

10 vs SS PSI  
GR. FAB & GR TAPE  
TENSION / COMPRESSION / SHEAR

FACSIMILE TRANSMITTAL SHEET

TO:	FROM:
Steve Denty	Nigel barker
COMPANY:	DATE:
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NOTES/COMMENTS:

Steve

Attached are selected sheets from memo report 891-NHB-973 "Co-cure Bonding of Composite Honeycomb sandwich Structure: Co-cure Reduction Factors."

This is a report summarizing the results of a series of engineering tests on cocured skins containing both RMS 060 and RMS 040 material.

If you need anything else, give me a call.

Cheers, Nigel

[CLICK HERE AND TYPE RETURN ADDRESS]

#### 4. TENSION PROPERTIES

The tension results include data from 4 point beam specimens and from coupon specimens extracted from cocured skins. They were tested at the room temperature/dry and 350°F/wet conditions. These results are reported in reference 5 and are attached as Appendix D.

##### 4.1 Tension strength

The following cross-tabulation table shows the relationships between the reduction factors and the variables in the test or specimen configuration.

Table 1. Cross-tabulation Table of Tension Test Results.

				REDUCTION FACTOR		Average	
				Ply direction (°)			
Temperature (°F)	Skin thickness	tool or bag	Cell size (")	0	90		
75	0.019	BF	0.125	0.81	0.92	0.87	
			0.1875	0.81	0.93	0.87	
	TF	0.125	#N/A	0.98	0.98		
		0.1875	1.09	#N/A	1.09		
		0.033	BF	0.125	0.91	#N/A	0.91
				0.1875	0.92	0.93	0.92
TF		0.1875	0.81	0.87	0.84		
		0.056	BF	0.125	#N/A	0.84	0.84
0.084		TF	0.125	0.98	1.12	1.05	
350		0.056	BF	0.125	1.07	1.08	1.07
	TF	0.125	1.11	1.24	1.18		
		0.168	BF	0.125	1.08	1.08	1.08
Average				0.96	1.00	0.98	

The data was analyzed using the Pearson function to determine what degree of correlation exists between the variables and the reduction factors. The correlation factors are shown in table 2.

Table 2. Pearson Correlation Coefficient,  $r$ 

	temp	Skin thickness	Cell size (")	tool or bag	Phy dir. (")
Reduction	0.71	0.47	-0.43	0.30	0.17
Reduction			-0.10*		

\* Controlled for temperature and skin thickness (RT/Dry results on 0.019" & 0.033" skins only)

A positive or negative value of 1 shows a perfect correlation. A positive or negative correlation of 0.5 or greater is considered a large effect size, a strong relationship. A positive or negative correlation of 0.3 to 0.5 is considered a medium effect size, a moderate relationship.

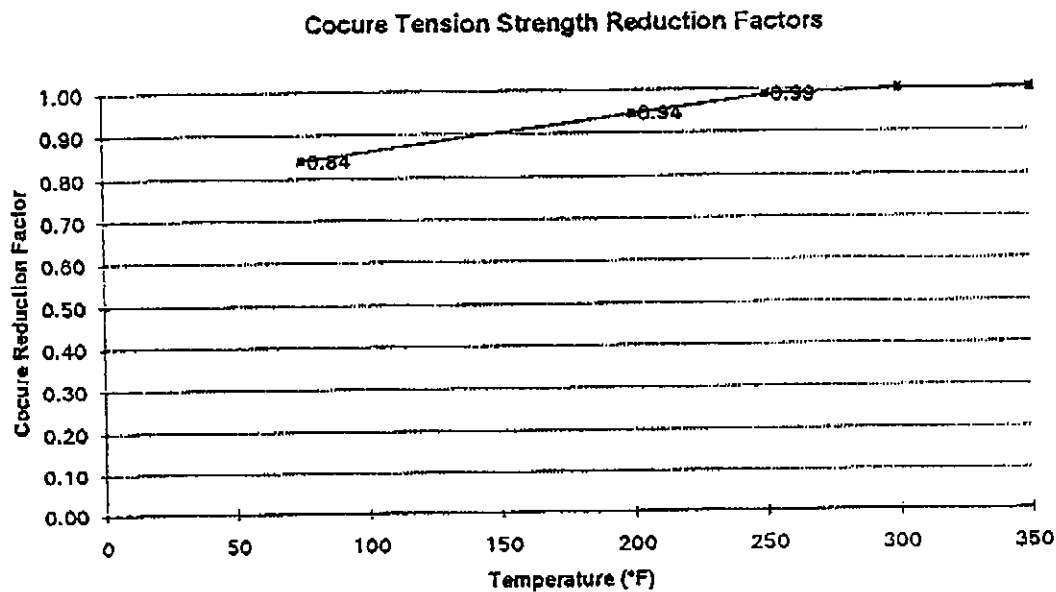
The results show a strong relationship between reduction factor and test temperature, and a moderate relationship between reduction factor and skin thickness, cell size and tooling. However, the effect of cell size was skewed because the higher temperature and thicker skin test specimens contained only 1/8" core, artificially boosting the test results from that core. No correlation between reduction factor and the two cell sizes existed when the analysis was rerun controlling for temperature and skin thickness. This was confirmed further by analysis of variance (anova) calculations, which indicated that different sets of results using the two cell sizes could be considered to come from the same population, provided all the other variables were equal.

