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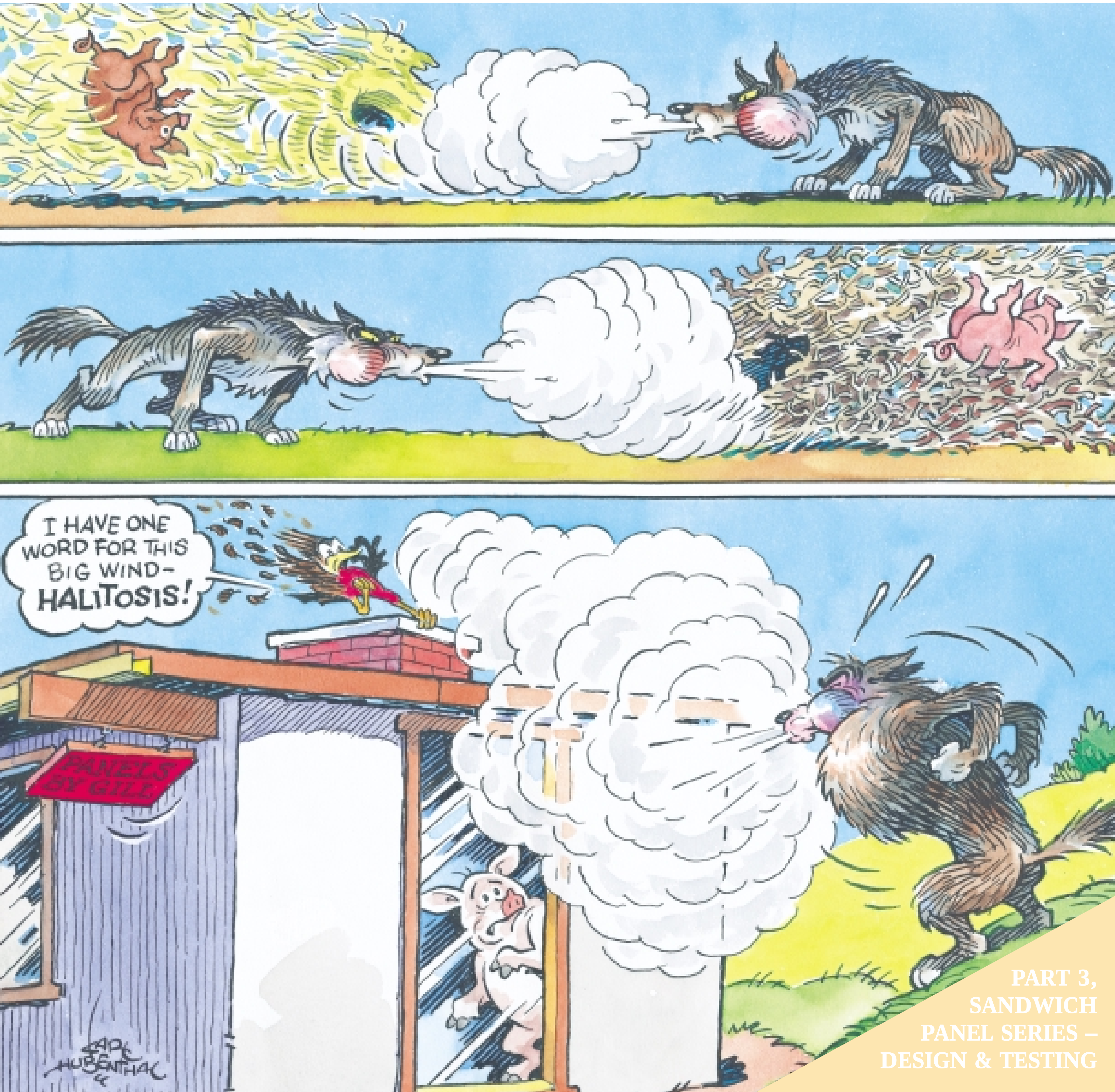
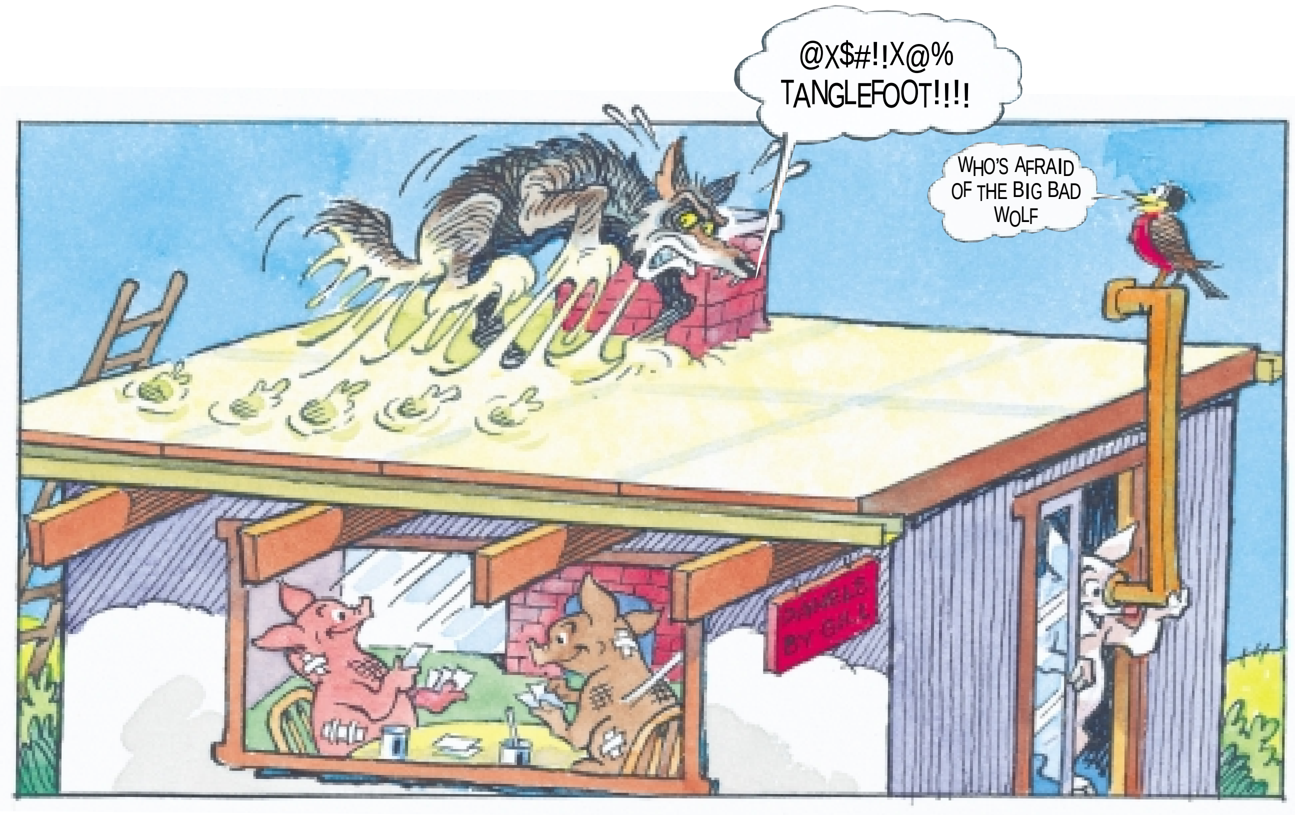


