3.1.3 Strain

Material strain properties are provided as functions of percent ± 45 degree plies in Figure 3.1.3-1. These values are reduced from typical to represent .95 confidence and .90 probability strength level (typical of "B" strength level). Compression and tension properties differ for unnotched laminates. A single curve is provided for 0.25 inch diameter open hole notched laminate properties. It applies equally to tension and compression, for all material forms. Curves represent RTD properties. Factors are provided as multipliers of RTD properties to obtain properties at the -65°F dry and 130°F wet conditions.

Ultimate strengths were computed using measured loads, measured specimen widths and nominal thicknesses. Strains were computed from ultimate strengths and environmental moduli for each tested laminate. Normality statistics were applied to average computed strains to establish "B" values. Allowables at all intermediate conditions can be obtained using linear interpolation between RTD and the condition of interest.

Figure 3.1.3-2 provides properties for selected laminates in both unnotched and notched conditions. RTD average strains are included for information purposes. Both RTD and 130°F wet B-basis properties are shown.

Figure 3.1.3-3 shows thickness effects applicable to unnotched, cocured sandwich faces. Laminates and precured secondary bonded sandwich faces do not show this thickness effect.

See Section 4 for design allowables.

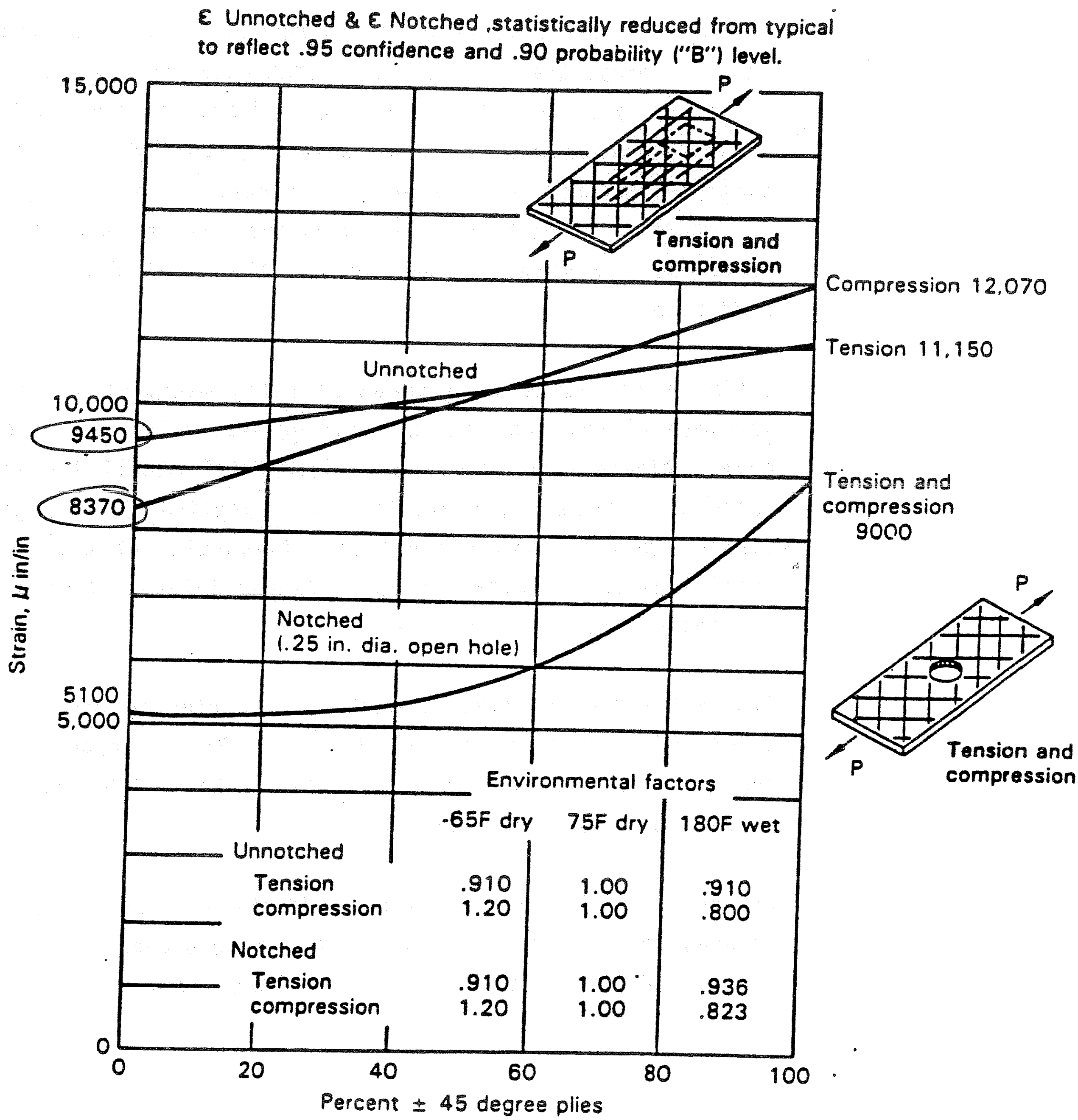


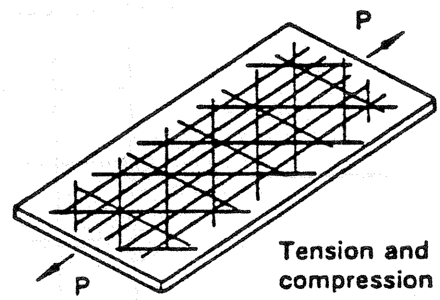
Figure 3.1.3-1. Laminate Axial Strain Properties

See Section 4 for design allowables.

