been created to define the requirements to be met by the qualified materials according to AMS 2980/1 and AMS 2980/2.

FOREWORD

AMS 2980/5 belongs to the Technical Specification system explained in AMS 2980.

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1. SCOPE:

This Material Specification defines the requirements of carbon fiber fabric and epoxy resin systems used for wet lay-up repair of carbon fiber reinforced epoxy structures, qualified according to AMS 2980/1 and 2980/2.

Unless otherwise specified by the drawing, the order or the inspection schedule, the present specification shall be used in conjunction with the referenced documents.

1.1 Field of Application:

This AMS is only applicable to carbon fiber fabric and epoxy resin systems used for wet lay-up repair of carbon fiber reinforced epoxy structures. Only fabric/resin combinations specified in PRI QPL AMS 2980 are allowed

2. APPLICABLE DOCUMENTS:

The issue of the following documents in effect on the date of the purchase order forms a part of this specification to the extent specified herein. The supplier may work to a subsequent revision of a document unless a specific document issue is specified. When the referenced document has been cancelled and no superseding document has been specified, the last published issue of that document shall apply.

2.1 SAE Publications:

Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001 or www.sae.org

AMS 2980/0	Carbon Fiber Fabric and Epoxy Resin Wet Lay-Up Repair Material Introduction
AMS 2980/1	Carbon Fiber Fabric and Epoxy Resin Wet Lay-Up Repair Material General Requirements
AMS 2980/2	Carbon Fiber Fabric and Epoxy Resin Wet Lay-Up Repair Material Qualification program
AMS 2980/3	Carbon Fiber Fabric and Epoxy Resin Wet Lay-Up Repair Material Purchasing Specification - Fabric
AMS 2980/4	Carbon Fiber Fabric and Epoxy Resin Wet Lay-Up Repair Material Purchasing Specification – Resin

2.2 PRI Publications:

Available from Performance Review Institute, 161 Thornhill Road, Warrendale PA 15086-7527 or www.pri-network.org.

PRI QPL AMS 2980	Qualified product list of AMS 2980
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3. DEFINITIONS:

Refer to AMS 2980/1.

4. REQUIREMENTS:

4.1 General Requirements:

4.1.1 Material Description: Shall be as shown in Table 1.

Table 1 - Material Description

No.	Material Description	Requirements
1.1	Material type	Wet lay-up composite material
1.2	Fabric	AMS 2980 part 3 (Carbon fiber, plain weave, 193 g/m ²)
1.3	Resin	AMS 2980 part 4 (Epoxy)
1.4	Technical specification	AMS 2980/1 and AMS 2980/2

4.1.2 Cure Cycle: Shall be as shown in Table 2.

Table 2 - Cure Cycle ¹⁾

No.	Cure Parameters	Units	Requirements
2.1	Heating rate	°C / min	1 to 3
2.2	Cure temperature	°C	< 95
2.3	Cure time	Min	< 240
2.4	Cure pressure	bar	> 0.75 vacuum pressure
2.5	Cooling rate	°C / min	5 max

¹⁾ Specific parameter values to be defined during qualification and recorded in the relevant Appendix (or IPS) of PRI QPL AMS 2980 for each material combination

4.1.3 Wet Lay-Up Process: Shall be as shown in Table 3.

Table 3 - Wet Lay-Up Process

No.	Process	Requirements
3.1	Squeeze-out	AMS 2980 part 1 § 6.7.6
3.2	Vertical bleeding	AMS 2980 part 1 § 6.7.7 and 6.7.8

4.1.4 Resin Work Life and Storage Conditions: Shall be as shown in Table 4.

Table 4 - Resin Work Life and Storage Conditions

No.	Property	Units	Requirements
4.1	Work life at RT	hours	≥ 1
4.2	Storage life at RT ¹⁾ components A and B	months	≥ 6
4.3	Storage life at 5 °C ¹⁾ components A and B	months	≥ 12

¹⁾ From the date of shipment

4.2 Specific Requirements:

In accordance with Tables 5 to 14. For qualification, all tests shall be performed. For release refer to AMS 2980 part 3 and AMS 2980 part 4.