PART 3, SANDWICH PANEL SERIES – DESIGN & TESTING



Simplified Sandwich Panel Design

A REVIEW, PART 3 *This issue updates Part 3 of our series issued in 1984/1985 and again in 1991. Part 1 dealt with a general overview of sandwich panels, the manufacture of their components, and some end uses. Part 2 covered similar subject matter but in greater depth. Part 3 now advances preliminary design considerations for sandwich panel construction. It is not intended as a definitive treatise on the subject but, rather, explores some of the considerations necessary for designing panels to meet specific applications. If you did not receive Parts 1 and/or 2 and would like a copy(s), please contact the Marketing Services Department at one of the numbers on the masthead and we will be pleased to fill your request.*

To our knowledge, sandwich panel design is yet to be taught in most universities and it can be an area of confusion within the aircraft industry. The original work on sandwich design was done by the Forrest Products Laboratory, (FPL Report 1505-A and others). This is a brief summary of simple calculation techniques, with some additional information believed pertinent by the M.C. Gill Corporation.

The formulas involve simplifying assumptions, and judgment has to be exercised in their use. These are preliminary design calculations for illustrative purposes only, and more detailed stress analysis would have to be used for critical applications.

Design Considerations

In selecting the facings and core materials, there are many considerations, depending upon weight, cost, strength, corrosion resistance, etc. The designer has to make his decision based upon the priorities of a given end use.