#### 4.1.1 Tension strength reduction factors

The reduction factor versus temperature curve (figure 7) was calculated using a straight line basis between the 75°F value and the 350°F value, with a maximum cut-off at 1.00.

For conservatism, 0.84 was chosen as the reduction factor at 75°F, and 1.07 as the 350°F reduction factor. These values represent the lower bound for the average values, and are coincidentally the factors associated with a 0.054" thick, bag-face skin.

Figure 7. Cocure Tension Strength Reduction Factors vs. Temperature



Note: These factors apply only when using 1/8" or 3/16" cell core.

#### 4.2 Tension Modulus

The reported moduli were equal to or exceeded either the moduli in the allowables database testing or the calculated value for a mixed fabric/tape skin. Hence, it is not necessary to apply a reduction factor to the tensile modulus.

### 5. IN-PLANE SHEAR PROPERTIES

The in-plane shear results were reported in reference 6, which is attached as appendix E. The tests were conducted at the room temperature/dry and 350°F/wet conditions.

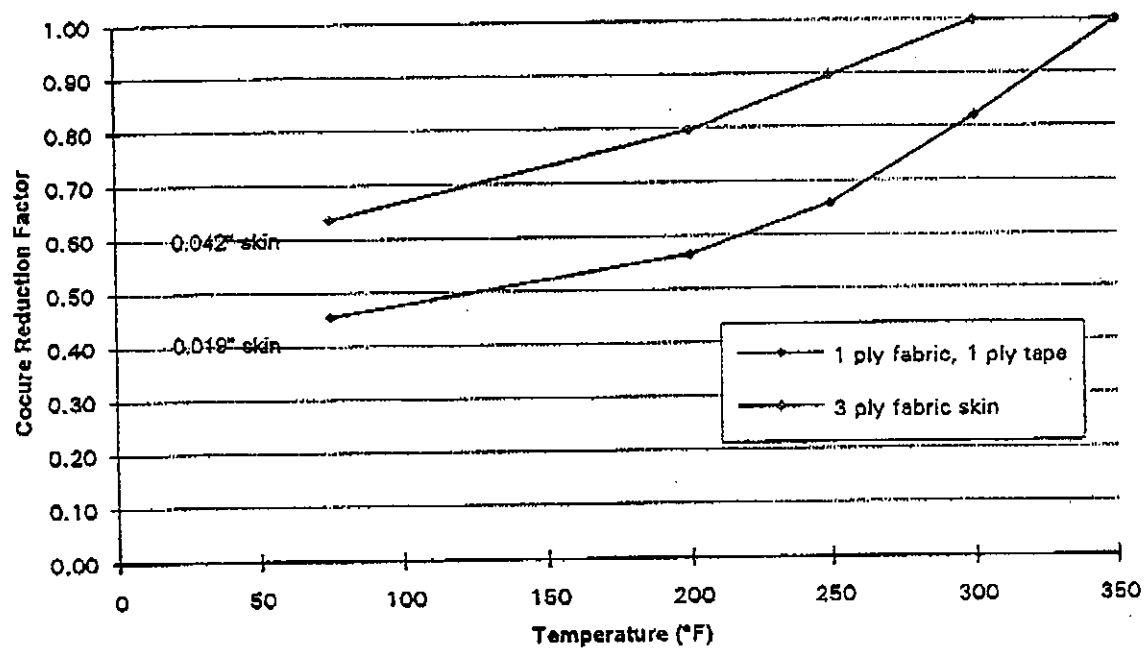
The comparison between the cocured results and the allowables database was complicated because different test methods were used. The database was developed using the Iosipescu specimen, a small coupon with a short, 0.37" gage length, unsuitable for cocured skins. The cocure testing used the sandwich rail shear specimen.