Strain
Basis: $\varepsilon = F/E_{avg}$

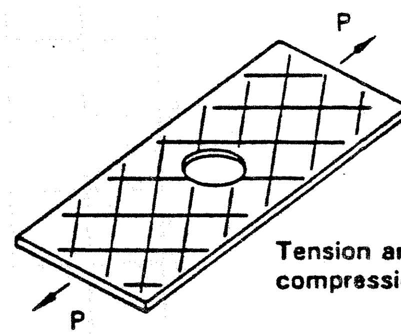
Unnotched
Tape - Fabric - Tape and fabric

			Material properties			
Property	RTD avg		RTD"B"		180W"B"	
Mode	T	C	T	C	T	C
50/0/50	10,000	-9000	9450	-8370	8600	-6700
60/30/10	10,510	-10,110	9960	-9480	9060	-7580
25/50/25	10,850	-10,850	10,300	-10,220	9370	-8180
40/50/10	10,850	-10,850	10,300	-10,220	9370	-8180
30/60/10	11,000	-11,200	10,470	-10,590	9530	-8470
0/100/0	11,700	-12,700	11,150	-12,070	10,150	-9660



Notched (.25 in. dia. open hole)
Tape - fabric - tape and fabric

			Material properties			
Property	RTD avg		RTD"B"		180W"B"	
Mode	T	C	T	C	T	C
50/0/50	5500	-5650	5100	-5100	4770	-4200
60/30/10	5600	-6000	5150	-5150	4820	-4240
25/50/25	6000	-6500	5550	-5550	5190	-4570
40/50/10	6000	-6500	5550	-5550	5190	-4570
30/60/10	6500	-6800	5960	-5960	5580	-4900
0/100/0	9800	-10,850	9000	-9000	8420	-7410