4.2.1 Requirements for Unmixed Resin and Curing Agent: Shall be as shown in Table 5.

Table 5 - Properties of Unmixed Resin and Curing Agent

No.	Variables Property	Water Content Test Method ²⁾	Requirements			
			RESIN		CURING AGENT	
			nom	max	nom	max
5.1	Epoxide Equivalent	ASTM D1652 or ISO 3001	1)	--	--	--
5.2	Amine Value	ASTM D 2896	--	--	1)	1)
5.3	IR (qualitative)	EN 6042 or ASTM E 1252	1)	--	1)	--
5.4	Water content	ASTM E-203 or ISO 760	1)	1)	1)	1)
5.5	Viscosity @ 25°C	ISO 2555	1)	1)	1)	1)
5.6	Density	ISO 1183 or ASTM D 1875	1)	--	1)	--

¹⁾ To be defined during qualification and recorded in the relevant Appendix (or IPS) of PRI QPL AMS 2980.

²⁾ Test method used in qualification shall be listed in the relevant Appendix (or IPS) of PRI QPL AMS 2980.

4.2.2 Requirements for Mixed Uncured Resin: Shall be as shown in Table 6.

Table 6 - Properties of Mixed Uncured Resin

No.	Variables Property	Water Content Mixing Ratio Test Method ³⁾	Requirements			
			nom		max	
			nom	max	min	min
6.1	Viscosity @25 °C	ISO 2555	1)	1)		
6.2	Viscosity profile ²⁾	EN 6043	1)		1)	1)
6.3	Gel time	EN 6043 or ASTM D 2471	1)			

¹⁾ To be defined during qualification and recorded in the relevant Appendix (or IPS) of PRI QPL AMS 2980.

²⁾ With the nominal cure cycle as specified in the relevant Appendix (or IPS) of PRI QPL AMS 2980.

³⁾ Test method used in qualification shall be listed in the relevant Appendix (or IPS) of PRI QPL AMS 2980.

4.2.3 Requirements for Cured Neat Resin: Shall be as shown in Table 7.

Table 7 - Properties of Cured Neat Resin

No.	Variables	Conditioning			Requirements ¹⁾	
	Property	Test Method ⁶⁾		Units	DRY ³⁾	WET ⁴⁾
7.1	Shore D	ISO 868			2)	--
7.2	Extent of cure ⁵⁾	EN 6064 or ISO 11357-5		%	≥ 90	--
7.3	DMA	EN 6032 or ASTM E 1640	T _{g onset}	°C	≥ 110	≥ 100
7.4	Density	ISO 1183 or EN 542		g/m ³	2)	--

¹⁾ Applicable to nominal and modified water content, mixing ratio and cure cycle as defined in AMS 2980/2

²⁾ To be defined during qualification and recorded in the relevant Appendix (or IPS) of PRI QPL AMS 2980.

³⁾ DRY: equilibrium at 40 °C

⁴⁾ WET: 336 ± 16 hours in water at 70 °C (EN 2489)

⁵⁾ If the curing enthalpy of the resin shows a minor exotherm at high temperature, 80% extent of cure is allowed

⁶⁾ Test method used in qualification shall be listed in the relevant Appendix (or IPS) of PRI QPL AMS 2980.

4.2.4 Requirements for Carbon Fiber: Shall be as shown in Table 8.

Table 8 - Requirements for Carbon Fiber

No.	Property	Test Method	Requirements
8.1	Tensile impregnated yarn (σ, E, ξ)	ISO 10618	1)
8.2	Density	ISO 10119	1)
8.3	Mass per unit length (Linear density)	ISO 10120	1)
8.4	Twist	ISO 1890	1)
8.5	Size content	ISO 10548	1)

¹⁾ To be defined during qualification and recorded in the relevant Appendix (or IPS) of PRI QPL AMS 2980.

