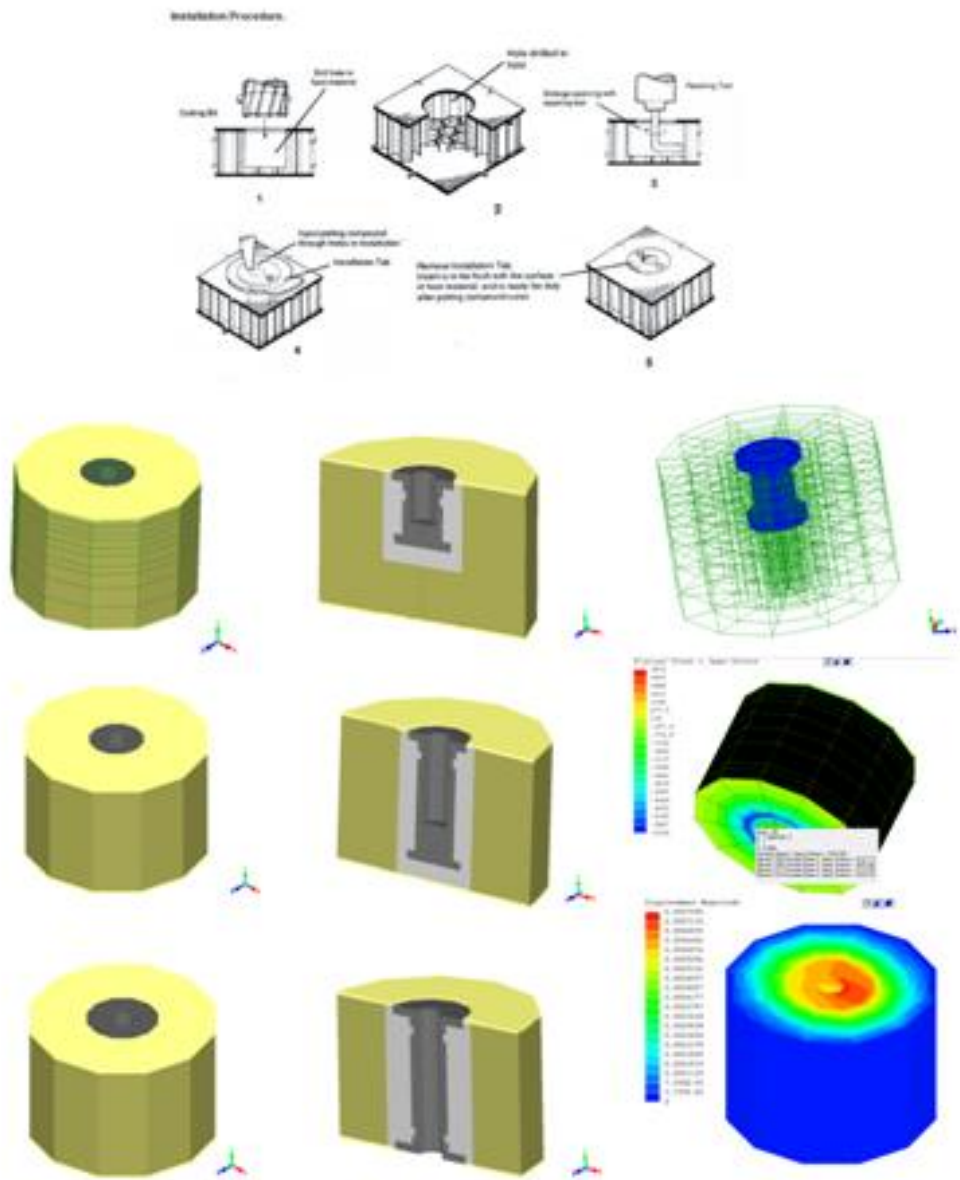
Test Verification of Finite Element Analysis for Honeycomb Panel Attachment Inserts



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Introduction

Aircraft interior details often require attachment of brackets for equipment and furnishings. Honeycomb panel face skins are very thin (.02”) which discourage direct mechanical attachment to them. Storage bins, television monitors and emergency equipment are typical installations requiring special fastening details. Since the walls of the partitions and monuments (lavatories, galleys and closets) are usually non metallic honeycomb panels, threaded inserts are universally employed to accept the attachment screws. The inserts are usually installed after the panel is manufactured by drilling large holes and bonding the metal inserts with room temperature curing epoxy potting compounds (Figure 1). Prediction of the local strength of the insert is complicated by the mix of materials and processes. Depending on the geometry of the insert and the direction of the load, several internal failures are possible. Although many sandwich configurations are feasible, this paper will focus on panels that are an inch thick with 3.0 lb/ft3, 1/8” cell Nomex honeycomb core and 2 plies of 7781 fiberglass/phenolic for each face skin. Test data to calibrate the LISA 8.0 (Reference 1) Finite Element Analysis (FEA) will be provided by published results of the TEKLAM company (Reference 2). This data was acquired using stringent test procedures and passed enough statistical evaluation to publish “A” Basis strength values. The meaning of this is that at least 99% of the population of material strength is expected to equal or exceed the “A” Basis value with 95% confidence.

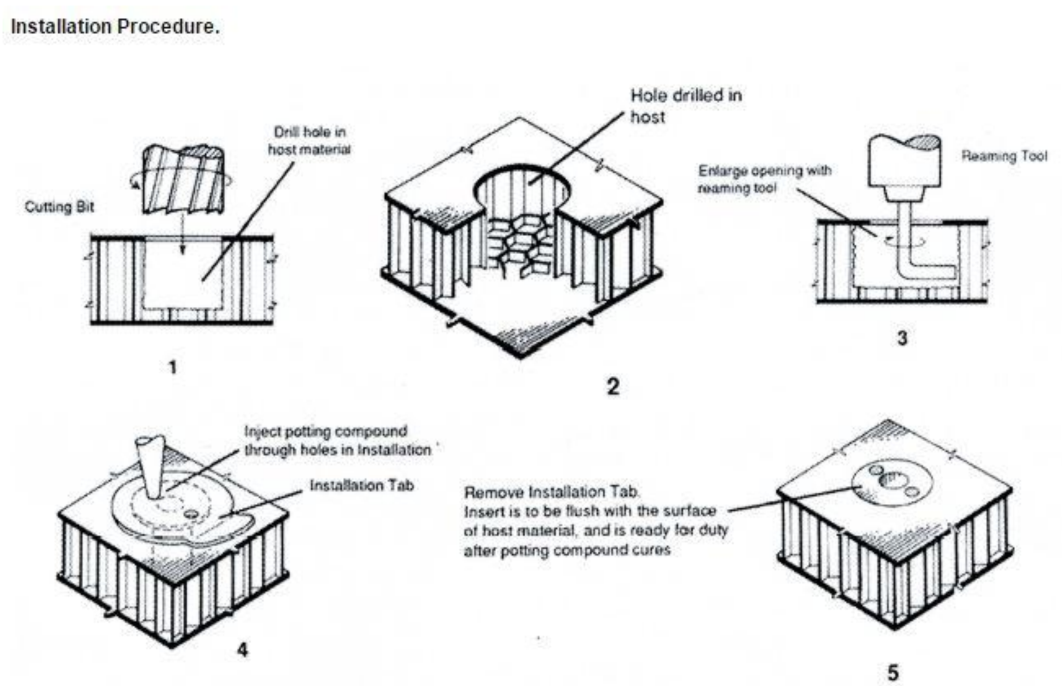

Figure 1 Insert installation procedure

Strength of Constituent Components

Figure 1 (from Reference 4) shows that the failure modes vary with core thickness, indicating the importance of accurate mechanical strength data on all the materials involved.

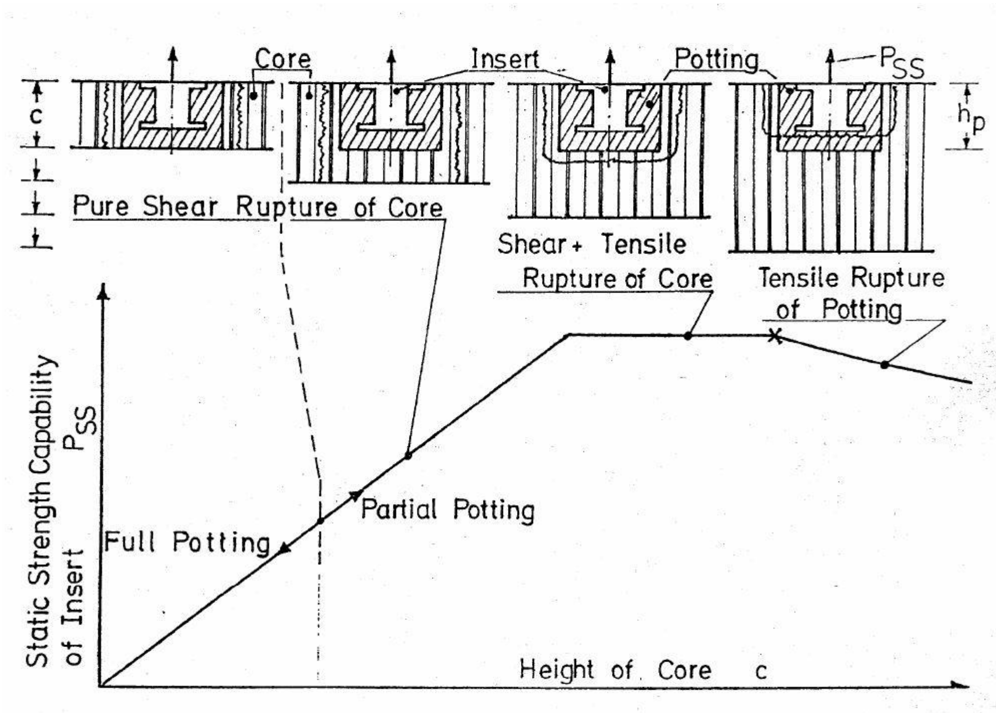

Figure 2 Insert Failure Mode Variation with Core Thickness

Some of these failure modes for an unrelated test program are illustrated in Figure 3 (from Reference 5) where the load/displacement plot shows a jagged progression indicating several internal failures precede the final one. Figure 4 (from Reference 6) is a section cut from another test program result that also shows evidence of many internal failures.

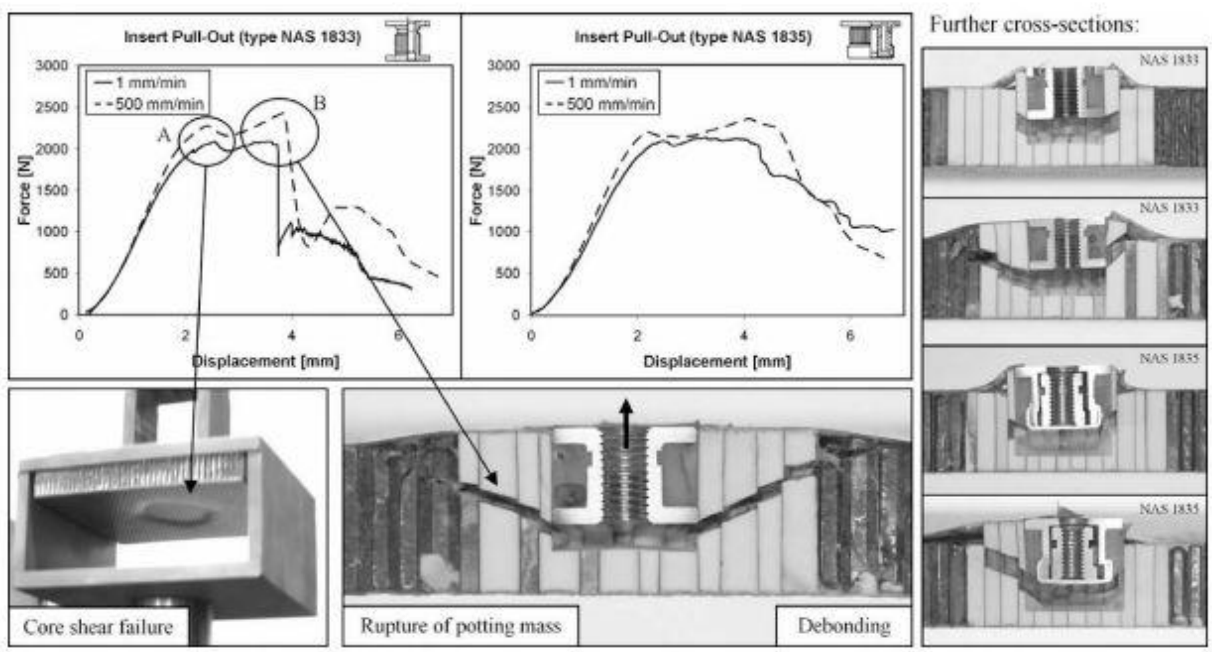

Figure 3 Illustration of Typical Test Results (Reference 5)