T = tension C = compression

Figure 3.1.3-2. Strain Properties (μin/in) Using Average Modulus

T300/934 BAC 5597
BMA BMS 8-297

See application in
Section 4.1, Figure 4.1

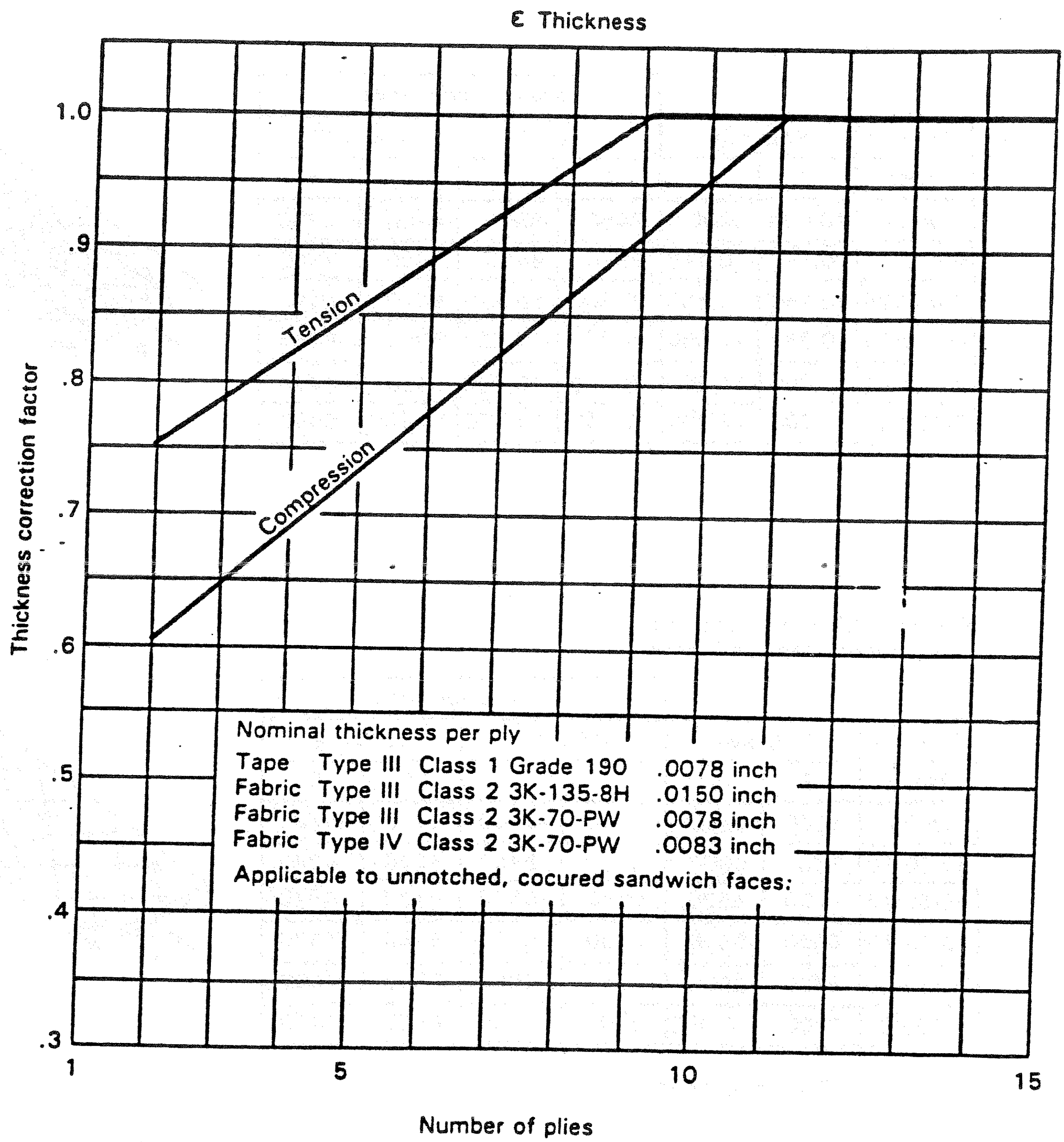


Figure 3.1.3-3. Strain Corrections for Thickness (Unnotched, Cocured Sandwich Faces)

T300/934
BMS 8-297 BAC 5597

4.4.1.2.3 Allowable Bearing Stress - F_{br}

The bearing design stress is calculated by multiplying a baseline value by "K" terms as shown in Figure 4.4.1.2.3-1. The baseline value is defined for specific material, form and nominal geometry. The "K" terms are correction factors for the specific geometry layup and loading.

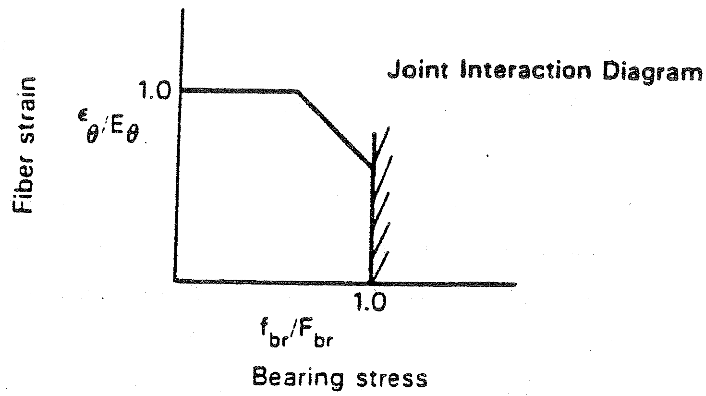
In this method all available bearing data was normalized to a baseline value through the use of correction terms. The correction factors were developed to represent best fit for the range of available data. These results give excellent correlation (generally within 5 percent) but are by necessity a compromise and may for some combinations be conservative. For specific cases where point design data is available and can be applied, analysis using this data could be substituted for these methods.

The defined bearing stress includes all potential failure modes. These include compression failure at the hole, tension failures around the hole circumference and shear out. No additional check is required for these failure modes.

Baseline Bearing Stress - $F_{BASELINE}$

The baseline bearing stress is shown in Table 4.4.1.2.3-1.

The baseline bearing stress represents the design value stress for a 0.25 inch diameter fastener in a 50/40/10 laminate loaded along the 0^{o} axis. This value is the "B" (.95 confidence, .90probability) allowable for the most critical environment from -65^{o} F to 130^{o} F, wet or dry reduced by a 1.15



CALCULATION OF ALLOWABLE BEARING STRESS F_{br}

$F_{br} = F_{BASELINE} \times K_L \times K_D \times K_{eD} \times K_{SS} \times K_{BUTT} \times K_E \times K_T \times K_{CSK}$

$F_{BASELINE}$ = Baseline bearing stress - function of material

K_L = Correction factor for laminate fiber orientation
K_L = 1.0 for 50/40/10 laminate

K_D = Correction for fastener diameter
K_D = 1.0 for 0.25 dia.

K_{eD} = Correction for end margin
K_{eD} = 1.0 for e/D = 2.5

K_{SS} = Correction for single shear eccentric load
K_{SS} = 1.0 for double shear

K_{BUTT} = Correction for butt spliced fabric laminates
K_{BUTT} = 1.0 for no butt splices

K_E = Correction for environment
K_E = 1.0 for worst case -65 to 180°F wet or dry

K_T = Correction for laminate thickness
K_T = 1.0 for laminates greater than 0.1 in.

K_{CSK} = Correction for countersink
K_{CSK} = 1.0 for protruding and countersunk head fasteners

Figure 4.4.1.2.3-1. Calculation of Allowable Bearing Stress Using Correction Factors ("K" Terms)

$F_{BASELINE}$

F_{br} - Baseline value

Table 4.4.1.2.3-1. Baseline Joint Values for Bearing Stress

Material	Class Tape/Fabric	Style	Type Resin Content	$F_{BASELINE}$ ksi
BMS 8-297 BMS 8-297-1 BMS 8-297-2 BMS 8-297-3	Tape, fabric & pultrusions Class 1,2 &4	Grades 95,145,190 Weaves 3k-70-PW 3k-70-PX 3k-135-8H	Type III Tape & fabric (37%) Type IV fabric (40%)	74 ↓
BMS 8-256	Fabric (Class 2) Tape (Class 1)	3k-70-PW Grade 190	Type I (44%) Type IV (40%) Type II (38%)	74 ↓

fitting/scale factor. These values represent the lowest of (1) maximum load, (2) 1.5X onset of bearing damage (2% diameter offset) or (3) excessive deformation (10% diameter). The baseline data was developed using low torque (finger tight) bolt bearing tests.