In general, a serviceable low weight panel will be obtained by having the facings comprise 60 to 67% of the total panel weight. For flooring the “ideal” sandwich panel has 50% of its weight in facings and 50% in core and adhesive, which optimizes durability and weight.

As a rule, the compressive strength of a facing material is the limiting factor and this is overcome by using an unbalanced construction whereby 20 to 30 percent more load bearing capacity is designed into the facing in compression.

However, uneven facings may create a problem with warpage.

Our simplified calculations do not consider the rigidity of the core, nor the effect of the adhesive, both of which can have a significant effect on panel structural strength.

In the calculations, we correct for foam cores which often have lower apparent facing stress. The reason for the correction is when the compressive modulus of the core is very much smaller than the facing modulus (250 x or more) it may allow the facing to wrinkle under flexural loading. This will result in premature failure of the facing. Panels obey these formulas when bonded with a thermoset adhesive (epoxy, phenolic, etc.), but if a contact adhesive is used the safety factor must be increased to perhaps 2.5-3.0.

Edge attachment, although not discussed here, can provide significant additional strength. A fixed attachment means that the panel will not rotate at the attachment point during loading. Determining the type of attachment requires some judgment. Some typical examples of attachment are:

“Simple”—1 row of fasteners, all stiffness of framing.

“Fixed” —2 rows of fasteners, rigid framing.

“Fixed” —Continuous over the framing.

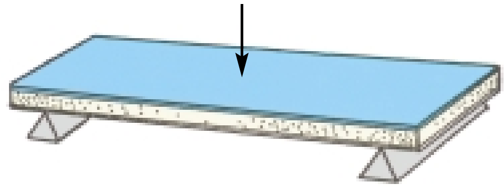
All other supports fall somewhere between simple and fixed supports.

An important design principle is that the panel rigidity increases in proportion to the third power of the panel thickness. Therefore, thicker panels are much more rigid.

NOMENCLATURE RELATIVE TO CALCULATIONS ON PAGES 4 & 5

Δ	Deflection, inches.
λ	Safety factor (usually 1.5-2.0).
a	Span, length, inches.
b	Span, width, inches.
c	Core thickness, inches.
C_s	Coefficient for core shear stress, from Figure 1.
C_b	Coefficient for facing stress, from Figure 1.
d	Total panel thickness, inches.
D	Panel rigidity
E_f,	Flexural modulus of either top or bottom facing, psi. (See Table 2).
G_c	Shear modulus of the core, psi. (See Table 3).
h	($t - t_f$), thickness of panel between centroids of facings
K_b	Coefficient for panel bending. (See Fig.1)
K_s	Coefficient for core shear.
K_f	Coefficient to correct for flexural modulus of facing. (See Table 2).
K_c	Coefficient to correct for core type: 2.2 for foam, 1.0 for honeycomb, 0.7 for plywood.
K_1	Bending constant, sandwich panel loaded as a plate* (See Figure 3).
K_2	Constant for facing stress for panel loaded as a plate* (See Table 1).
K_3	Constant for core shear stress.
P	Load applied to panel, lbs./inch width.
q	Uniform load, psi (P = qa).
S	Core shear stress, in psi.
t_f	Thickness of facing, inches.
t	Total panel thickness, inches.

**Assumes constant properties in thickness direction.*



Sandwich Panels as Beams

The equations covering beam calculations for a sandwich panel are:

$$\text{Deflection, } \Delta = \frac{K_b P a^3}{D} + \frac{K_s P a}{h G_c}$$

$$\text{Panel Rigidity, } D = \frac{E_{f1}\, t_{f1} E_{f2} t_{f2} h^2}{E_{f1}\, t_{f1} + E_{f2}\, t_{f2}}$$

K_b = Coefficient From Figure 1 (below).

The second part of the deflection equation, $K_s pa/hG_c$, represents the rigidity contributed by the core, and is ignored for simplicity in our calculations here.

By assuming the facings are the same thickness and type of material, and that the facing stress on the skins is not very large, and that the contribution the core makes on panel stiffness is negligible, a relatively accurate preliminary design technique is:

Step I: Calculate Panel Rigidity—D

$$D = \lambda\, K_f\, K_b\, P_c\, \frac{a^3}{\Delta}$$

Where:

- K_b = Bending constant found in Figure 1
- P_c = $K_c P$
- P = Load, in lbs. per inch of width (total load ÷ b or qa where q = load per unit area)
- K_c = Coefficient to correct for foam weakness
- K_c = 2.2 for foam cores, 1 for honeycomb and balsa cores, 0.7 for plywood
- a = Unsupported span in inches
- λ = Safety factor, usually 1.5-2.0
- Δ = Maximum allowable deflection
- K_f = Flexural coefficient for facing, from Table 2 (page 6)

Step II:
Refer to Figure 2 (page 7) to select combinations of t_f and d for the calculated D. Read across D horizontally and select a combination of d and t_f that intersect this D value. Note: Although many considerations enter into the design, thin facings usually lower panel weight and cost.