4.2.5 Requirements for Carbon Fabric: Shall be as shown in Table 9.

Table 9 - Requirements for Carbon Fabric

No.	Property	Test Method	Unit	Requirements
	Yarn count			
9.1	warp	AMS 2980/1 § 4.4.3.2	yarns/cm	4.8 ± 0.2
	weft		yarns/cm	4.7 ± 0.2
9.2	Areal weight	AMS 2980/1 § 4.4.3.1	g/m^2	193 ± 8
9.3	Fabric width	AMS 2980/1 § 4.2.2.2	mm	1)
9.4	Tracer yarns	AMS 2980/1 § 4.2.2.2	-	1)
9.5	Defects	AMS 2980/1 § 4.2.2.3	-	AMS 2980/1 § 4.2.2.3
9.6	Storage life at RT ²⁾	AMS 2980/1 § 4.2.2.5	months	≥ 24

¹⁾ To be defined during qualification and recorded in the relevant Appendix (or IPS) of PRI QPL AMS 2980.

²⁾ From the date of receipt

4.2.6 Requirements for Main Laminate Composite Properties: Shall be as shown in Table 10.

Table 10 - Main Laminate Composite Properties

				Requirements ¹⁾²⁾											
		Laminating Process		Squeeze Out											
		Conditioning Cured Specimens		DRY						WET ³⁾					
Variables		Test Temperature (°C)		-55		RT		80		60		80		120	
No.	Property	Test Method	Units	X _{ave}	X _{min}	X _{ave}	X _{min}	X _{ave}	X _{min}	X _{ave}	X _{min}	X _{ave}	X _{min}	X _{ave}	X _{min}
10.1	Tensile weft ⁴⁾	EN 2561C	F ₁ ^{tu} MPa	500	440	500	440	-	-	-	-	500	440	440	370
			E ₁ ^{tu} GPa	62±7	62±10	62±7	62±10	-	-	-	-	62±7	62±10	62±7	62±15
			V ₁₂	-	-	0.04 ± 0.03 ⁶⁾		-	-	-	-	-	-	-	-
			ε ₁ tu με	11±2	11±3	11±2	11±3	-	-	-	-	11±2	11±3	11±2	11±3
10.2	Compressive weft ⁴⁾	EN 2850B	F ₁ ^{cu} MPa	-	-	600	540	450	400	450	400	450	400	370	340
			E ₁ ^{cu} GPa	-	-	56±7	56±10	56±7	56±10	56±7	56±10	56±7	56±10	56±10	56±22
10.3	Tensile in-plane shear ⁵⁾	EN 6031	τ ₁₂ MPa	85	80	65	60	50	45	55	50	50	45	35	30
			G ₁₂ GPa	5.0 ± 0.5	5.0 ± 1.0	4.0 ± 0.5	4.0 ± 1.0	3.5 ± 0.5	3.5 ± 1.0	3.8 ± 0.5	3.8 ± 1.0	3.2 ± 0.6	3.2 ± 1.0	1.5 ± 0.5	1.5 ± 1.0

¹⁾ Applicable to nominal and modified water content, mixing ratio and cure cycle as defined AMS 2980/2

²⁾ X_{ave} means minimum batch average value

³⁾ X_{min} means minimum individual value

⁴⁾ WET: 336 ± 16 hours in water at 70 °C (EN 2489)

⁵⁾ Normalized values to 55% Fiber Volume. Nominal laminate thickness: 0.200 mm per cured ply

⁶⁾ Actual values (actual laminate thickness)