Laminate Factor - K_L

The baseline laminate is a 50/40/10 laminate. A correction factor for other laminate fiber percentages is shown in Figure 4.4.1.2.3-2. As shown this factor is a product of factors for each of the fiber directions.

The bearing analysis method is based on a fastener load at a hole in laminates constructed with "standard" orientations of 0^o, $\pm$ 45; and 90^o fibers and loading in these standard directions. Laminates with up to 10 percent fibers at other than standard angles and other load axes, can be evaluated with the defined methods by adjusting to reflect non-standard conditions. These adjustments are given in Figures 4.4.1.2.3-3 and 4.4.1.2.3-4.

Diameter Factor - K_D

The baseline fastener diameter is 0.25 inch. The correction factor for another diameter is shown on Figure 4.4.1.2.3-5.

Edge Margin Factor - K_{ed}

The baseline bearing strength is for edge margin to diameter ratios (e/D) of 2.5. Figure 4.4.1.2.3-6 presents corrections for other end margins. Also shown are assumptions that may be used to establish corrections for fastener spacing.

Bearing allowable calculation for load in 0° direction ▷1 and for laminates with fibers at "standard" angles of 0°, +45°, −45° and 90° ▷2

Laminate bearing factor

$$\boxed{K_L = 1.165 \times K_{0^\circ} \times K_{45^\circ} \times K_{90^\circ} \times K_{LIMIT}}$$

$F_{BASELINE}$ for 50/40/10 laminate

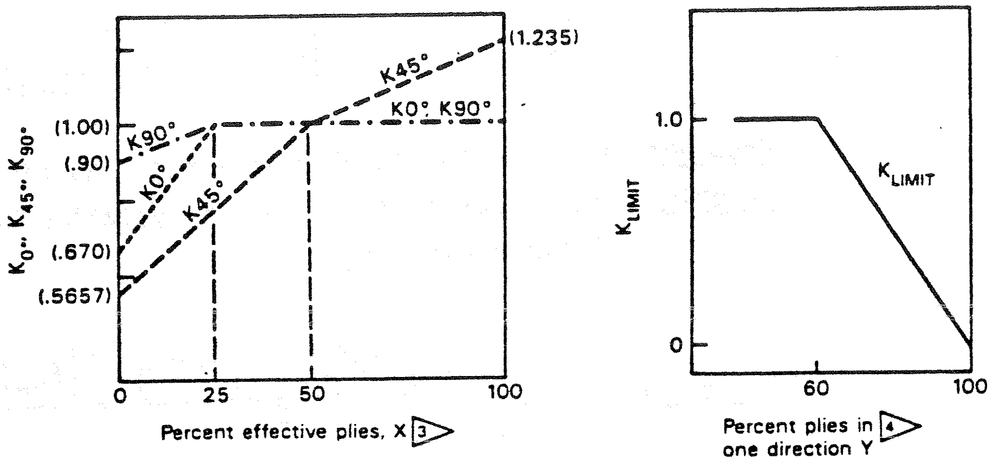
Factor to correspond to 50/40/10 baseline

Correction for shortage of 0° plies

Correction for shortage of 45° plies

Correction for shortage of 90° plies

Limit for excessive plies in one direction



▷1 For bearing load direction at standard angles other than 0°, redefine layup in bearing load axis angle.

For bearing loads between standard axes, interpolate as shown in Figure 4.4.1.2.3-4.

▷2 For fibers at angles other than standard angles, redefine fiber percentages as shown in Figure 4.4.1.2.3-4.

▷3 For:

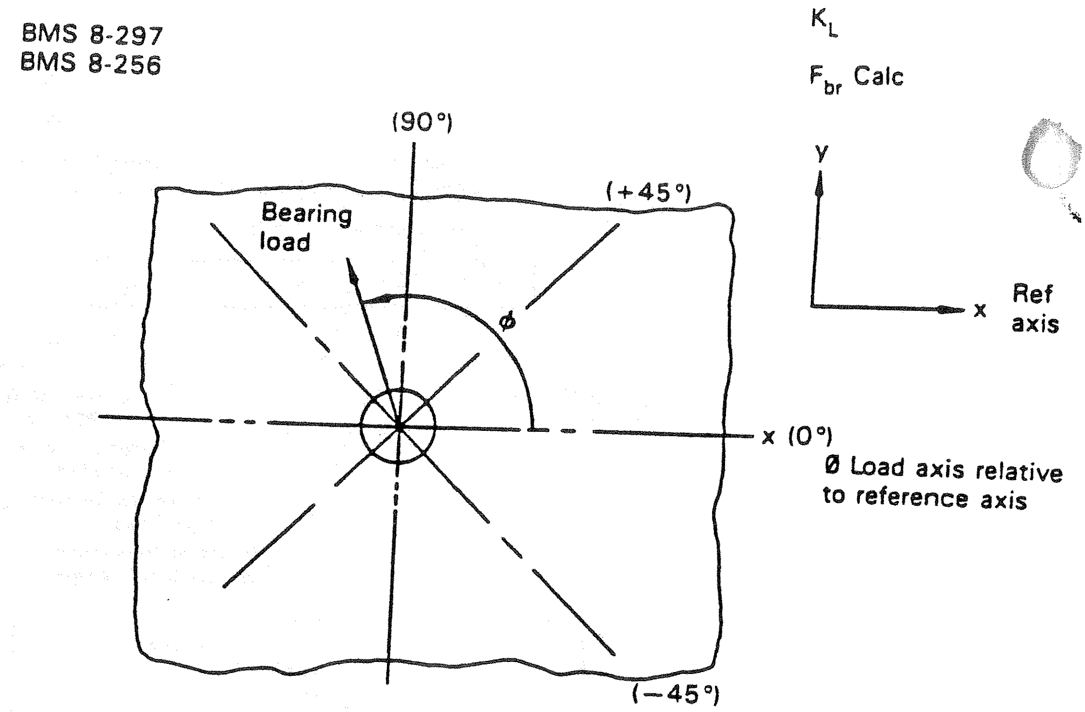
K_{0° x = % 0° plies

K_{90° x = % 90° plies

K_{45° x = % ±45° plies − $\frac{1}{2}$ | % +45° plies − % − 45° plies |

▷4 Y = Max of %0°, %90°, %+45°, %-45° plies or any angle if plies exit at other angle

Figure 4.4.1.2.3-2. Laminate Factor Calculaton for Bearing Stress



<u>Problem:</u> To find bearing allowable for load direction ϕ

<u>Solution:</u> Use a cosine function interpolation between adjacent "common angles" [1]

i.e.,

$$0^{\circ} \leq \phi \leq 45^{\circ} \quad F_{br_{\phi}} = \frac{\left[F_{br}(0^{\circ}) + F_{br}(45^{\circ})\right]}{2} + \frac{\left[F_{br}(0^{\circ}) - F_{br}(45^{\circ})\right]}{2} \cos 4\phi$$

$$45^{\circ} \leq \phi \leq 90^{\circ} \quad F_{br_{\phi}} = \frac{\left[F_{br}(45^{\circ}) + F_{br}(90^{\circ})\right]}{2} + \frac{\left[F_{br}(45^{\circ}) - F_{br}(90^{\circ})\right]}{2} \cos 4(\phi - 45)$$

In general

$$A < \phi < B \qquad F_{br_{\phi}} = \frac{\left[F_{br}(A) + F_{br}(B)\right.}{2} + \frac{\left.F_{br}(A) - F_{br}(B)\right]}{2} \cos 4(\phi - A)$$

A = 0, 45, 90, 135, 180 ...

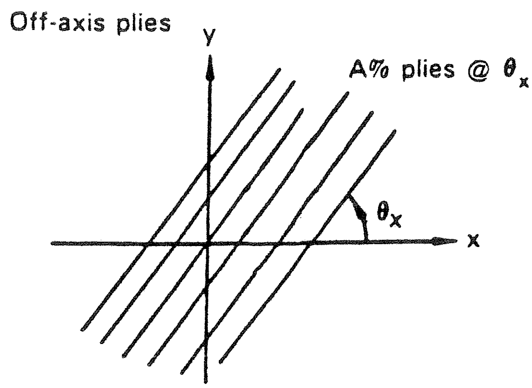
B = A + 45

Alternate method: Adjust K_L

$$K_{L_{\phi}} = \frac{\left[K_L(A) + K_L(B)\right]}{2} + \frac{\left[K_L(A) - K_L(B)\right]}{2} \cos 4(\phi - A)$$

[1] Common angles are 0°, $+45^{\circ}$, 90°, -45° matching major fiber axes.

Figure 4.4.1.2.3-3. Interpolation of Bearing Stress Between Common Angles



<u>Problem:</u> To find bearing allowable for laminate with non-standard ply orientation.

<u>Solution:</u> Consider ply with non-standard angle as adjacent standard angle plies with fraction equal to relative rotation. Compute bearing laminate factor with these percentages added to percentages at standard angles.

i.e., A% plies @ $\Theta_x{}^{o}$

Note: This analysis requires A to be less than 10 percent.

For

$0° \leq \Theta_x \leq 45°$ Use $A\left(\frac{45 - \Theta_x}{45}\right)$ @ 0° and $\left(A\,\frac{\Theta_x}{45}\right)$ @ 45°

$45° \leq \Theta_x \leq 90°$ Use $A\left(\frac{90 - \Theta_x}{45}\right)$ @ 45° and $A\left(\frac{\Theta_x - 45°}{45°}\right)$ @ 90

In general

$\Theta_A \leq \Theta_x \leq \Theta_B$ $\Theta_A = 0, 45, 90, 135, 180...$

$\Theta_B = \Theta_A + 45$

Use $A\left(\frac{\Theta_B - \Theta_x}{45}\right)$ @ Θ_A and $A\left(\frac{\Theta_x - \Theta_A}{45}\right)$ @ Θ_B