Step III: Calculate core shear stress and select core.

$$S = \frac{C_s P}{h}$$

Where C_s is found from Figure 1 and
$h = t_c + t_f$

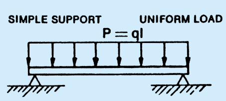
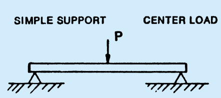
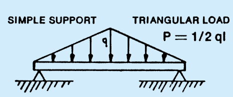
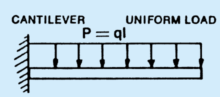
Select core material that has core shear well above the value calculated, see Table 3 (page 6). If it is decided to use a foam core, be sure to calculate D using $K_c = 2.2$.

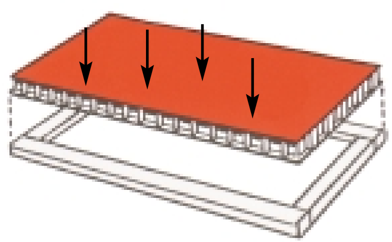
Step IV:
Check Facing Stress $F_s = \dfrac{C_b P_c a}{h t_f}$

Where C_b is found from Figure 1. If calculated facing stress is over 75% of rated facing stress, re-select a thicker or stronger facing.

FIGURE 1 ***Beam Chart*** (P must be determined for a unit width — b = 1")

Note: Center load x 2 = uniform load

BEAM TYPE				
Bending Deflection Constant K_b	.013	1/48	1/60	1/8
C_b	1/8	1/4	1/6	1/2
C_s	1/2	1/2	1/2	1



Sandwich Panels as Plates

For a sandwich panel supported on more than two sides, the deflection is less than sandwich panels supported as beams. By making the same assumptions as were made in sandwich panels as beams, we can make the same simplified calculations for preliminary design.

$$D = \lambda\, K_1 K_f\, qc\, \frac{B^4}{\Delta}$$

Where:

K_1 is obtained from Figure 3 (page 7).

K_f is obtained from Table 2 (page 6).

$q_c = K_c q$

q = Uniform load in psi

The calculation of D, and selection of skin thickness, t_f, and total panel thickness, d, are done the same as for beams. When checking skin stress and core shear stress use the following formula: Core Shear Stress use the following formula:

$$S = \frac{K_3 q_c b}{h}$$

Where: K3 is approximately 0.45

Facing Stress

$$F_s = \frac{K^2 q_c b^2}{h t_f}$$

K_2 is found by calculating b/a and referring to the following table:

TABLE 1 – K_2 VALUES

b/a	K_2
0.0 – 0.2	.125
0.2 – 0.4	.112
0.6	.090
0.7	.075
0.8	.066
1.0	.048

The calculated core shear and facing stresses should not be over 75% of the rated stress from Tables 2 & 3. If the load is not uniform, a uniform loading to simulate actual loading must be assumed for these equations to work.

Sample Problem

A 48" x 30" panel carries a uniform load of 5 psi. It is supported along the 30" width. Maximum allowable deflection is 0.75". It is attached by one row of fasteners (simply supported).

I. Calculate $D = \lambda\, K_f\, K_b\, P_c\, \dfrac{a^3}{\Delta}$

Since we don't know what kind of core we want, assume $K_c = 1.0$ for first calculation.

$P = qa$

$P_c = K_c qa = (1.0)\,(5\ \text{Ib./in.}^2)\,(48\ \text{in.}) = 240\ \text{Ib./in.}$

$a =$ 48 in., the unsupported span

$K_b = 0.013$, from Figure I for simply supported beams

$\lambda = 1.5$, safety factor

We select 2024T3 aluminum facings in this example for high rigidity–$K_f = 1.0$ from Table 2.

$$D = (1.5)\,(1.0)\,(0.013)\ \frac{(240\ \text{lb./in.})\,(48\ \text{in.})^3}{(0.75\ \text{in.})} = 6.9 \times 10^5\ \text{psi}$$

II. Referring to Figure 2, we select:

$t_f = 0.025"$

$d = 2.25"$

III. Calculate Core Shear Stress

$$S = \frac{C_s P_c}{h} = \frac{(0.5)\,(240\ \text{Ib./in.})}{(2.25\ \text{in.}-0.025\ \text{in.})}$$

Since this does not require a very strong core we could use 2.3 pcf aluminum honeycomb but say for some reason we decided to use a 4 lb. rigid polyurethane foam core. What needs to be done is go back to Step I and recalculate D using $K_c = 2.2$.