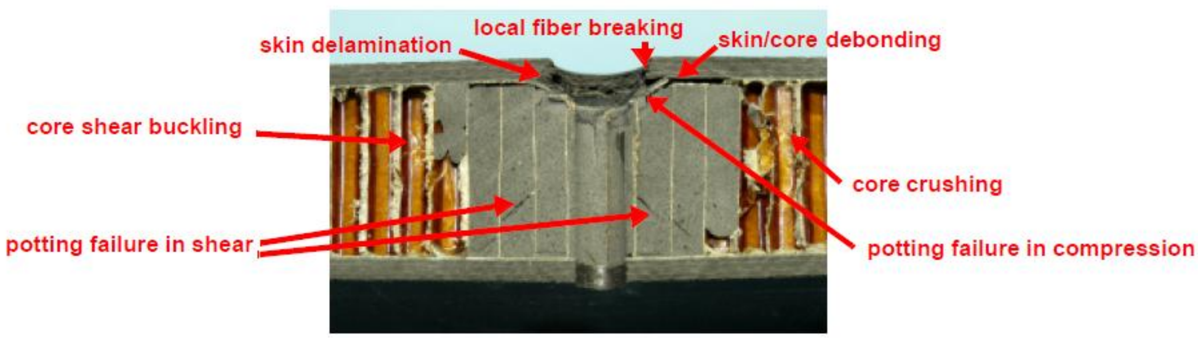

Figure 4 Section cut of Test Specimen (Reference 6)

The TEKLAM data sheet (Figure 5) contains most of the information required to predict performance. Strength test for constituent materials are presented at the same level of statistical “A” Basis quality as the overall fastener system joint strength. However, important material properties of the potting compound are missing from the inventory. Unfortunately, those values must be estimated by other means. It will be shown that the consequences of this inconsistency are not dramatic because the potting is not limiting joint strength in any of the tests.

TEKLAM *FAA APPROVED*
P/N NP2G1-02-1000 (N510)

Product Data Sheet

- **FACINGS: 2-PLY PHENOLIC/7781 FIBERGLASS PER FAR 25.853, AMS-C-9084**
- **CORE: 1/8 (3.0) NOMEX® HONEYCOMB PER AMS-C-81986**
- **PANELS MANUFACTURED PER TEKLAM PROCESS SPECIFICATION TPS-CN-500**

PROPERTY	TEST METHOD	UNIT	VALUE		
			Mean	'B' Basis	'A' Basis
Thickness	ASTM C366	inch	1.000		
Weight	ASTM C29	lbs/sq ft	.70		
Long Beam Flexural ('L' Direction) Bending Moment Facing Stress Deflection @ 100 lbs.	AMS-STD-401	in-lbs/in psi inch	526 29,810 0.099	477 27,011	442 25,046
Long Beam Flexural ('W' Direction) Bending Moment Facing Stress Deflection @ 100 lbs.	AMS-STD-401	in-lbs/in psi inch	377 21,287 0.105	350 19,751	331 18,673
Short Beam Core Shear ('L' Dir.)	AMS-STD-401	psi	127	119	112
Short Beam Core Shear ('W' Dir.)	AMS-STD-401	psi	76	71	67
Climbing Drum Peel	ASTM D1781-76	in-lbs/3" width	24		
Flatwise Compression	AMS-STD-401	psi	310	284	267
Insert Pull-Out (Tension) NAS-1832-3-7 (Blind) NAS-1834-3-1000 (Through) NAS-1836-3-16 (Blind)	TPS-SF-2000, Type II, Rev. B	lbs lbs lbs	375 434 338	269 352 250	194 295 188
Insert Shear NAS-1832-3-7 (Blind) NAS-1834-3-1000 (Through) NAS-1836-3-16 (Blind)	TPS-SF-2000, Type II, Rev. B	lbs lbs lbs	574 670 573	438 560 459	343 483 379

'A' and 'B' basis design allowable data FAA-approved per TEKLAM Test Plan TTP-1005 under FAA Project No. ST7145LA-T 3-22-00

Flammability – 60-Second Vertical	FAR 25.853, Part I	Pass
OSU Heat Release	FAR 25.853, Part IV	Pass
NBS Smoke Emission	FAR 25.853, Part V	Pass

- STANDARD PANEL SIZES: 48" X 96", 48" X 144", OTHER SIZES AVAILABLE.
- STANDARD DIMENSIONAL TOLERANCES: WIDTH AND LENGTH: +/- 1/2"; THICKNESS: +/- 0.010".
- FLATNESS: MAX. DEVIATION, DELTA, INS.= (LxL) x .004/T, WHERE L=LENGTH IN FT, T=THICKNESS IN INS.

REV. NOV. 2005

Figure 5 TEKLAM Product Data Sheet (Reference 2)

Typical strength of an epoxy potting material, so called DAPCO 3040, was obtained from Reference 11. As with all composite materials, the typical, or average, values are not used for design strength prediction. Variability in these materials is often much greater than in metals. In order to proceed, the typical strength data were converted into estimated “A” Basis equivalents using conservative assumptions. The chief assumption was to claim that the statistical standard deviation was 10% of the mean (or typical) value. For reference, a well made composite material would have about 5-10% of the average as a standard deviation. Another assumption is that a reduction from the mean value measuring 3.064 standard deviations is enough to achieve the “A” Basis levels. The 3.064 factor is the one sided tolerance factor associated with 99% probability at 95% confidence for a 30 specimen test program. So, the “A” Basis equivalent is the Mean – (3.064 x .10 x Mean) = .69 x Mean.

The constituent strengths to be used for analysis are then:

Fiberglass Tension - 25046 psi, Compression 18673 psi (Figure 5)
Nomex Core - Compression 236 psi, L shear 112 psi, W shear 67 psi (Figure 5)
Nomex Core - Tension = .69 x 333.5 psi = 230 psi (Reference 7 and Appendix E)
Potting - Tension = .69 x 3500 = 2415 psi, Compression = .69 x 4000 = 2760 psi
Potting - Shear = .69 x 2000 = 1380 psi (Reference 4 and Appendix C)

Additional comparison for the validity of the potting compound strength properties can be seen by comparing values from Reference 4, Table 1.2.8.

The basic properties of a typical resin compound (Lekutherm X227) considered here are (at room temperature):

Density	γ_R	0.6 - 0.7 kg/dm^3	
Tensile strength	$\sigma_{R\ crit}$	14 N/mm^2	2030 psi
Compressive strenth	σ_R	36 N/mm^2	5220 psi
Shear strength	$\tau_{R\ crit}$	10 N/mm^2	1450 psi
Tensile modulus	E_R	2300 N/mm^2	333500 psi
Temperature resistance		up to 100 °C	

Table 1.2.8: Potting Material Properties

Figure 6 Potting Material Property Comparison (from Reference 3)

Finite Element Model geometry parameters

The parametric geometry of the potting used for the Finite Element Models is consistent with accepted panel insert installation instructions used in industry (Figure 7). The rationale is that when the hole is drilled, on average, it will remove half the cell on the circumference of the hole and leave half the cell to fill with potting. Instructions for insert installation also include direction to fill cells under any partial height insert so that the bottom of the insert is bonded to the honeycomb core. This is modeled by a volume of potting that is one cell diameter thick below the insert.

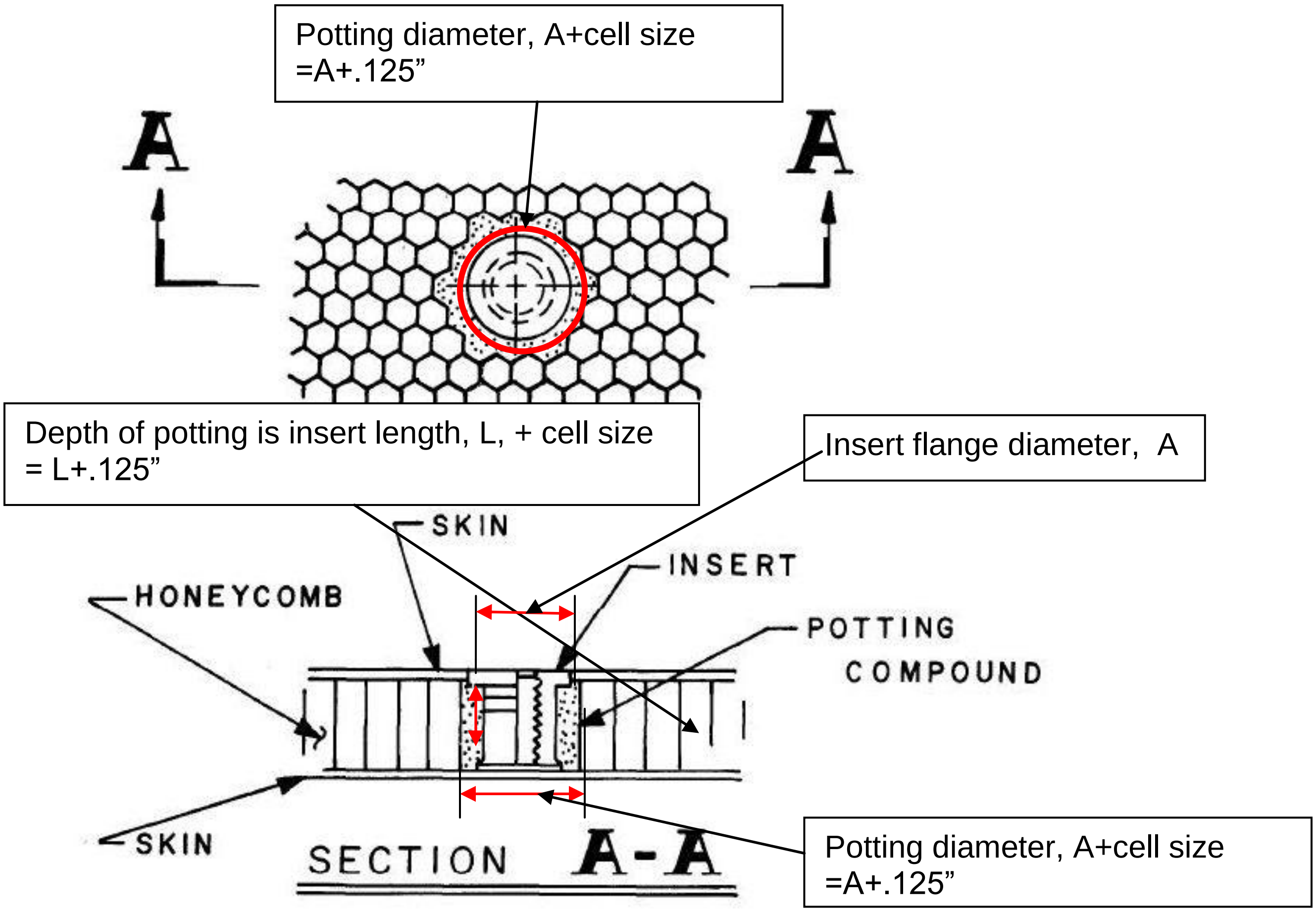

Figure 7 Typical configuration

Finite Element Model Material Elastic Properties

Since the internal loads in the constituent parts of the sandwich structure are dependent on their relative elasticity, it is important to include the best estimate of those properties in the analytical models. The core properties are extracted from published vendor values shown in Appendix C.