Figure 4.4.1.2.3-4. Effective Percent Standard Angle Plies For Off-Axis Plies

K_D

F_{br} Calc

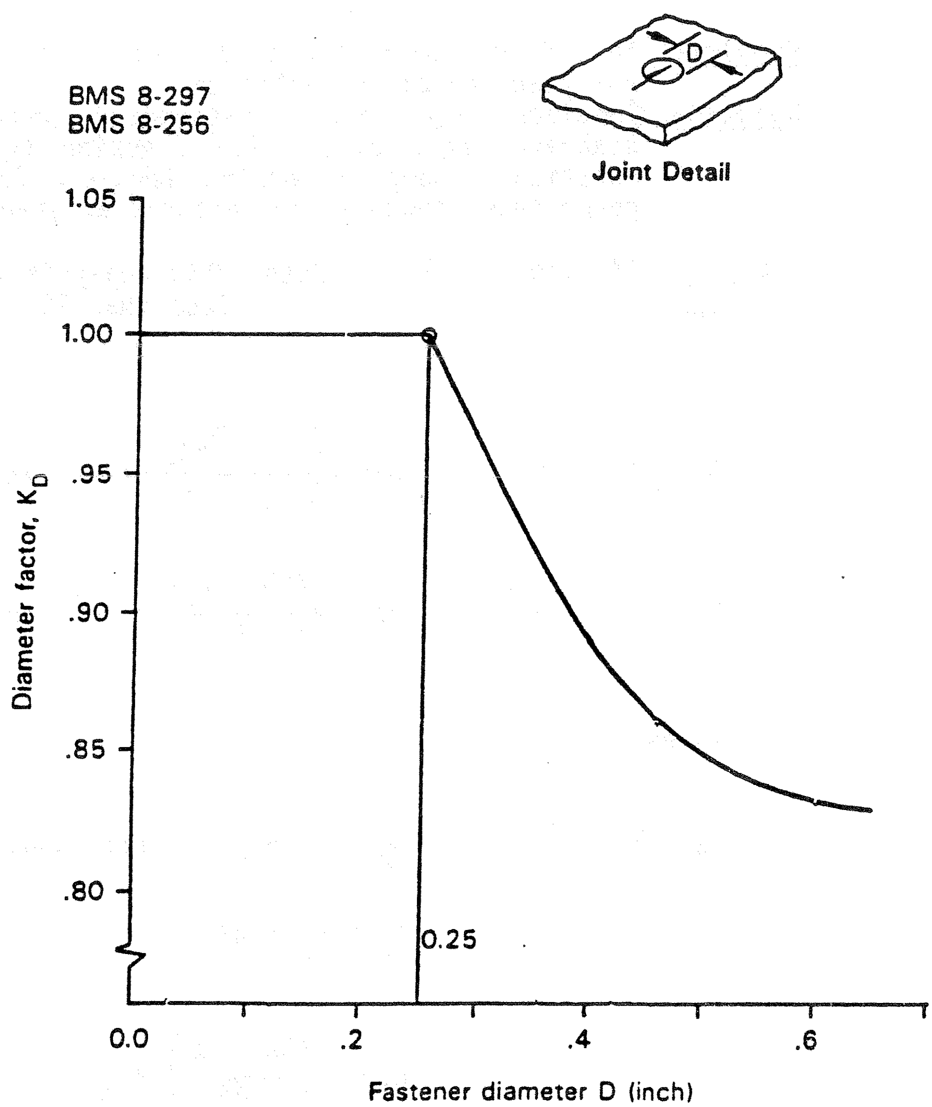


Figure 4.4.1.2.3-5. Diameter Factor For Bearing Stress

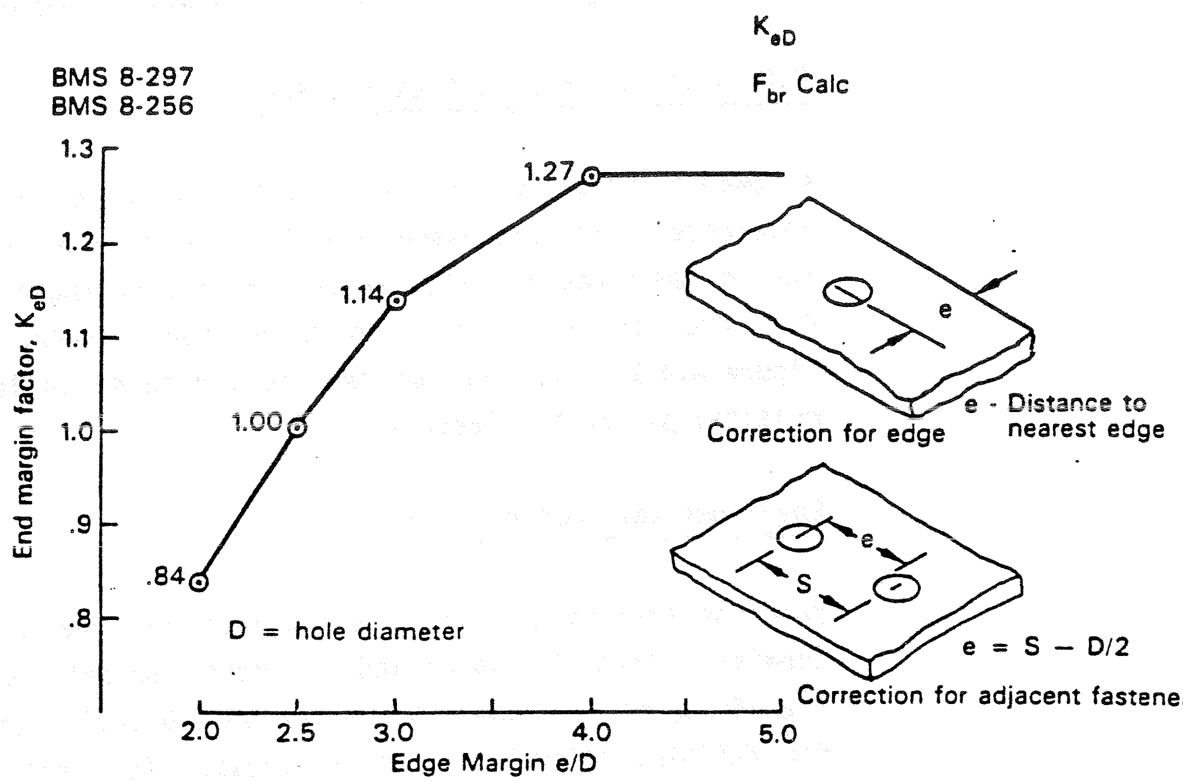


Figure 4.4.1.2.3-6. End Margin Factor For Bearing Stress

Single Shear Factor - K_{SS}

The baseline bearing strength is for double shear. Figure 4.4.1.2.3-7 presents corrections for single shear as a function of fastener diameter. Also included in this figure is a guide for when to apply single shear corrections to bearing stress in single shear joints with nonprotruding head fasteners.

Butt Spliced Laminate Factor - K_{BUTT}

Allowance needs to be made for the hole countersink depth tolerance. As discussed for by-pass strain, butt splices in fabric laminates can also reduce bearing strength. The reduction for one in five ply splicing for bearing is shown in Figure 4.4.1.2.3-8. These results are based on loss of the most critical ply at the fastener.

Environmental Factors - K_E

Baseline bearing strength was defined for the hot-wet (180° F) condition that is specified in most current design criteria. Therefore, an environmental factor of 1.0 shall generally be used for defining allowable bearing stress. For test data reduction the results in Figure 4.4.1.2.3-9 can be used.

Thickness Factor - K_T

The results presented are for thicknesses greater than 0.1 in. Limited data indicates that laminates less than 0.1 in. have lower bearing strengths. Factors for thickness are not yet available so the application of these results to thin laminates should be checked with test data.