⁷⁾ Batch average and range

4.2.7 Requirements for Fluid Resistance and Glass Transition Temperature: Shall be as shown in Table 11.

Table 11 - Fluid Resistance and Glass Transition Temperature

					Requirements ^{1) 2)}											
					Laminating Process				Squeeze Out							
					Conditioning Cured Specimens				Solvent ³⁾		Fuel ⁴⁾		Hydraulic Fluid ⁵⁾		Dry ⁶⁾	WET ⁷⁾
					Test temperature (°C)				RT		80		80		-55 to (T _g + 50)	
No.	Property	Test Method		Units	X _{ave}	X _{min}	X _{ave}	X _{min}	X _{ave}	X _{min}						
11.1	Tensile in plane ⁸⁾	EN 6031	τ ₁₂	MPa	9)		9)		9)		-					
			G ₁₂	GPa	9)		9)		9)							
11.2	DMA composite	EN 6032-A or ASTM E1640	T _{g onset}	°C			-				≥ 120	≥ 100				

¹⁾ Applicable to nominal water content, mixing ratio and cure cycle as defined in AMS 2980/2

²⁾ X_{ave} means minimum batch average value

³⁾ X_{min} means minimum individual value

⁴⁾ Solvent (defined in AMS 2980/1) at 23 + 2 °C for 1 hour (EN 2489).

⁵⁾ Fuel (defined in AMS 2980/1) at 23 + 2 °C for 1000 + 64 hours (EN 2489).

⁶⁾ Hydraulic fluid (defined in AMS 2980/1) at 70+ 2 °C for 1000 + 64 hours (EN 2489).

⁷⁾ DRY: equilibrium at 40 °C

⁸⁾ WET: equilibrium at 70 °C / 85% RH. Weight gain (%) at 70 °C/85% RH equilibrium ≤ 2.0

⁹⁾ Actual values (actual laminate thickness)

¹⁰⁾ These values shall be within ± 10 percent of the dry value at the equivalent temperature

4.2.8 Requirements for Composite Design Related Properties: Shall be as shown in Table 12.

Table 12 - Composite Design Related Properties

					Requirements ^{1) 2)}							
					Laminating Process		Squeeze Out					
					Conditioning Cured Specimens		DRY				WET ³⁾	
Variables		Test temperature (°C)			-55		RT		80		120	
No.	Property	Test Method		Units	X _{ave}	X _{min}	X _{ave}	X _{min}	X _{ave}	X _{min}	X _{ave}	X _{min}
12.1	Tensile QI ⁴⁾	EN 6035 A	F _x ^t	MPa	-	-	540	500	-	-	-	-
			E _x ^t	GPa	-	-	45±3	45±5	-	-	-	-
12.2	Tensile Openhole QI ⁴⁾	EN 6035 A	F _x ^{oh}	MPa	330	300	350	340	350	340	-	-
12.3	Compression QI ⁴⁾	SACMA SRM 3 Issue 1994	F _x ^c	MPa	-	-	380	360	290	270	-	-
			E _x ^c	GPa	-	-	43±3	43±6	41±3	41±6	-	-
12.4	Compression Openhole QI ⁴⁾	SACMA SRM 3 Issue 1994	F _x ^{ohc}	MPa	340	300	290	270	230	220	180	160
12.5	Bearing QI ⁴⁾	EN 6037 B	P _{2%}	MPa	-	-	410	250	-	-	-	-
			P _u	MPa	-	-	970	925	720	575	-	-
12.6	Compression after Impact ⁴⁾	EN 6038										
	Impact energy: one level below ⁶⁾		F _{cai}	MPa	-	-	195	185	-	-	-	-
	Impact energy ^{5) 6)}		F _{cai}	MPa	-	-	180	170	-	-	-	-
	Impact energy: two levels above ⁶⁾		F _{cai}	MPa	-	-	170	160	-	-	-	-

¹⁾ Applicable to nominal water content, mixing ratio and cure cycle as defined in AMS 2980/2.²⁾ X_{ave} means minimum batch average value³⁾ X_{min} means minimum individual value⁴⁾ WET: 336 ± 16 hours in water at 70 °C (EN 2489)⁵⁾ Normalized values to 55% Fiber Volume. Laminate thickness: 0.200 mm per cured ply⁶⁾ Impact energy to produce BVI (0.3 mm indentation depth) as defined in AMS 2980/1 § 6.5.11.2⁷⁾ Energy levels defined in EN 6038