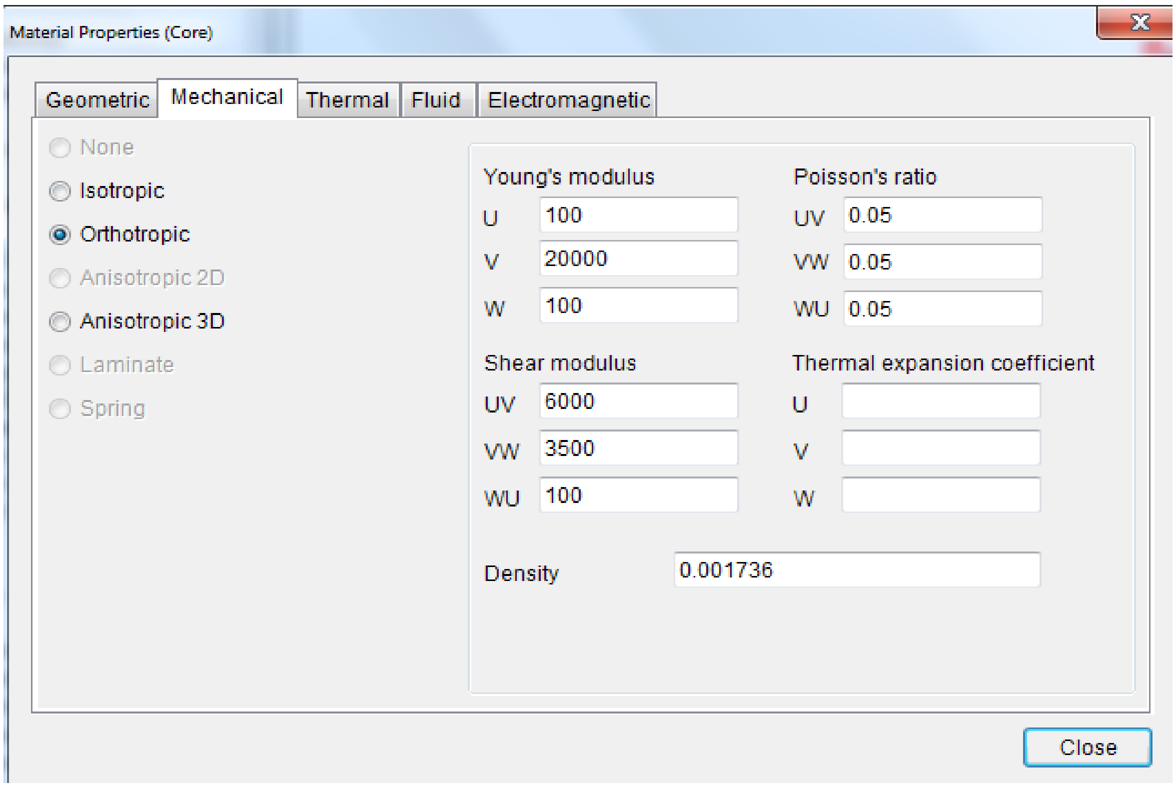

Figure 8 Honeycomb core elastic properties

Fiberglass/Phenolic face sheet elastic properties are calculated from the Long Beam Flexural test data of Figure 5. The AMS-STD-401 test specimen dimensions had a 20 inch span, 10 inches between load points and a 3 inch width. Using the test configuration of Figure 9 and the beam formula in Figure 10, the face sheet Modulus of Elasticity that is consistent with test may be calculated.

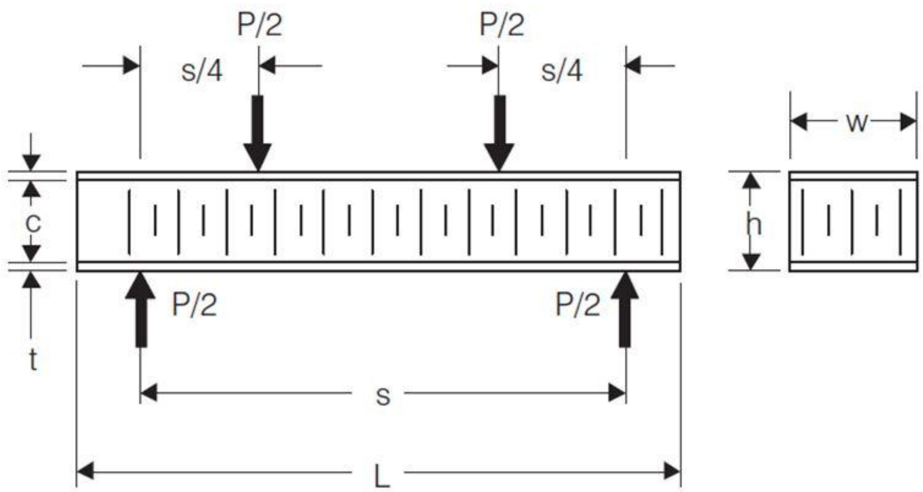

Figure 9 Test Set Up and Test Specimen Configuration for Long Beam Flexure Test

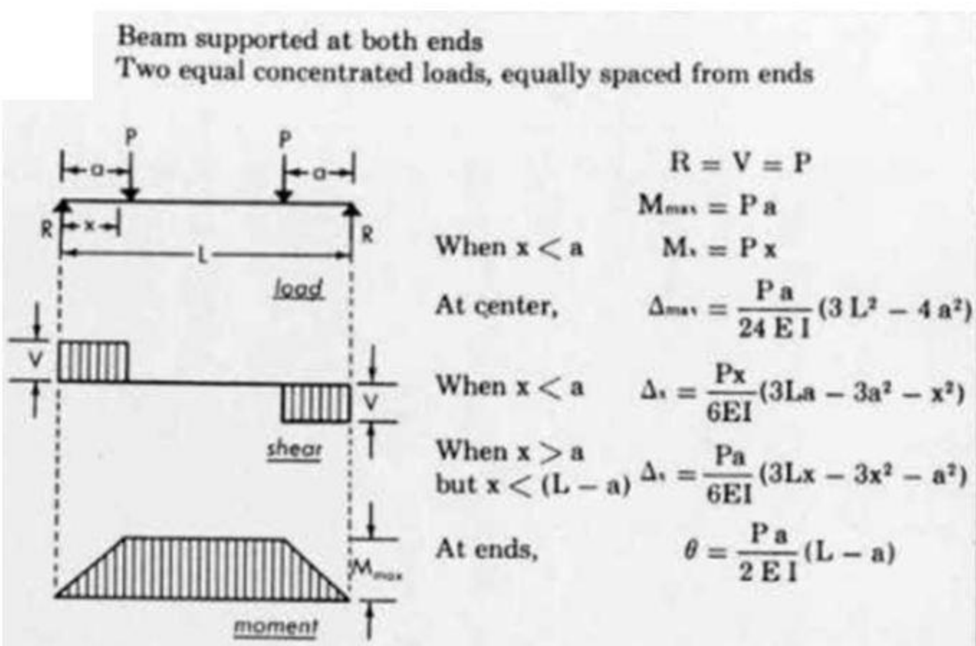

Figure 10 AMS-STD-401 Relevant Beam Formula

Where:

L = s = 20 inch, a = s/4 = 5 inch, P =100 lbs, W = 3 inch , h = 1, c = .96

The area moment of inertia, I is calculated, $I = W \times c \times (h\text{-}c)^2 = 3 \times .02 \times (1\text{-}.02)^2 = .05762 \text{ in}^4$

$E = 1/\Delta_{max} \times (P \times a)/(24 \times I) \times (3 \times L^2 - 4 \times a^2) = \Delta_{max} \times (100 \times 5)/(24 \times .05762) \times (3 \times 20^2 - 4 \times 5^2)$

$E = 1/\Delta_{max} \times 397720$

Δ_{max} for L direction flexure is .099 inch, $E_L = 397720/.099 = 4.02 \times 10^6$ psi

Δ_{max} for W direction flexure is .105 inch, $E_W = 397720/.105 = 3.79 \times 10^6$ psi

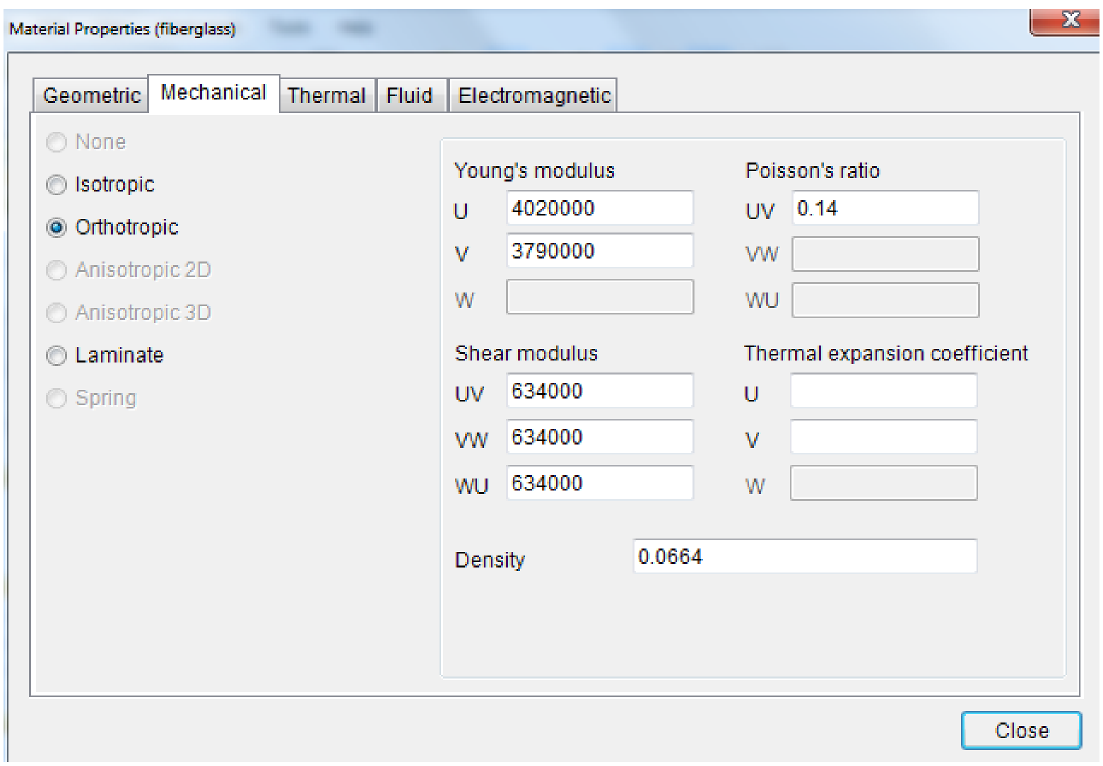

Figure 11 Fiberglass Skin Elastic Properties

Elastic properties of the potting compound were extracted from the aforementioned Reference 4, Table 1.2.8.

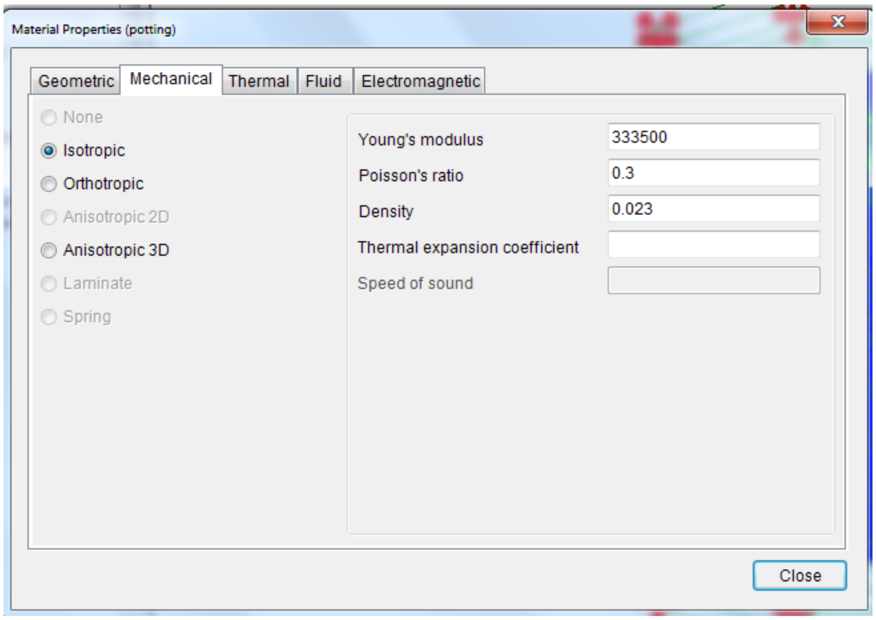

Figure 12 Potting Compound Elastic Properties

The generic steel insert elastic properties are as follows:

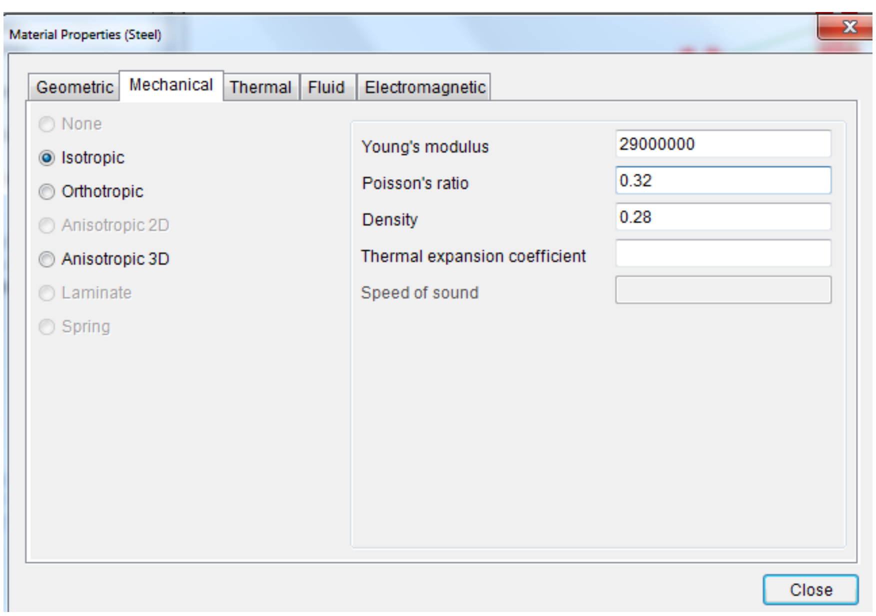

Figure 13   Steel Insert Elastic Properties

Modeling Philosophy and Geometry

Analysis of many insert geometries was anticipated, and an economic number of nodes and elements was a major consideration. Since the results were to be correlated by test, peak stress prediction was not necessary. A coarser discretization was acceptable, and consistent with the goals. Seeking prediction of local failure in proximity to the insert led to limiting the overall dimensions of the model to about 3x the insert dimension. The general arrangement and proportions of all the models is as shown in Figure 14. As the details of the specific insert were accommodated into this format, individual finite elements were molded to fit each configuration. The procedure was to draw the outline of a section of the insert in 2-D, surround the insert outline in elements representing the potting, add core elements out to a ¾ inch radius and 1 inch depth, and revolve the 2-D geometry around the insert axis. The resulting model had 10 elements through the thickness, 8 elements radially and 12 elements azimuth.