## **Appendix A**

### **Co-cure Reduction Factors for RMS 040 and RMS 060 Materials**

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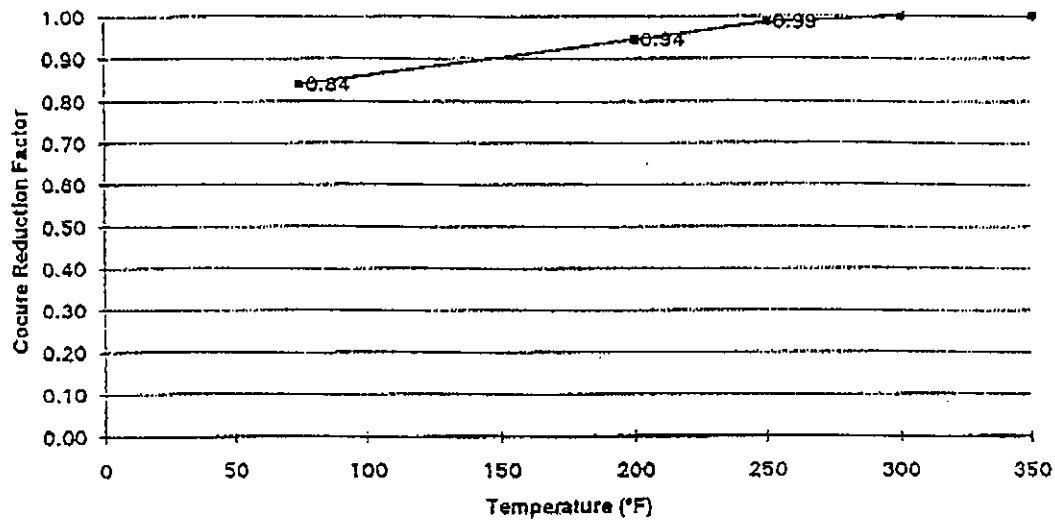
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	75°F/ Wet	200°F/ Wet	250°F/ Wet	300°F/ Wet	350°F/ Wet
1 ply fabric, 1 ply tape skin	0.45	0.57	0.66	0.82	1.00
3 ply fabric skin	0.64	0.80	0.90	1.00	1.00

### Compression Strength Reduction Factors

### Cocure Tension Strength Reduction Factors

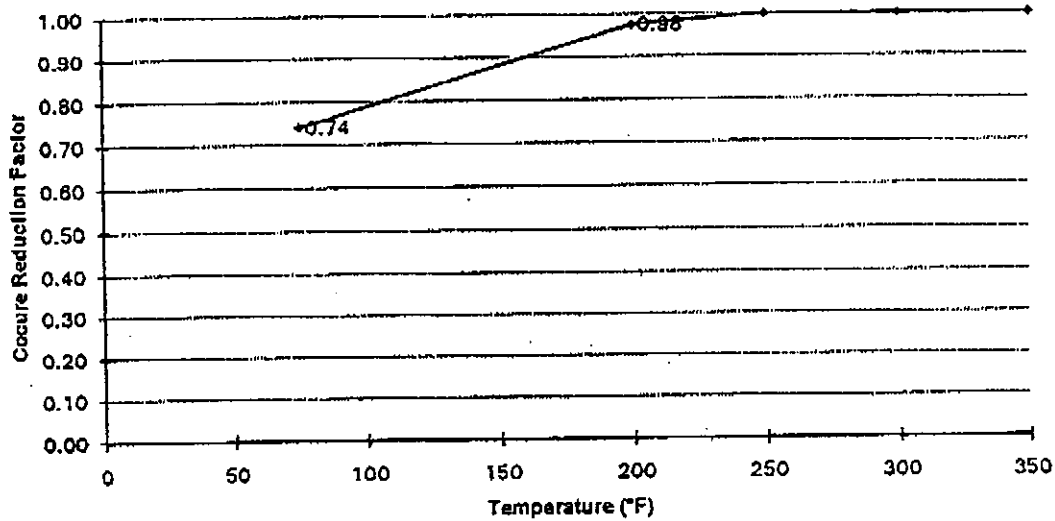


Note: These factors apply only when using 1/8" or 3/16" cell core.