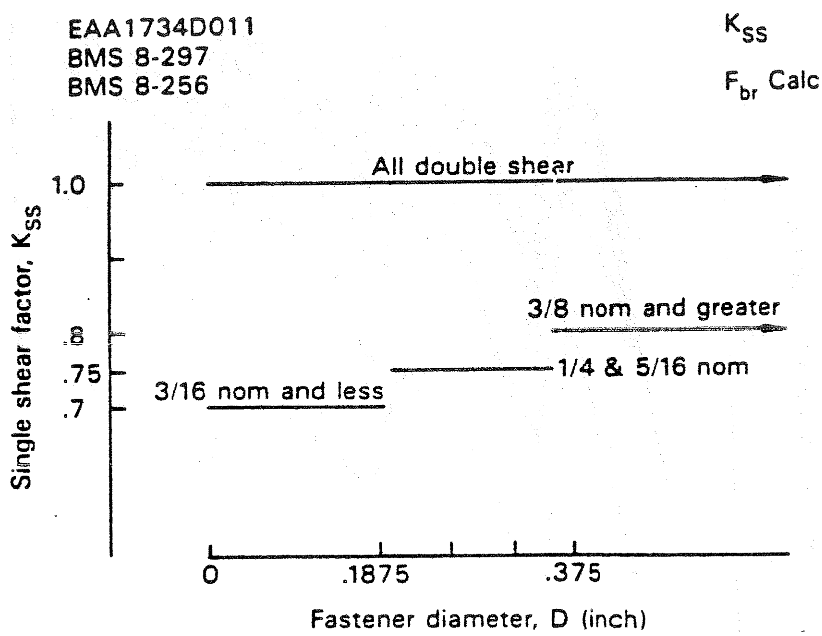


Figure 4.4.1.2.3-7. Single Shear Factor For Bearing Stress

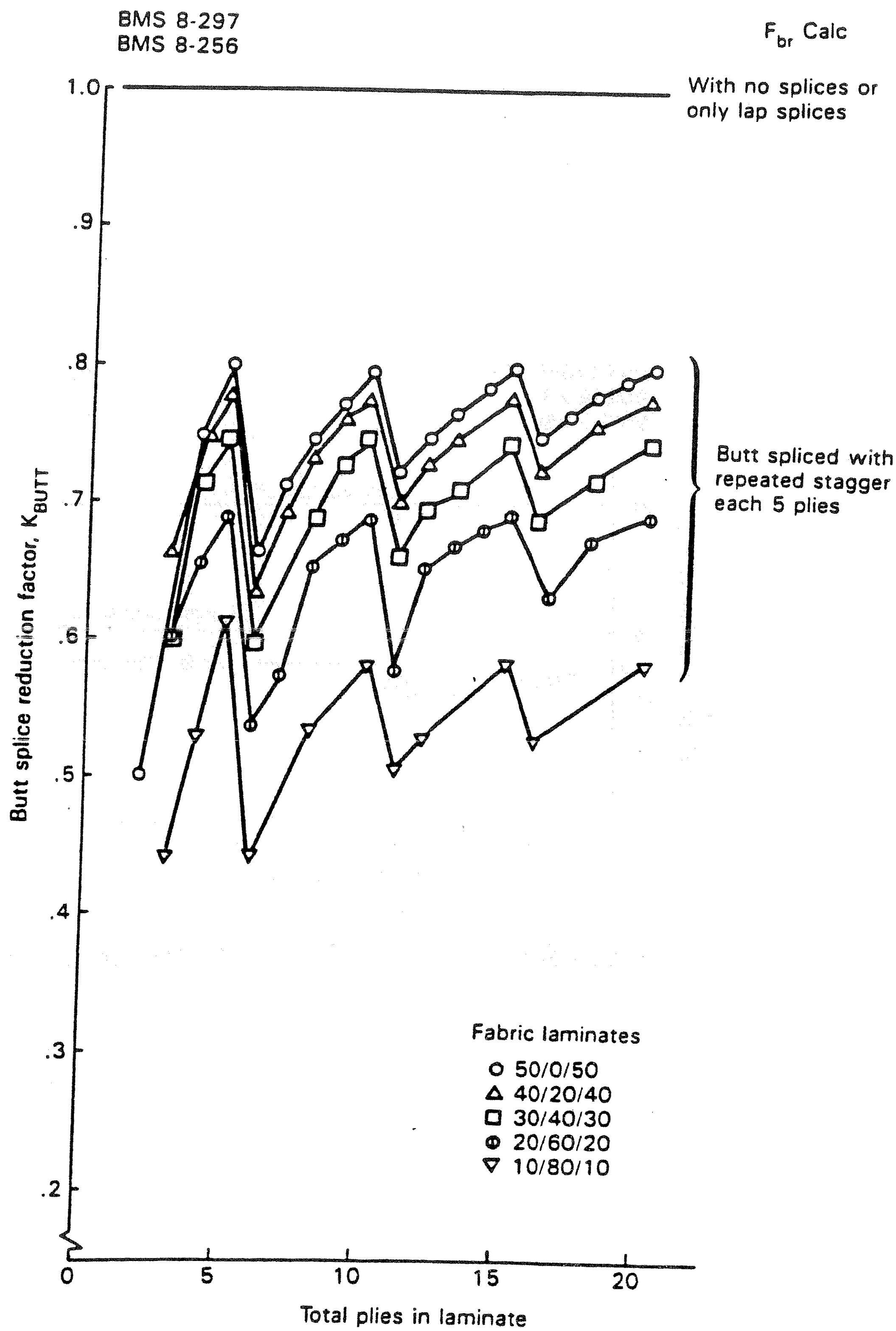


Figure 4.4.1.2.3-8. Butt Splice Reduction Factor For Bearing