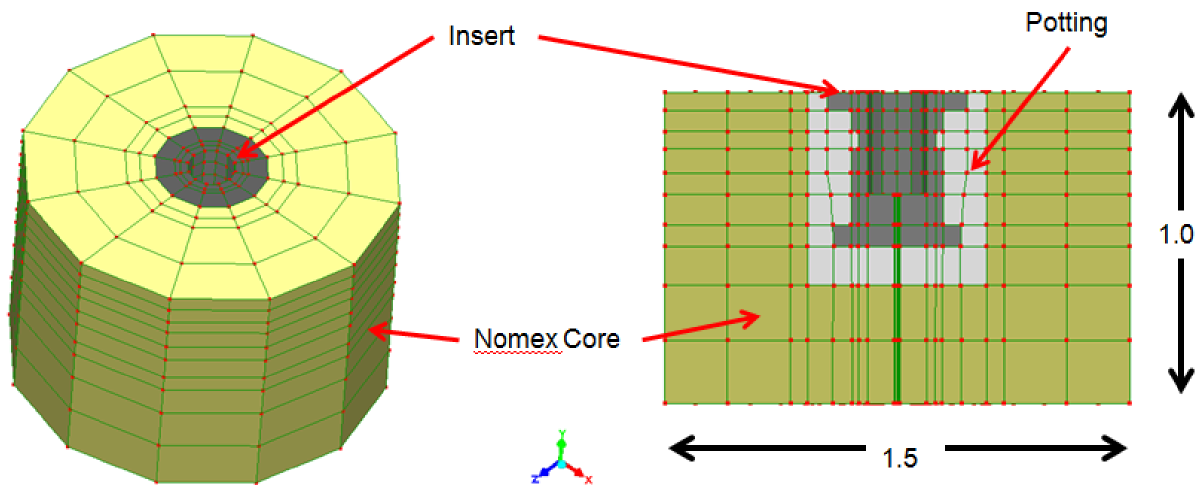

Figure 14 Typical Finite Element Model Lay-out

Orthotropic properties are used for the core and the face skins, but it is only important for the core because the strength ratio is almost a factor of two, as is the modulus of elasticity. The weak direction for core strength is always critical for these analyses. As can be seen in the typical plots of load vs. deflection of Figure 3, failure of the first constituent does not necessarily produce total failure. The internal load redistributes to the alternate load paths, until they too fail as the load increases. The method used here claims that first failure defines the allowable load. It is therefore conservative, compared to the test failure value.

Loads and Constraints

The 1.5 inch diameter cylinder is supported in all directions as shown in Figure 15, where the red triangle symbols represent constrained degrees of freedom. The tension load is applied as a circular distribution at the bottom of the bolt hole, simulating the nut contact circle. The in-plane shear load is applied on a semi-circle of nodes at the top of the insert. The two loads are applied as separate load conditions, like the test cases they represent. A 200 pound load level was arbitrarily selected for the evaluation. This load is scaled to the lowest value required to achieve material failure in any of the constituents.

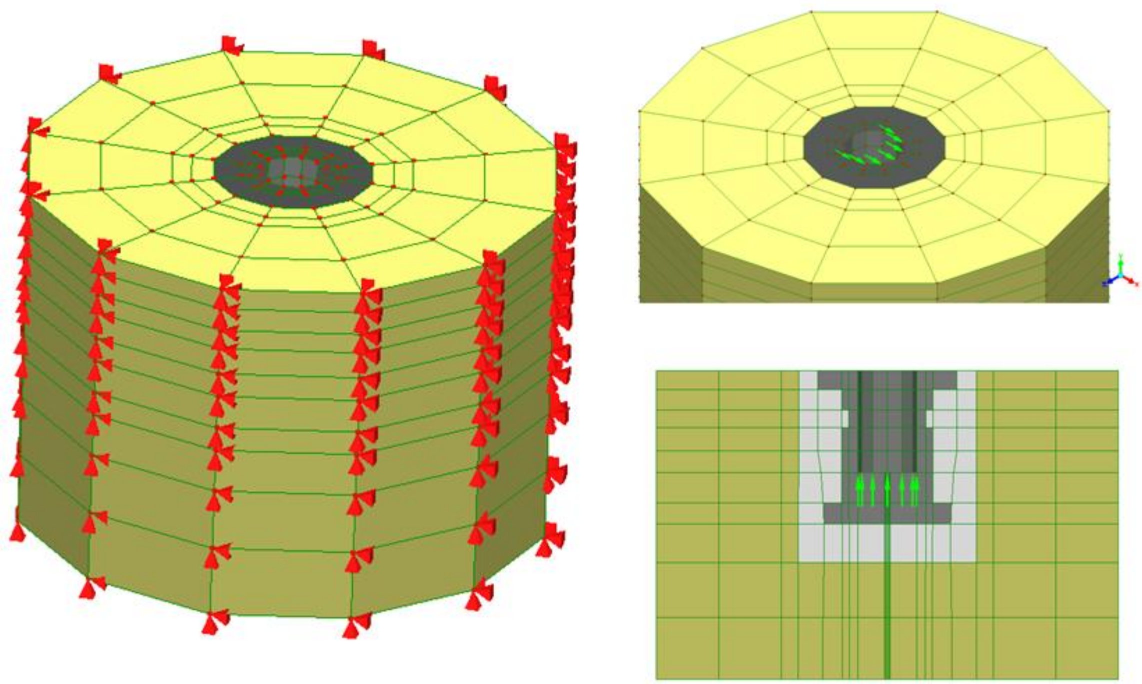

Figure 15 Loads and Constraints

Resulting Model Configurations

The configurations of the analysis models constructed with the process described above is shown in figure 16. The shapes of the inserts and the assumed potting enclosure are clearly visible.

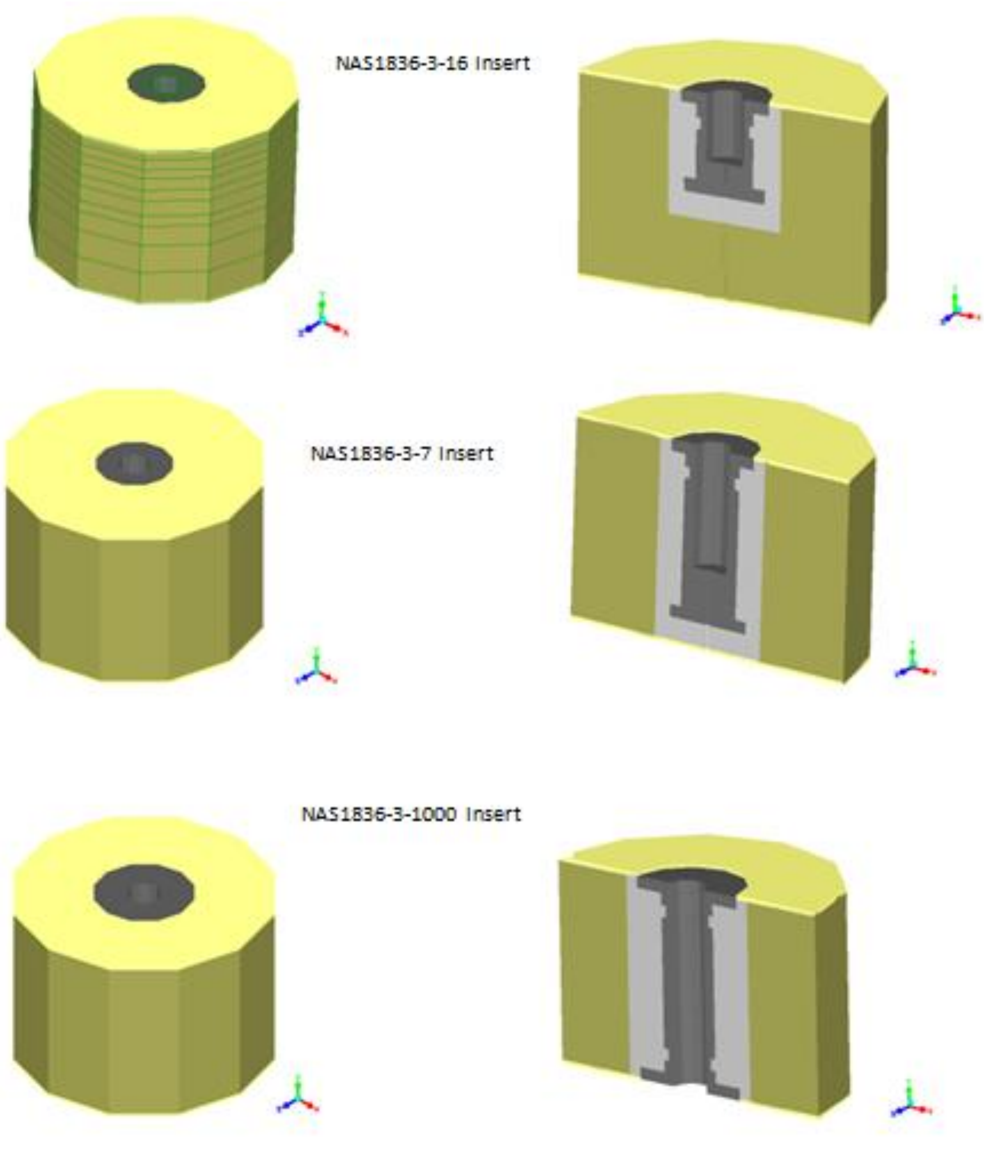

Figure 16 Model Configurations

Detail Results for NAS1836-3-16 Insert

The deformed shape of any Finite Element Model should be examined for anomalies. Figures 17 and 18 show these shapes are reasonable.