	75°F	200°F	250°	300°Ft	350°F
Reduction Factor	0.84	0.94	0.99	1.00	1.00

### Tension Strength Reduction Factors

### Cocure In-plane Shear Strength Reduction Factors

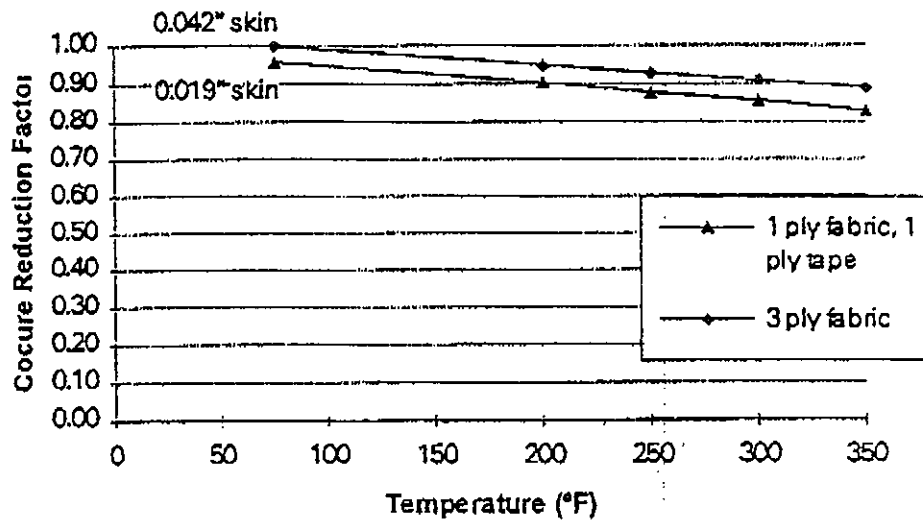


Note: These factors apply only when using 1/8" or 3/16" cell core.

	75°F	200°F	250°	300°F	350°F
Reduction Factor	0.74	0.98	1.00	1.00	1.00

### In-Plane Shear Strength Reduction Factors





	75°F/ Wet	200°F/ Wet	250°F/ Wet	300°F/ Wet	350°F/ Wet
1 ply fabric, 1 ply tape skin	0.96	0.90	0.88	0.86	0.83
3 ply fabric skin (1)	1.00	0.95	0.93	0.91	0.89

Note: These factors apply only when using 1/8\" or 3/16\" cell core.

### Compression Modulus Reduction Factors

	75°F	200°F	250°	300°Ft	350°F
Reduction Factor	1.00	1.00	1.00	1.00	1.00

### Tension Modulus Reduction Factors

	75°F	200°F	250°	300°Ft	350°F
Reduction Factor	1.00	1.00	1.00	1.00	1.00

### In-Plane Shear Modulus Reduction Factors

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4.0.0 EXHAUST NOZZLE  
 4.4.0 ALLOWABLES  
 4.4.2 COMPOSITE MATERIALS

A340  
 70 vs 35 psi  
 KNOCKDOWN FACTOR

RMS060, TYPE 2, FABRIC - WET PROPERTIES @ VARIOUS TEMPERATURES

SPEC RMS060W  
 C/E FABR WET RHR88-107, '90  
 Temp= 70. Degrees

E1 = 99.77E+05 psi Nu12 = .064  
 E2 = 98.87E+05 psi Nu21 = .063  
 G = 76.74E+04 psi

Ft1 = 93003 psi et1 = .00000  
 Ft2 = 89379 psi et2 = .00000  
 Fc1 = 76805 psi ec1 = .00000  
 Fc2 = 66251 psi ec2 = .00000  
 Fs = 17818 psi es = .00000

t = 0.0140 in

SPEC RMS060W  
 C/E FABR WET RHR88-107, '90  
 Temp= 180. Degrees

E1 = 89.80E+05 psi Nu12 = .064  
 E2 = 92.20E+05 psi Nu21 = .066  
 G = 62.53E+04 psi