K_E

F_{br} Calc

BMS 8-297 and EAA1734D011 only

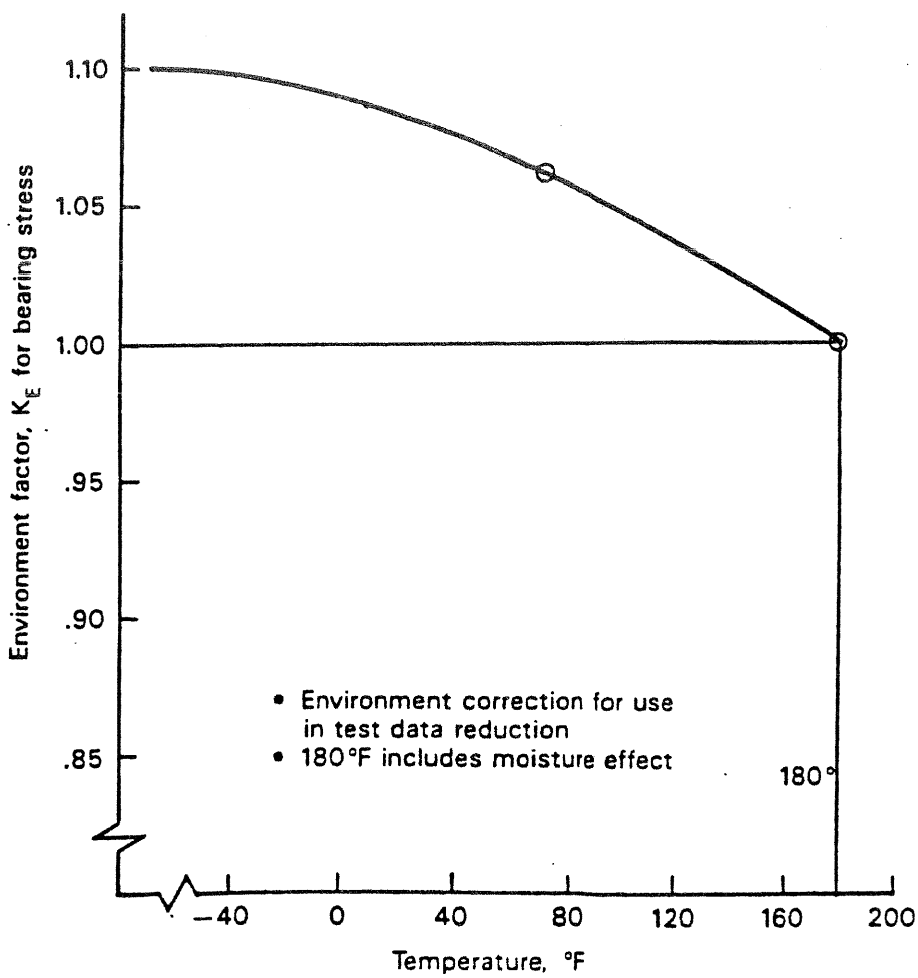


Figure 4.4.1.2.3-9. Environment Factor For Bearing Stress K_E