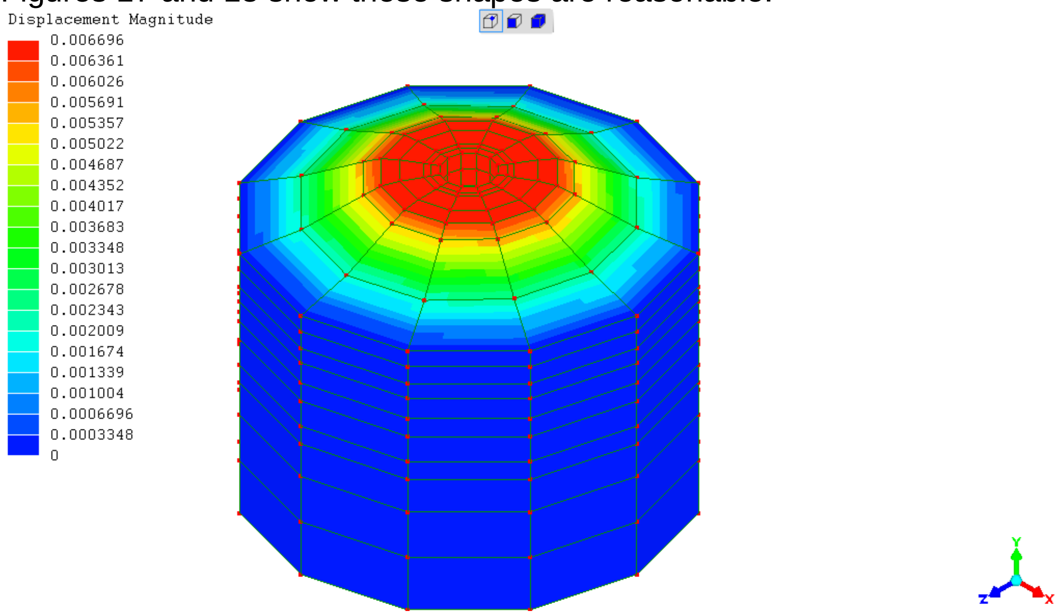

Figure 17   Typical Tension Load deformed shape

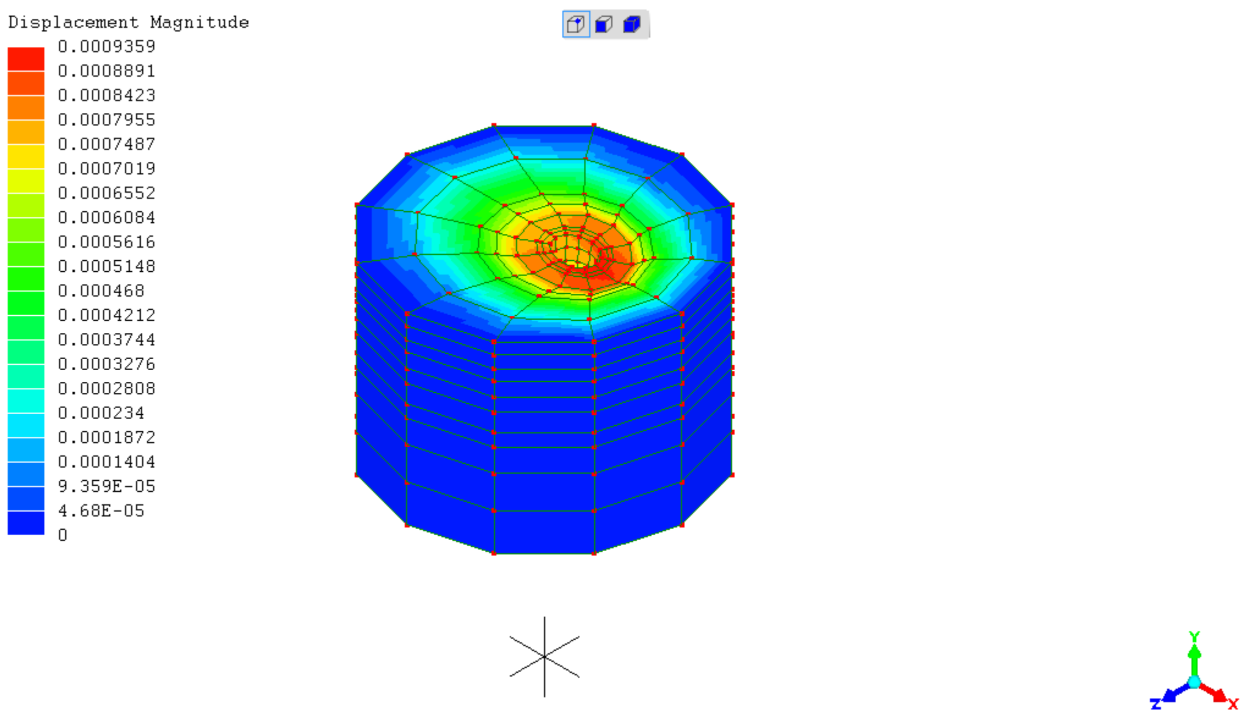

Figure 18 Typical Shear Load deformed shape

LISA allows selection of output file format. This feature was used to prepare segregated element files representing the different constiuents (aka “components” in LISA). These were were imported into Excel spreadsheets for evaluation simply by cut-and-paste (Figure 19). The maximum and minimum values of selected internal stresses were examined (Figure 20) and compared to the allowables. Then the location of the critical element was determined to gain insight to the predicted failure. The procedure is detailed below:

1) Scan stress analysis results

1	Element	Local node	Stress XX	Stress YY	Stress ZZ	Stress XY	Stress YZ	Stress ZX	Prin Strs 1
2	1	1	0.718443	15.51156	0.167199	-12.522	-28.6307	0.045296	40.06366
3	1	2	0.750089	15.82647	0.136399	-12.7085	-29.039	0.032221	40.68297
4	1	3	0.00749	0.079663	0.095332	-15.1997	-33.0902	0.020736	36.5019
5	1	4	0.01127	0.1191	0.127992	-15.0122	-32.6819	0.030089	36.0897
6	1	5	0.781251	16.15562	0.142443	-8.61476	-31.7846	0.156615	42.08746
7	1	6	0.796108	16.30295	0.117628	-8.80175	-32.194	0.11288	42.59357
8	1	7	0.039775	0.401826	0.081578	-16.047	-34.9348	0.079536	38.71257
9	1	8	0.055794	0.563434	0.109876	-15.8591	-34.5257	0.111241	38.36853

Figure 19 LISA Results Imported to Excel Spreadsheet

2) Examine the Maximums an Minimums

	Core Stress					
	Stress XX	Stress YY	Stress ZZ	Stress XY	Stress YZ	Prin Strs 1
Max	12.56	252.13	0.63	145.86	105.44	291.35
Min	-3.82	-76.23	-1.25	-145.86	-105.44	8.54

	Potting Stress							
	Stress XX	Stress YY	Stress ZZ	Stress XY	Stress YZ	Stress ZX	von Mises	Prin Strs 1
max	202.65	543.88	208.51	454.08	508.92	49.65	1029.95	643.23
min	-469.08	-837.87	-502.29	-454.08	-508.92	-49.92	25.97	-224.27

Figure 20 Max/Min Scans

3) Compare stresses to allowables

All Analyses were performed with an arbitrary Insert load of 200 lbs. This load was scaled to the level of the allowable for each load type and failure mode.

The Tension load case results were as follows:

Honeycomb Core allowables (TEKLAM data sheet, Figure 5)
xy = 112 psi
yz = 67 psi
yy = -267 psi, +230 psi
The core is shear YZ critical (Figure 20)
Allowable tension load =67/105.44 x 200 = **<u>127 lbs ult</u>**

Potting allowables (DAPCO 3040 data sheet, Appendix D)
Shear xy = 2000 psi typical, .69 x 2000 =1380 psi estimated A basis allowable equivalent
Compression = 4000 psi typical, .69 x 4000 = 2760 psi, A basis allowable equivalent
Tension = 3500 typical, .69 x 3500 = 2415 psi, A Basis allowable equivalent
The potting is shear YZ critical (Figure 20)
Allowable shear = (1380/508.92) x 200 lb = 542 lbs ult. (not critical)
Compare the von Mises stress to the tension allowable
Allowable shear load = 2415/1029.95 x 200 = 469 lb (less critical than core)

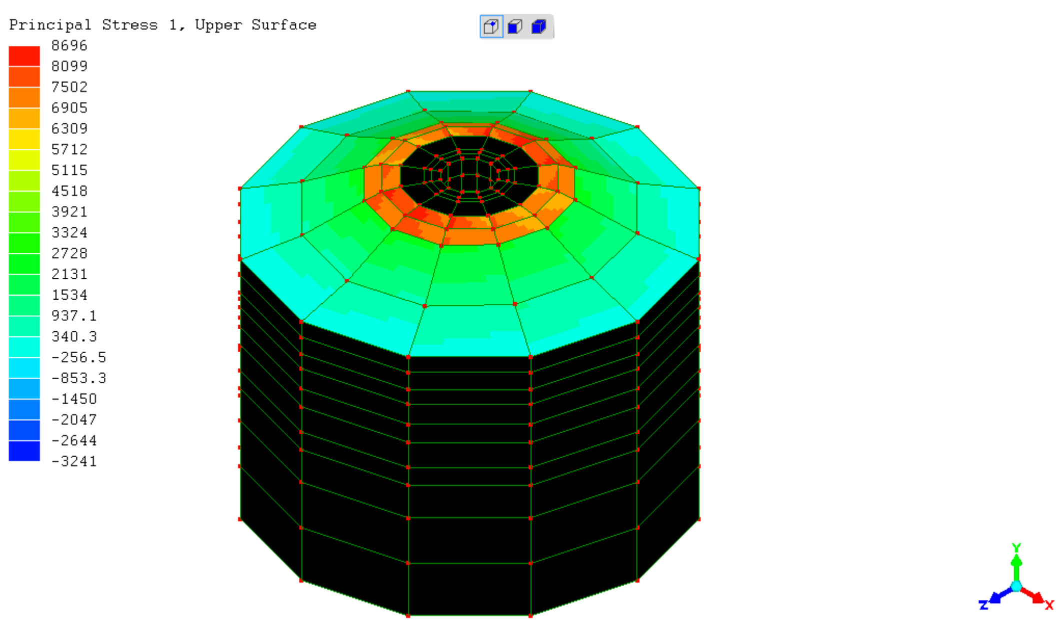

Figure 21 LISA Graphic Display of Fiberglass Skin Stress – Tension Load

Fiberglass allowables (TEKLAM data sheet, Figure 5)
Compression = 18673 psi (A Basis W direction)
Use compression allowable
The corresponding shear load to achieve the compression allowable in the fiberglass is (Using Figure 21):
Allowable tension load = 18763/8696 x 200 lbs = 432 lbs (not as critical as the core)

Similarly, the shear load condition internal stresses were compared to the allowables:

For the honeycomb core

Stress XX	Stress YY	Stress ZZ	Stress XY	Stress YZ	Stress ZX	von Mises
0.86	20.27	0.11	11.07	4.50	0.57	34.54
-1.00	-23.56	-0.13	-17.41	-5.75	-0.59	0.05

Honeycomb Core allowables (TEKLAM data sheet)
xy = 112 psi
yz = 67 psi
yy = 267 psi
Stress XY critical
Allowable shear =112/17.41 x 200 = 1287 lbs ult (not critical)

For the potting compound

	Stress XX	Stress YY	Stress ZZ	Stress XY	Stress YZ	Stress ZX	von Mises	Prin Strs 1
max	1075.33	409.83	411.32	152.61	103.99	424.81	976.28	1117.78
min	-1115.41	-429.41	-420.72	-391.04	-175.93	-422.95	1.00	-361.20

For the fiberglass face skins

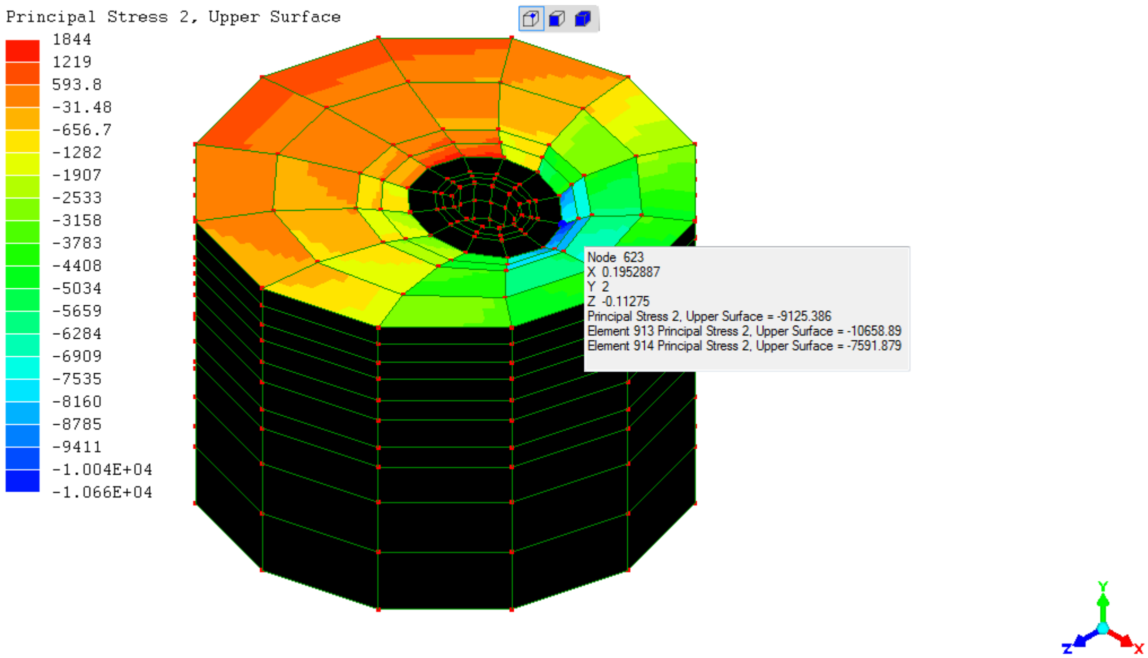

Figure 22 LISA Graphical Display of Fberglass Skin Stress – Shear Load

Fiberglass allowables (TEKLAM data sheet)
Tension/Compression = 18673 psi (A Basis W direction)
The corresponding shear load to achieve the compression allowable in the fiberglass is:
Allowable shear load = 18763/10660 x 200 lbs = **352 lbs** (critical failure mode)

4) Determine location of predicted failure

In all cases, a search was conducted to reveal the location of the highest stress area of each constituent component. The LISA section cut feature of Figure 23 shows one of these examinations where the critical core stress is just below and off the corner of the potting material.