Ft1 = 86282 psi et1 = .00000  
 Ft2 = 77673 psi et2 = .00000  
 Fc1 = 55005 psi ec1 = .00000  
 Fc2 = 46507 psi ec2 = .00000  
 Fs = 12906 psi es = .00000

t = 0.0140 in

SPEC RMS060W  
 C/E FABR WET RHR88-107, '90  
 Temp= 200. Degrees

E1 = 87.97E+05 psi Nu12 = .064  
 E2 = 91.02E+05 psi Nu21 = .066  
 G = 59.96E+04 psi

Ft1 = 85002 psi et1 = .00000  
 Ft2 = 75459 psi et2 = .00000  
 Fc1 = 50987 psi ec1 = .00000  
 Fc2 = 42966 psi ec2 = .00000  
 Fs = 12006 psi es = .00000

t = 0.0140 in

SPEC RMS060W  
 C/E FABR WET RHR88-107, '90  
 Temp= 250. Degrees

E1 = 83.60E+05 psi Nu12 = .064  
 E2 = 87.48E+05 psi Nu21 = .067  
 G = 53.96E+04 psi

Ft1 = 81747 psi et1 = .00000  
 Ft2 = 69922 psi et2 = .00000  
 Fc1 = 40714 psi ec1 = .00000  
 Fc2 = 34178 psi ec2 = .00000  
 Fs = 9785 psi es = .00000

t = 0.0140 in

SPEC RMS060W  
 C/E FABR WET RHR88-107, '90  
 Temp= 350. Degrees

E1 = 74.25E+05 psi Nu12 = .064  
 E2 = 74.69E+05 psi Nu21 = .064  
 G = 15.96E+04 psi

Ft1 = 73191 psi et1 = .00000  
 Ft2 = 58581 psi et2 = .00000  
 Fc1 = 10730 psi ec1 = .00000  
 Fc2 = 10091 psi ec2 = .00000  
 Fs = 4073 psi es = .00000

t = 0.0140 in

REF. B2 AND B6.

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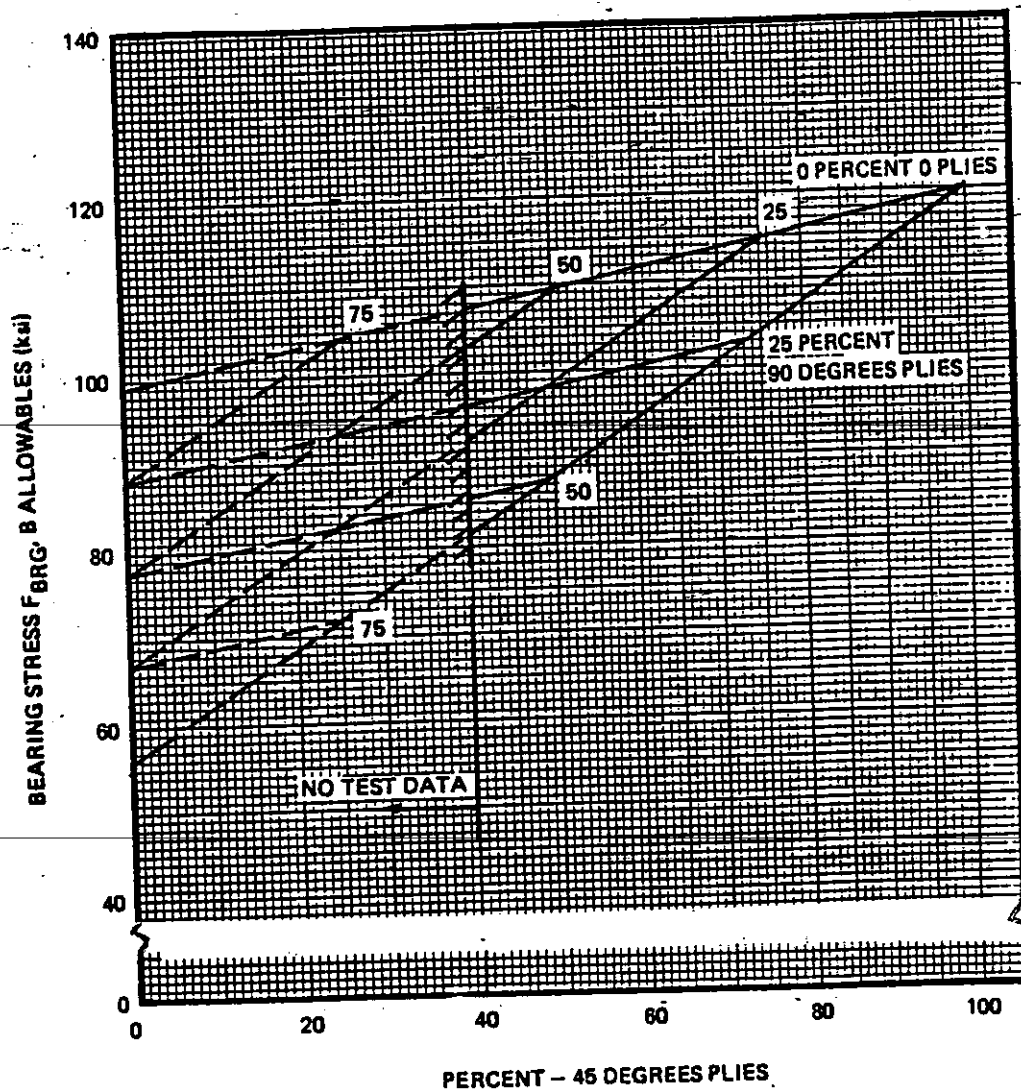
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- 4.0.0 EXHAUST NOZZLE
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- 4.4.2 COMPOSITE MATERIALS