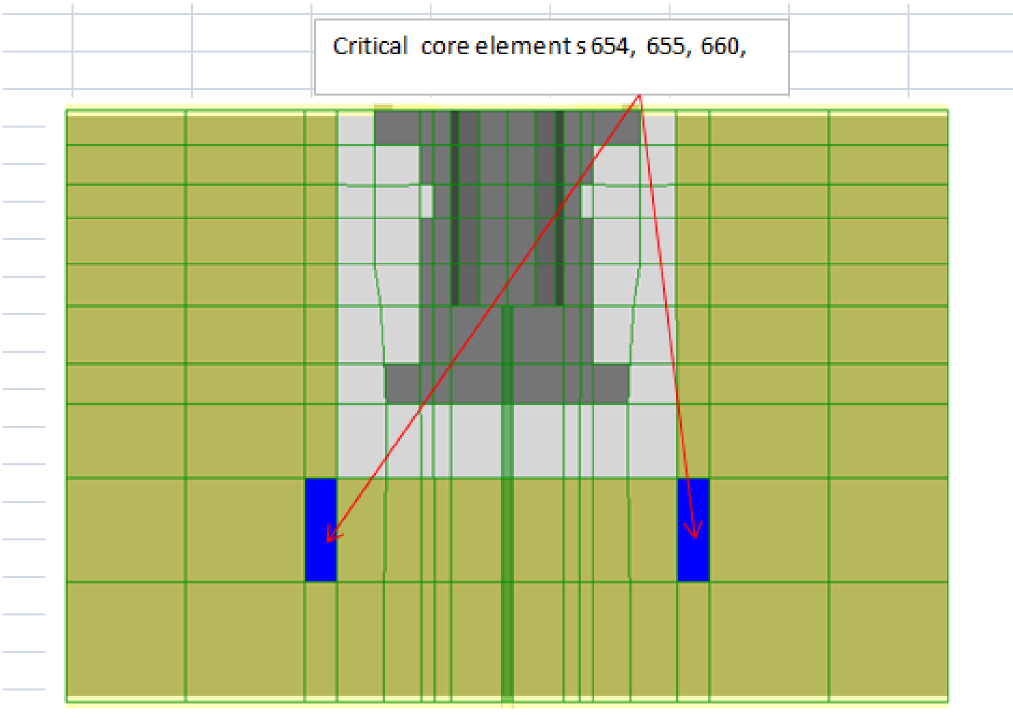

Figure 23 Critical Finite Element Location

Summary of Results

Figure 24 shows the full comparison between the TEKLAM test results and the LISA Finite Element Analysis. Apparently, tension load capability is determined by the honeycomb core and in-plane shear capability is determined by the fiberglass skins. The correlation is useful for documenting strength with this method, varying from 32% conservative to 1% unconservative as shown in Figure 25.

Load Type	**Tension**				**Shear**			
	Test	analysis failure			Test	analysis failure		
Insert Type		core	facing	potting		core	facing	potting
	lbs	lbs	lbs	lbs	lbs	lbs	lbs	lbs
1832-3-7	**194**	**171**	488	498	**343**	1361	**347**	433
1834-3-1000	**295**	**270**	541	672	**483**	1690	**423**	604
1836-3-16	**188**	**127**	432	469	**379**	1287	**352**	432

Figure 24 Comparison of Analysis and Test

Tension Load

Insert Type	Test	Analysis	Difference % *
1832-3-7	194	171	12
1834-3-1000	295	270	8
1836-3-16	188	127	32

Shear Load

Insert Type	Test	Analysis	Difference %
1832-3-7	343	347	-1
1834-3-1000	483	423	12
1836-3-16	379	352	7

* positive is conservative

Figure 25 Percentage Conservatism in analysis

Conclusion

The LISA Finite Element Analysis modeling tool is useful for conservative predictions of the strength of potted inserts into honeycomb core. With practice, relatively coarse models can be constructed in minutes that can analytically demonstrate adequate strength to “A” Basis levels. Strength substantiation documentation using LISA analysis is therefore a valid representation of minimum strength.

No data was available to compare strength predictions for load conditions that combine pull-out (tension) with in-plane shear (shear). However, there is no reason the methods shown in this report can not be extended to predict the strength of combined load cases also.

Appendix A

One Sides Tolerance Factors…(From Reference 7)

Table 9.10.1. One-Sided Tolerance Limit Factors[a], k, for the Normal Distribution, 0.95 Confidence, and n-1 Degrees of Freedom

Note: These P values should only be used for substantiation of S-basis minimum properties (see Section 9.4). Weibull, Pearson, or nonparametric procedures should be used when calculating T_{90} and T_{99} values to determine A- and B-basis minimum static properties (see Section 9.5).

n	P = 0.99	n	P = 0.99	n	P = 0.99	n	P = 0.99
30	3.064						
31	3.048	61	2.802	91	2.704	121	2.648
32	3.034	62	2.798	92	2.701	122	2.646
33	3.020	63	2.793	93	2.699	123	2.645
34	3.007	64	2.789	94	2.697	124	2.643
35	2.995	65	2.785	95	2.695	125	2.642
36	2.983	66	2.781	96	2.692	126	2.640
37	2.972	67	2.777	97	2.690	127	2.639
38	2.961	68	2.773	98	2.688	128	2.638
39	2.951	69	2.769	99	2.686	129	2.636
40	2.941	70	2.765	100	2.684	130	2.635
41	2.932	71	2.762	101	2.682	131	2.634
42	2.923	72	2.758	102	2.680	132	2.632
43	2.914	73	2.755	103	2.678	133	2.631
44	2.906	74	2.751	104	2.676	134	2.630
45	2.898	75	2.748	105	2.674	135	2.628
46	2.890	76	2.745	106	2.672	136	2.627
47	2.883	77	2.742	107	2.671	137	2.626
48	2.876	78	2.739	108	2.669	138	2.625
49	2.869	79	2.736	109	2.667	139	2.624
50	2.862	80	2.733	110	2.665	140	2.622
51	2.856	81	2.730	111	2.663	141	2.621
52	2.850	82	2.727	112	2.662	142	2.620
53	2.844	83	2.724	113	2.660	143	2.619
54	2.838	84	2.721	114	2.658	144	2.618
55	2.833	85	2.719	115	2.657	145	2.617
56	2.827	86	2.716	116	2.655	146	2.616
57	2.822	87	2.714	117	2.654	147	2.615
58	2.817	88	2.711	118	2.652	148	2.613
59	2.812	89	2.709	119	2.651	149	2.612
60	2.807	90	2.706	120	2.649	150	2.611

Appendix B

Insert Dimensions (From Reference 9)

NAS 1832

INSERT, MOLDED IN, THREADED, SANDWICH PANEL

APPLICATIONS: SELF LOCKING AND NON SELF LOCKING THREADS

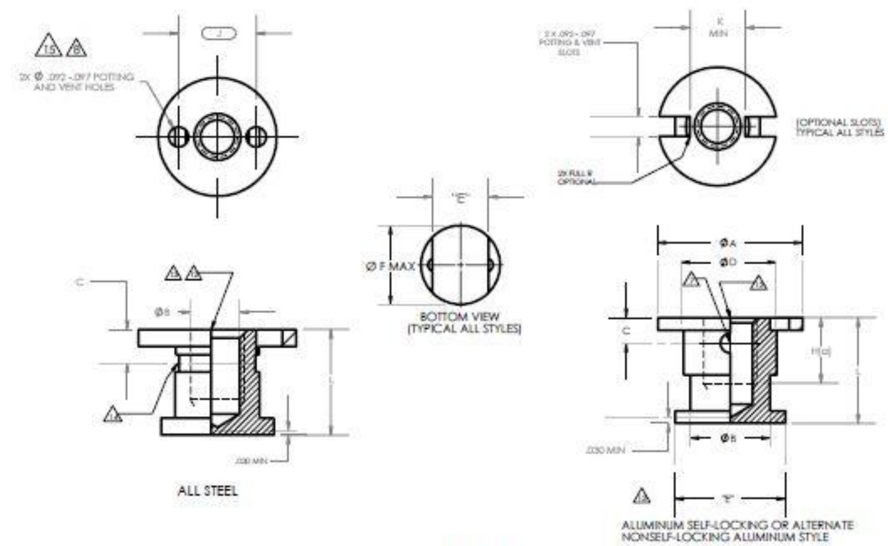

TABLE 1

FIRST DASH NO.	THREAD CLASS 3B MINOR DIA	ØA +.000 -.010	ØB	C	ØD	E	ØF MAX	H(a) MIN	J BASIC	K MIN	L(B) MIN	INSTALLATION HOLE SIZE
-06	.1380-32 UNJC	.560	.300	.12	.375	.400	.560	.250	.367	.260	.37	.561 - .566
-08	.1640-32 UNJC	.560	.300	.12	.375	.400	.560	.250	.367	.260	.37	.561 - .566
-3	.1900-32 UNJF	.560	.300	.12	.375	.400	.560	.250	.367	.260	.37	.561 - .566
-4	.2500-28 UNJF	.685	.375	.14	.440	.520	.685	.310	.467	.360	.50	.686 - .691
-5	.3125-24 UNJF	.685	.475	.16	.500	.520	.685	.310	.467	.360	.50	.686 - .691
-6	.3750-24 UNJF	.841	.500	.22	.550	.560	.841	.370	.591	.484	.50	.842 - .847

(a) MINIMUM THREAD "H" IN SHORT LENGTHS. MINIMUM THREAD "H" WHERE LENGTH PERMITS SHALL BE 2X DIAMETER OF THREAD.

(b) MINIMUM LENGTH WHICH MAY BE SPECIFIED.

MATERIAL: CARBON STEEL PER ASTM-A-108. ASTM-A-576 OR MATERIAL COMPOSTION PER FED-STD-66, ULTIMATE TENSILE STRENGTH 85 KSI MINIMUM. ALUMINUM ALLOY , GRADE 2024 (UNS AS2024), TEMPER T4 OR T351 PER QQ-A-225/6.
CORROSION RESISTANT STEEL, TYPE 303 (UNS 30300 PER ASTM-A-582. NONMETALLIC LOCKING ELEMENT - POLYAMIDE PER FED SPEC L-P-410.

FINISH: CARBON STEEL - CADMIUM PLATE PER SAE-AMS QQ-P-416, TYPE 2, CLASS 2.
ALUMINUM ALLOY - ANODIZE PER MIL-A-8625 TYPE 1, CLASS OPTIONAL.
CRES - PASSIVATE PER ASTM-A-967, SILVER PLATE PER AMS2410 OR AMS2411
OR CADMIUM PLATE PER SAE-AMS-QQ-P-416, TYPE 2, CLASS 2.
SOLID FILM LUBRICANT PER AS5272, TYPE 1, APPLIED TO THREADS ONLY.

CODING: NO LETTER AFTER BASIC NUMBER INDICATES CARBON STEEL, CADMIUM PLATED.
SUFFIX A TO BASIC NUMBER INDICATES AL ALLOY, ANODIZED.
SUFFIX C TO BASIC NUMBER INDICATES CRES. PASSIVATED.
FIRST DASH NUMBER INDICATES NOMINAL THREAD SIZE, SEE TABLE 1.
SUFFIX N TO FIRST DASH NUMBER INDICATES NON SELF-LOCKING.
SECOND DASH NUMBER INDICATES LENGTH IN .125 INCREMENTS. SEE NOTE 6.
NO LETTER AFTER SECOND DASH NUMBER FOR CRES INDICATES PASSIVATE ONLY. SEE NOTE 5.
SUFFIX M TO SECOND DASH NUMBER INDICATES SOLID FILM LUBRICANT. SEE NOTE 5.
SUFFIX P TO SECOND DASH NUMBER INDICATES CADMIUM PLATE ON CRES INSERT. SEE NOTE 5.
SUFFIX S TO SECOND DASH NUMBER INDICATES SILVER PLATE ON CRES INSERT. SEE NOTE 5.

EXAMPLE OF PART NUMBER:

NAS 1832-3-4M .1900-32 UNJF -3B THREAD,CARBON STEEL, CADMIUM PLATED WITH MOLYCOAT 3402C LUBRICANT, .500 LONG, SELF-LOCKING.