RMS060 Fabric Bearing Strength, Wet @ 180-F (Ref. B7, Fig. 7.4.1)



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CH'KD WS DATE 2/96

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4.0.0 EXHAUST NOZZLE  
4.4.0 ALLOWABLES  
4.4.2 COMPOSITE MATERIALS

### RMS060 TYPE 2 COCURED GRAPHITE/EPOXY FABRIC

VARIOUS TEST RESULTS FROM REF. B14 WERE USED TO DEVELOP DESIGN ALLOWABLES IN THIS REPORT FOR COCURED RMS060 TYPE 2 FABRIC. FROM REF. B14 TEST RESULTS, CURVES WERE DEVELOPED FOR THE REDUCTION OF PRECURED MATERIAL ALLOWABLES FOR USE ON COCURED LAMINA.

THE FOLLOWING REDUCTION FACTORS (RELATIVE TO PRE-CURED-ALLOWABLES) ARE USED TO CALCULATE THE RMS060 TYPE 2 COCURED ALLOWABLES:

TENSION ALLOWABLES  
COMPRESSION ALLOWABLES  
SHEAR ALLOWABLE

ROOM TEMP.	200 F **
0.81	0.90
0.64	0.80
0.78	0.94

(THESE FACTORS ARE FOR THE BAG SIDE SINCE THE ONLY COCURED RMS060 TYPE 2 FABRIC USED ON THE NOZZLE IS ON THE BAG SIDE.)

ALSO, BASED ON ROHR TEST RESULTS, THE REDUCTION FACTOR USED FOR THE ELASTIC MODULI FOR COCURED RMS060 TYPE 2 FABRIC (BAG SIDE) IS 0.74.

APPLYING THE ABOVE FACTORS TO THE B-BASIS ALLOWABLES FROM REF. B2, RHR 88-107, FOR PRECURED RMS060 TYPE 2 FABRIC (WET), THE FOLLOWING COCURED BAG-SIDE RMS060 TYPE 2 FABRIC ALLOWABLES ARE OBTAINED:

	Room Temp./Wet	200 F/Wet
Ft1, psi:	75,332	76,502
Ft2, psi:	72,397	67,913
Fc1, psi:	49,155	40,790
Fc2, psi:	42,401	34,373
Fs, psi:	13,898	11,286
E1, Msi:	7.383	6.510
E2, Msi:	7.316	6.735
G12, Msi:	0.568	0.444
nu12* :	0.064	0.065

ALLOWABLES AND MATERIAL PROPERTIES FOR INTERMEDIATE TEMPERATURES (TEMPERATURES BETWEEN 70 F AND 200 F) CAN BE INTERPOLATED.

\* THE POISSON'S RATIO, nu12, IS ASSUMED TO BE THE SAME FOR COCURED AND PRECURED LAMINA.

\*\* SEE NEXT PAGE

BY W Shen DATE FEB 96  
CH'KD A DATE 2/96



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- 4.4.0 ALLOWABLES
- 4.4.2 COMPOSITE MATERIALS

Since the Feb 95 analysis, the cocured reduction factors for the tension and shear allowables have been recalculated resulting in higher allowables (Ref B17).

Any analysis performed using the cocure allowables determined on the previous page is therefore conservative.