NAS 1832A3N4 .1900-32 UNJF -3B THREAD, ALUMINUM ALLOY, ANODIZED, .500 LONG NONSELF LOCKING.

NAS 1832CO8-3S .1640-32 UNJC -3B THREAD, CRES, SILVER PLATED, .375 LONG. SELF-LOCKING.

NAS 1832C08-3P .2500-28 UNJF -3B THREAD, CRES, PASSIVATED, .625 LONG NONSELF-LOCKING

NAS 1832C4N5 .2500-28 UNJF -3B THREAD, CARBON STEEL, CADMIUM PLATED,1.250 LONG, SELF-LOCKING.

NOTES:

1. THREADS PER MIL-S-8879.

2. LOCKING TORQUE PER MIL-DTL 25027 EXCEPT SELF-LOCKING. CORROSION RESISTANT STEEL INSERT WITHOUT PLATING OR LUBRICANT WILL BE TESTED USING A SILVER PLATED BOLT OR SCREW.

NAS 1834

INSERT, MOLDED IN, CSK AND THRU CLEARANCE HOLE, SANDWICH PANEL

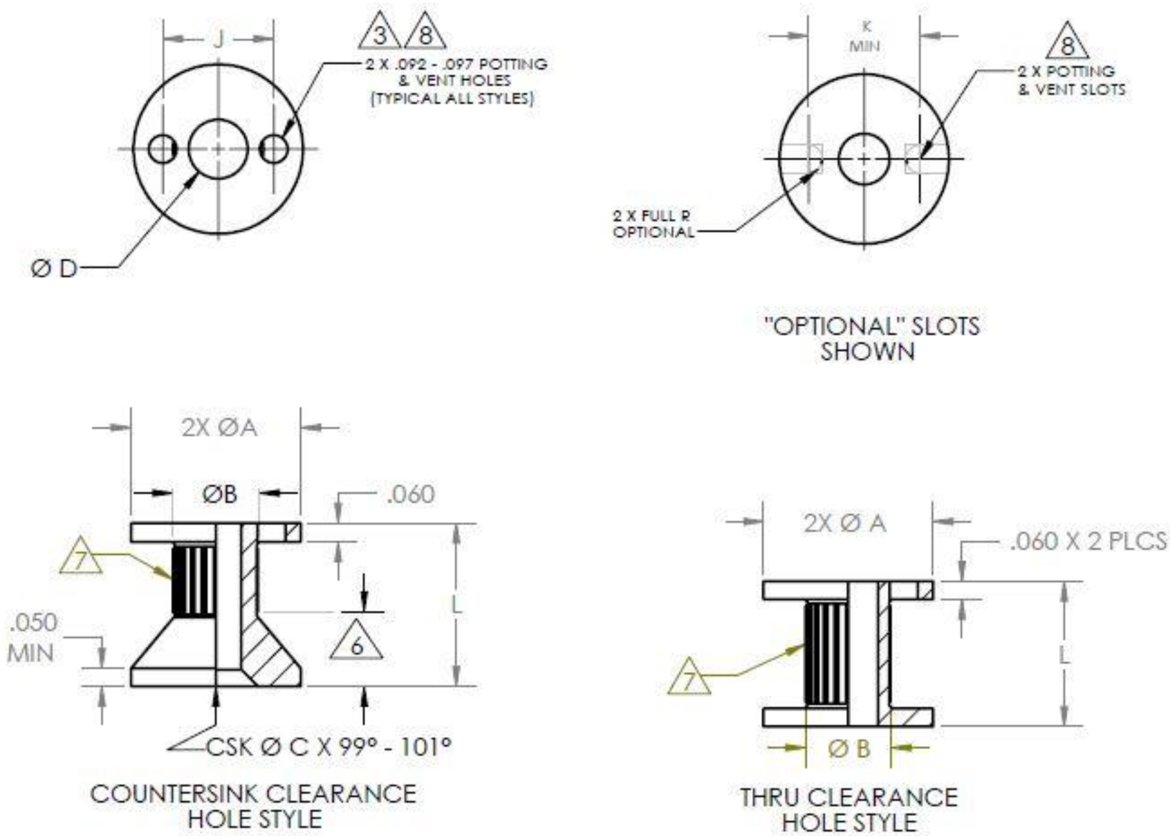

TABLE I

FIRST DASH NO	Ø A +.000 -.010	Ø B	ØC	ØD CLEARANCE HOLE	J BASIC	K MIN	L (a) MIN	INSTALLATION HOLE SIZE
-06	.560	.30	.280	.139 - .145	.367	.260	.250	.561 - .566
-08	.560	.30	.332	.168 - .174	.367	.260	.250	.561 - .566
-3	.560	.30	.385	.195 - .201	.367	.260	.250	.561 - .566
-4	.685	.37	.507	.256 - .263	.467	.360	.312	.686 - .691
-5	.685	.47	.625	.315 - .322	.467	.360	.312	.686 - .691
-6	.841	.50	.750	.376 - .383	.591	.484	.375	.842 - .847

(a) MINIMUM LENGTH WHICH MAY BE SPECIFIED.

MATERIAL: CARBON STEEL PER ASTM-A-108, ASTM A576 OR MATERIAL COMPOSITION PER FED-STD-66.
ULTIMATE TENSILE STRENGTH , 85 KSI MINIMUM
ALUMINUM ALLOY, GRADE 2024 (UNS A92024) TEMPER T4 OR T351 PER QQ-A-225/6.
CORROSION RESISTANT STEEL, TYPE 303 (UNS S30300) PER ASTM A582.

FINISH: CARBON STEEL - CADMIUM PLATE PER SAE-AMS QQ-P-416, TYPE II, CLASS 2.
ALUMINUM ALLOY - ANODIZE PER MIL-A-8625 TYPE I, CLASS OPTIONAL.
CRES - PASSIVATE PER ASTM-A-967.

CODING: NO LETTER AFTER BASIC NUMBER INDICATES CARBON STEEL, CADMIUM PLATED.
SUFFIX A TO BASIC NUMBER INDICATES AL ALLOY ANODIZED.
SUFFIX C TO BASIC NUMBER INDICATES CRES, PASSIVATED.
FIRST DASH NUMBER INDICATES CLEARANCE HOLE SIZE SEE TABLE I.
SUFFIX K TO FIRST DASH NUMBER INDICATES COUNTERSUNK TYPE.
SECOND DASH NUMBER INDICATES LENGTH IN THOUSANDTHS.

EXAMPLE OF PART NUMBER:

NAS1834-3-500 CARBON STEEL, CADMIUM PLATED, .500 LONG WITH THRU CLEARANCE HOLE FOR .1900 BOLT.

NAS 1834C4-500 CRES, PASSIVATED, .500 LONG, WITH THRU CLEARANCE HOLE FOR Ø .2500 BOLT

NAS 1834C4K1250 CRES, PASSIVATED, 1.250 WITH COUNTERSUNK THRU CLEARANCE HOLE FOR Ø .2500 BOLT.

NOTES:

1. TOLERANCES UNLESS OTHERWISE SPECIFIED:
   .XXX = ±.010
   .XX = ±.02
2. AN ADHESIVE BACKED INSTALLATION TAB NAS 1837 (PLASTIC WITTEN 2007) SHALL BE FURNISHED WITH EACH INSERT.
3. (△) BURRS CAUSED BY MACHINING POTTING HOLES OR SLOTS PERMISSIBLE UNDER FLANGE.
4. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M-1982.
5. DIMENSIONS ARE IN INCHES UNLESS OTHERWISE NOTED.
6. (△) EXTERNAL CONFIGURATION OPTIONAL IN THIS AREA FOR SHORT LENGTHS THROUGH .375.
7. (△) STRAIGHT OR DIAMOND ANTI-ROTATIONAL KNURL. (MANUFACTURER'S OPTION)
8. (△) POTTING AND VENT HOLES OR SLOTS. (MANUFACTURER'S OPTION)
9. ALL DIAMETERS TO BE CONCENTRIC (SAME AXIS) WITHIN .010".
10. DIMENSIONAL LIMITS APPLY AFTER PLATING.

NAS 1836

INSERT, MOLDED IN, THREADED, SELF-LOCKING NONSELF-LOCKING,LIGHTWEIGHT, SANDWICH PANEL

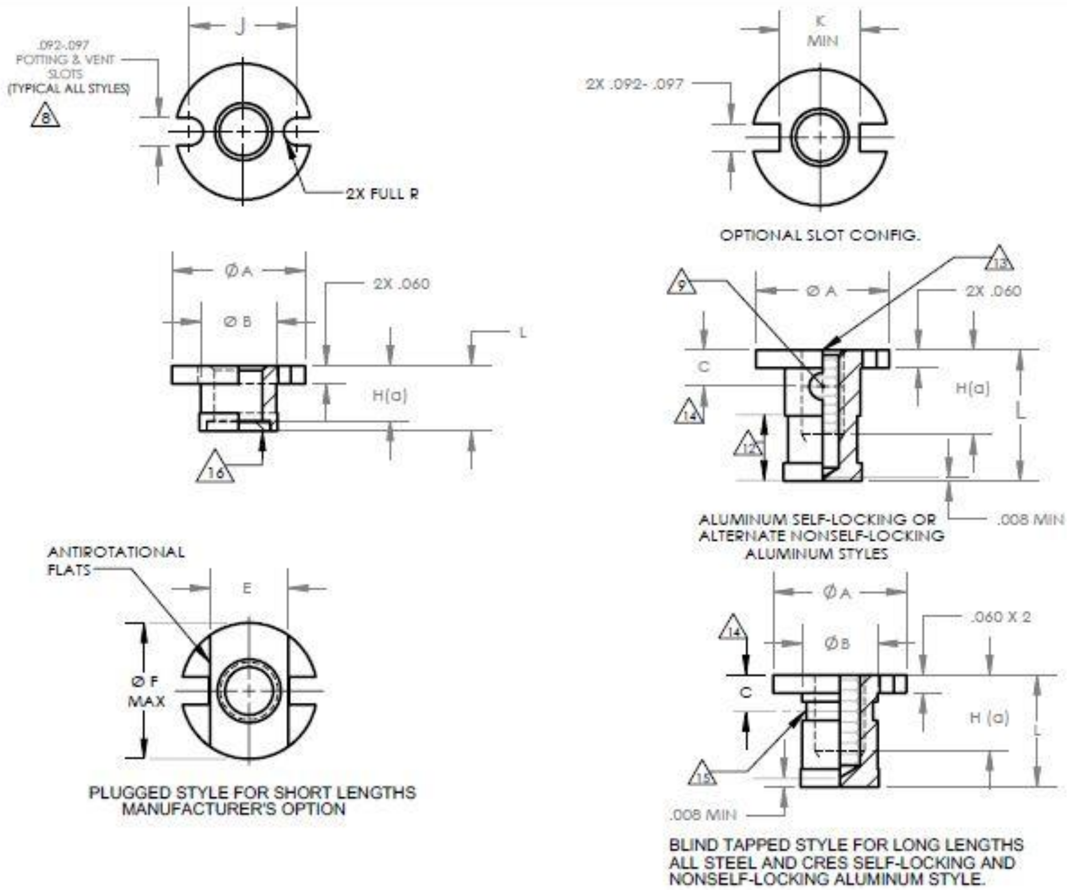

TABLE 1

FIRST DASH NO	THREAD CLASS 3B MINOR DIA	ØA +.000 -.010	ØB	C	E	ØF MAX	H(a)	J BASIC	K MIN	L(b) MIN	INSTALLATION HOLESIZE
-06	.1380-32 UNJC	0.451	0.3	0.1	0.26	0.45	0.187	0.358	0.251	0.217	.452 - .457
-08	.1640-32 UNJC	0.451	0.3	0.1	0.26	0.45	0.187	0.358	0.251	0.217	.452 - .457
-3	.1900-32 UNJF	0.451	0.3	0.1	0.26	0.45	0.187	0.358	0.251	0.217	.452 - .457
-4	.2500-28 UNJF	0.498	0.3	0.1	0.31	0.49	0.25	0.405	0.298	0.279	.499 - .504

(a) MINIMUM THREAD "H" IN SHORT LENGTHS. MINIMUM THREAD "H" WHERE LENGTH PERMITS SHALL BE 2 X DIAMETER OF THREAD.

(b) MINIMUM LENGTH WHICH MAY BE SPECIFIED.