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## 4.0.0 EXHAUST NOZZLE

## 4.4.0 ALLOWABLES

## 4.4.2 COMPOSITE ALLOWABLES

## RMS060 TYPE 3 COCURED GRAPHITE/EPOXY FABRIC

Due to the limited amount of data available on cocured RMS060 Type 3 fabric, data from ref. B2, ref. B4, and various test results (ref. B14) for cocured RMS060 Type 3 fabric were used to develop analysis allowables used in this report.

From ref. B4, the following material allowables and properties are for precured RMS060 Type 3 fabric:

	Room Temp./Wet	200 F/Wet
Ft1, psi:	79615	88900
Ft2, psi:	92515	87260
Fc1, psi:	68460	51505
Fc2, psi:	82655	77960 <sup>△</sup>
Fs, psi:	14500 <sup>△</sup>	9400 <sup>△</sup>
E1, ksi:	8.36	8.24
E2, ksi:	8.38	8.66
G12, ksi:	0.75 <sup>△</sup>	0.60 <sup>△</sup>
nu12	0.06 <sup>△</sup>	0.06 <sup>△</sup>

## Notes:

<sup>△</sup> Fc2 = (Fc2/Ft2)@RT/Wet x (Ft2)@200F/Wet.

<sup>△</sup> Precured RMS060 Type 2 Fabric Values from ref. B2.

<sup>△</sup> Assumed to be similar to RMS060 Type 2, ref. B2.

The following compression allowables based on minimum values obtained from tests (ref. B14) are for cocured RMS060 Type 3 fabric in the 0 deg. direction:

	Room Temp./Wet	250 F/Wet
Tool Side, psi:	41160	34220
Bag Side, psi:	32440	20350

For conservatism, in analyzing cocured structures, only bag side allowables are used for the 0 and 90 deg. directions.

From experiences with precured RMS060 Type 2 fabric (ref. B2) and cocured RMS060 Type 2 fabric, the cocured tension allowables are 80% of the precured tension allowables (ref. B14).

Shear allowables are reduced by the following reduction factors (ref. B14):

	Room Temp./Wet	350 F/Wet
Reduction Factor:	0.65	1.0

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4.0.0 EXHAUST NOZZLE  
 4.4.0 ALLOWABLES  
 4.4.2 COMPOSITE ALLOWABLES

RMS060 TYPE3 COCURED GRAPHITE/EPOXY FABRIC

Using the data presented on the previous page, the following allowables and properties for cocured RMS060 Type 3 fabric were derived and used for analysis:

	Room Temp/Wet	200 F/Wet
Ft1, psi:	63692 $\Delta$	71120 $\Delta$
Ft2, psi:	74012 $\Delta$	69808 $\Delta$
Fc1, psi:	32440 $\Delta$	23708 $\Delta$
Fc2, psi:	32440 $\Delta$	23708 $\Delta$
Fs, psi :	9425 $\Delta$	7638 $\Delta$
E1, msi :	8.36	8.24
E2, msi :	8.38	8.66
G12, msi:	0.75	0.60
nu12 :	0.06 $\Delta$	0.06 $\Delta$

## Notes:

- $\Delta$  Precured RMS060 Type 3 values multiplied by 0.80.
- $\Delta$  From compression tests, ref. B14.
- $\Delta$  Using shear allowable reduction factors from previous page.
- $\Delta$  Poisson ratio is assumed to be unaffected by temperature.

Allowable/material values for intermediate temperatures (temperatures between 70 F and 200 F) are interpolated.

Finally, since no bearing allowable data exists for cocured RMS060 Type 3 fabric, Fbru is assumed to be 45,000 psi. This is based on past experiences with Gr/Ep laminates which include laminates that are comprised of only 0/90 deg. plies.

Cocured

F<sub>br</sub> = 45000 psi

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4.0.0 EXHAUST NOZZLE  
4.4.0 ALLOWABLES  
4.4.2 COMPOSITE MATERIALS

#### LAMINATE FLATWISE TENSION

The following laminate flatwise allowables are used for analysis:

TEMPERATURE (F)	"B" Allowable (psi) (*)
72	1086
200	777
350	415

Ref. B12, TIR No. 17364.00; 12 ply RMS060 laminate.

Note: Allowable at 200 F was interpolated.

(\*) MIL-HDBK-SE "B" BASIS METHOD USED.