MATERIAL: CARBON STEEL PER ASTM-A-108, ASTM A576 OR MATERIAL COMPOSITION PER FED-STD-66.
ULTIMATE TENSILE STRENGTH , 85 KSI MINIMUM
ALUMINUM ALLOY, GRADE 2024 (UNS A92024) TEMPER T4 OR T351 PER QQ-A-225/6.
CORROSION RESISTANT STEEL, TYPE 303 (UNS S30300) PER ASTM A582.
NONMETALLIC LOCKING ELEMENT - POLYAMIDE PER FED SPEC L-P-410

FINISH: CARBON STEEL - CADMIUM PLATE PER SAE-AMS QQ-P-416, TYPE II, CLASS 2.
ALUMINUM ALLOY - ANODIZE PER MIL-A-8625 TYPE I, CLASS OPTIONAL.
CRES - PASSIVATE PER ASTM-A-967, TYPE II. SILVER PLATE PER AMS2410 OR AMS2411OR CADMIUM PLATE PER SAE-AMS QQ-P-416 TYPE II, CLASS 2.
SOLID FILM LUBRICANT PER AS5272, TYPE I, APPLIED TO THREADS ONLY.

CODING: NO LETTER AFTER BASIC NUMBER INDICATES CARBON STEEL, CADMIUM PLATED.
SUFFIX A TO BASIC NUMBER INDICATES AL ALLOY ANODIZED.
SUFFIX C TO BASIC NUMBER INDICATES CRES, PASSIVATED.
FIRST DASH NUMBER INDICATES NOMIMAL THREAD SIZE SEE TABLE I.
SUFFIX N TO FIRST DASH NUMBER INDICATES NON SELF-LOCKING.
SECOND DASH NUMBER INDICATES LENGTH IN .031 INCREMENTS;
ALWAYS USE 2 DIGIT DASH NUMBER. (SEE NOTE 6)
NO LETTER AFTER SECOND DASH NUMBER FOR CRES INDICATES PASSIVATE ONLY. (SEE NOTE 5).
SUFFIX M TO SECOND DASH NUMBER INDICATES SOLID FILM LUBRICANT. (SEE NOTE 5).
SUFFIX P TO SECOND DASH NUMBER INDICATES CADMIUM PLATE ON CRES INSERT. (SEE NOTE 5).
SUFFIX S TO SECOND DASH NUMBER INDICATES SILVER PLATE ON CRES INSERT. (SEE NOTE 5).

EXAMPLE OF PART NUMBER:

NAS 1836-3-08M	.1900-32 UNJF-3B THREAD, CARBON STEEL, CADMIUM PLATED, WITH SOLID FILM LUBRICANT, .248 LONG, SELF-LOCKING.
NAS 1836A3N09	.1900-32 UNJF-3B THREAD, AL ALLOY, ANODIZED, .279 LONG, NONSELF-LOCKING.
NAS 1836C08-10S	.1640-32 UNJC-3B THREAD, CRES, SILVER PLATED, .310 LONG, SELF-LOCKING.
NAS 1836C4N12	.2500-28 UNJF-3B THREAD, CRES, PASSIVATED, .372 LONG, NONSELF-LOCKING.

Appendix C

Honeycomb core vendor properties (from Reference 10)

Specifications

HexWeb HRH-10 has been evaluated and approved for numerous corporate specifications and meets the requirements of SAE specifications AMS3711B and MIL-C-81986, Amendment 1. In addition, HexWeb HRH-10 meets the following parameters and properties.

HexWeb® HRH-10® *Product Data*

Mechanical Properties of HexWeb® HRH-10® at Room Temperature

Typical Values Represented Below

Hexcel Honeycomb Designation Material – Cell – Density	Compressive					Plate Shear					
	Bare		Stabilized			L Direction			W Direction		
	Strength psi		Strength psi		Modules ksi	Strength psi		Modulus ksi	Strength psi		Modulus ksi
Hexagonal	typ	min	typ	min	typ	typ	min	typ	typ	min	typ
HRH-10 - 1/8 - 1.8	105	85	115	95	8	90	75	3.8	50	40	1.5
HRH-10 - 1/8 - 3.0	300	235	325	270	20	175	155	6.0	100	85	3.5
HRH-10 - 1/8 - 4.0	520	400	575	470	28	255	225	8.6	140	115	4.7
HRH-10 - 1/8 - 5.0	700	560	770	620	37	325	275	10.2	175	150	5.4
HRH-10 - 1/8 - 6.0	1050	850	1125	925	60	385	330	13.0	200	170	6.5
HRH-10 - 1/8 - 8.0	1675	1370	1830	1450	78	480	400	16.0	260	210	9.5
HRH-10 - 1/8 - 9.0	2000	1525	2100	1600	90	515	425	17.5	300	250	11.0
HRH-10 - 3/16 - 1.8	120	95	130	105	8	90	75	3.8	50	40	1.9
HRH-10 - 3/16 - 2.0	120	100	140	105	11	110	90	4.3	60	45	2.1
HRH-10 - 3/16 - 3.0	300	235	325	270	20	175	140	6.5	100	85	3.4
HRH-10 - 3/16 - 4.0	500	430	540	470	28	245	215	7.8	140	110	4.7
HRH-10 - 3/16 - 6.0	935	780	1020	865	60	420	370	13.0	225	200	6.5
HRH-10 - 1/4 - 1.5	80	65	90	75	6	70	55	3.0	35	25	1.3
HRH-10 - 1/4 - 2.0	140	115	155	125	11	105	85	4.0	50	40	2.0
HRH-10 - 1/4 - 3.1	285	240	310	265	21	185	160	6.5	90	75	3.0
HRH-10 - 1/4 - 4.0	440	360	480	390	28	250	205	8.0	125	100	3.5
HRH-10 - 3/8 - 1.5	95	75	105	80	6	70	55	3.0	35	25	1.5
HRH-10 - 3/8 - 2.0	140	115	155	125	11	90	72	3.7	55	36	2.4
HRH-10 - 3/8 - 3.0	290	240	320	270	17	185	160	5.6	95	80	3.5
OX-Core											
HRH-10/OX - 3/16 - 1.8	110	85	120	95	7	65	45	2.0	70	50	3.0
HRH-10/OX - 3/16 - 3.0	320	260	350	285	17	115	95	3.0	135	110	6.0
HRH-10/OX - 3/16 - 4.0	600	500	650	550	26	130	105	4.6	150	130	8.4
HRH-10/OX - 1/4 - 3.0	350	280	385	310	17	110	90	3.0	135	110	6.0

Test data obtained at 0.500 inch thickness.

Other cell sizes, densities, and dimensions may be available on special request. Please contact your nearest Hexcel Sales Office for additional information. One block minimum buy may apply.

HEXCEL

Appendix D

Vendor potting compound strength (Reference 11)

> DAPCO™ 3040 Self-Extinguishing Insert and Potting Epoxy

Technical Data Sheet

Cytec
ENGINEERED MATERIALS

Description

DAPCO™ 3040 is a two-component, very fast curing, self-extinguishing edge filling insert potting epoxy which cures at normal room temperature [77°F (25°C)].

Properties

Table 2 | Typical Cured Properties

Property	Value
Hardness, Shore D (ASTM D224)	70 – 80
Tensile Strength, psi (MPa)	3500 (24.13)
Tensile Elongation, %	16
Shear Adhesion to Aluminum (2024 T3), psi (MPa)	2000 (13.79)
Compression Strength, psi	
At room temperature	4000 (27.58)
At 180°F (82°C)	1000 (6.895)

Appendix E

Fiberglass Material Elastic Properties (Reference 8)

TABLE A1.40 *Summary of Mechanical Properties of Narmco N506/7781 (ECDE-1/0-A1100) Fiberglass Phenolic.*

Fabrication	Lay-up: Balanced	Vacuum:	Pressure:	Bleedout: Vertical	Cure:	Postcure:	Plies: 8
Physical Properties	Weight Percent Resin: 25.3 - 32.3	Avg. Specific Gravity: 1.72 - 1.85	Avg. Percent Voids: Figure 4.40.5	Avg. Thickness: 0.071 - 0.095 inches			
Test Methods	Tension: ASTM D638 TYPE 1	Compression: CMH-17	Shear: Rail	Flexure: ASTM D790	Bearing: ASTM D953	Interlaminar Shear: Short Beam	

Temperature		-65°F				75°F				160°F				400°F	
Condition		Dry		Wet		Dry		Wet		Dry		Wet		Dry	
		Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD
Tension															
ultimate stress, ksi	0°	48.1	2.4	49.8	3.3	38.9	1.5	37.2	1.8	35.3	1.4	30.6	3.0	21.6	1.6
	90°	37.9	1.8	40.0	2.7	31.5	1.5	32.1	1.4	27.9	1.7	26.2	2.2	21.6	1.7
ultimate strain, %	0°	1.76	0.07	1.76	0.13	1.33	0.14	1.34	0.13	1.19	0.10	1.15	0.14	0.69	0.05
	90°	1.63	0.08	1.65	0.13	1.26	0.15	1.32	0.07	1.11	0.07	1.11	0.14	0.78	0.06
proportional limit, ksi	0°	13.6	0.9	18.1	1.2	13.5	0.6	17.0	1.0	13.9	1.0	14.9	0.70	9.7	1.1
	90°	9.9	0.4	12.5	0.9	9.2	0.8	12.8	0.7	10.3	0.8	11.6	0.70	8.6	0.5
initial modulus, 10^6 psi	0°	3.40	0.21	3.35	0.20	3.94	0.69	3.14	0.26	3.74	0.41	3.01	0.19	3.57	0.24
	90°	3.08	0.29	3.04	0.22	3.54	0.41	2.81	0.24	3.33	0.37	2.78	0.21	3.18	0.30
secondary modulus, 10^6 psi	0°														
	90°														
Compression															
ultimate stress, ksi	0°	66.7	6.2	65.9	5.0	59.7	4.7	54.5	7.1	50.6	2.3	49.2	4.2		
	90°	57.7	5.8	56.2	5.8	49.0	4.6	48.7	4.0	43.0	4.3	42.9	3.7		
ultimate strain, %	0°	1.85	0.09	1.69	0.18	1.58	0.14	1.49	0.12	1.45	0.06	1.40	0.12		
	90°	1.70	0.21	1.63	0.13	1.40	0.09	1.43	0.07	1.37	0.12	1.31	0.15		
proportional limit, ksi	0°	45.8	3.8	38.5	7.9	39.0	2.4	41.2	4.6	39.9	2.4	35.0	1.7		
	90°	35.2	3.8	34.4	5.0	32.6	4.4	35.5	3.0	32.4	3.1	31.1	3.3		
initial modulus, 10^6 psi	0°	3.90	0.19	4.17	0.29	3.95	0.28	3.89	0.26	3.68	0.21	3.67	0.12		
	90°	3.69	0.25	3.68	0.17	3.70	0.20	3.57	0.20	3.30	0.23	3.45	0.21		
Shear															
ultimate stress, ksi	0°-90°	13.8				12.3	0.97			11.4					
	±45°														

		-65°F Dry			75°F Dry			160° Dry		
		Avg	Max	Min	Avg	Max	Min	Avg	Max	Min
Flexure										
ultimate stress, ksi	0°	68.2	72.8	65.2	58.4	64.0	52.1	52.7	56.3	47.4
proportional limit, ksi	0°	59.3	66.1	54.6	48.9	56.8	42.5	42.4	46.2	38.8
initial modulus, 10^6 psi	0°	2.97	3.04	2.88	2.89	2.99	2.78	2.97	3.06	2.82
Bearing										
ultimate stress, ksi	0°	65.7	73.2	57.0	58.9	64.0	46.8	49.5	55.8	44.5
stress at 4% elong., ksi	0°	25.1	26.0	23.7	24.5	24.9	23.8	21.6	22.6	20.7
Interlaminar Shear										
ultimate stress, ksi	0°	4.83	5.10	4.29	4.64	4.92	3.94	4.62	4.88	4.08

Appendix F

Nomex Honeycomb Material Tension Properties (Reference 6)

BONDING OF SANDWICH STRUCTURES - THE FACESHEET/HONEYCOMB INTERFACE - A PHENOMENOLOGICAL STUDY

Subhotosh Khan
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Advanced Fibers System
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1. L. Lapane,et al; SAMPE J., **40** (3), 77 (2004).

Table 1 Typical properties of Honeycombs from aramid papers.

	Paper Thick µm	Cell size mm	HC Density kg/m^3	FWT Strength MPa	L-Shear Strength MPa	L-Shear Mod. MPa	W-Shear Strength MPa	W-Shear Mod. MPa	CDP N.m/m
1.8N636	45	3	48	4.6	1.8	138	1.0	76	**30**
2T412	56	3	48	2.3	1.2	58	0.7	26	**60**

2.3 MPa = 333.5 lbs/in^2

FWT = Flatwise Tension

Nomex Core, HRH-10, 1/8” cell, 3.0 lb/ft^3 density