$D = \Delta\, K_f K_b P_c a^3/\Delta$ where P_c is corrected for foam

$P_c = (2.2)\,(5\ \text{lb./in.}^2)\,(48\ \text{in.}) = 528\ \text{lb./in.}$

$D = 1.5 \times 10^6$ psi

Referring to Figure 2 select a new value of t_f and d.

We select $d = 2.25"$ $t_f = 0.050"$; foam core has affected our design allowables. Recheck core shear stress.

IV. Check Facing Stress

Since we are using foam core use $P_c = 528$ lb./in. (if honeycomb core is used, $P_c = 240$ lb./in.).

$$FS = \frac{C_b P_c a}{h t_f} =$$

$$\frac{(1/8)\,(528\ \text{lb./in.})\,(48\ \text{in.})}{(2.25\ \text{in.}-0.050\ \text{in.})\,(0.050\ \text{in.})} = 28{,}800\ \text{psi}$$

Since 28,800 is under 75% of the 42,000 psi facing stress of 2024T3 aluminum (Table 2) we have a satisfactory panel design.

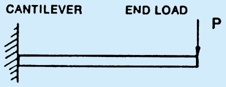
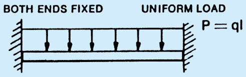
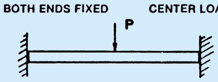
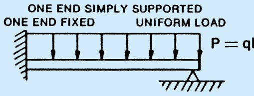
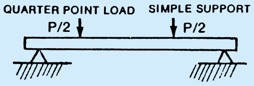
V. Additional Design

The core weighs $4\ \text{lb./ft.}^3 \times \dfrac{(2.15")}{12\ \text{m./ft.}} = 0.72\ \text{Ib./ft.}^2$

The skin weighs $2 \times (0.050") \times 14\ \text{lb./in.-ft.}^2 = 1.40\ \text{lb./ft.}^2$

Adhesive weighs = $0.10\ \text{lb./ft.}^2$

A thicker panel with lighter skins would reduce the sandwich panel weight.

CANTILEVER END LOAD  P	BOTH ENDS FIXED UNIFORM LOAD  P = ql	BOTH ENDS FIXED CENTER LOAD  P	ONE END SIMPLY SUPPORTED ONE END FIXED UNIFORM LOAD  P = ql	QUARTER POINT LOAD SIMPLE SUPPORT  P/2 P/2
1/3	.0026	.0052	.0054	.0143
1	1/12	1/8	1/8	1/8
1	1/2	1/2	5/8	1/2

Plate—Sample Problem

A 40" x 50" panel must withstand a 5 psi uniform load. The panel edges are fixed along all four sides. We assume a maximum allowable deflection of 1.0" ($\Delta = 1.0"$) and a safety factor of 2.0 ($\lambda = 2.00$).

I. Calculate Flexural Rigidity

We want to use epoxy—FRP skin ($K_f = 3.0$). Since all the edges are fixed we obtain a $K_1 = 0.0015$ (From Figure 3) for a b/a = 0.80, all edges fixed. As a first approximation choose $K_c = 1.0$.

$$D = l\, K_1 K_f\, q_c\ \frac{b^4}{\Delta}$$

$$D = \frac{(2.0)\,(0.0015)\,(3.0)\,(5\ \text{psi})\,(40")^4}{(1.0")}$$

$D = 1.2 \times 10^5$

II. Select d and t_f from Figure 2. Checking Figure 2 we select a skin thickness of 0.025" and a panel thickness of 1.00"

$d = 1.00"$

$t_f = 0.025"$

$t_c = 0.950"$

III. Calculate Core Shear Stress

$$S = \frac{K_3 q_c b}{h}$$

$$S = \frac{(0.45)\,(5\ \text{psi})\,(40")}{(1" - 0.025")} = 92.3\ \text{psi}$$

We decide to use 9 pcf balsa wood core. Since we are using balsa core instead of foam, we continue on with the design (if foam core was decided then a new D would need to be calculated etc.).

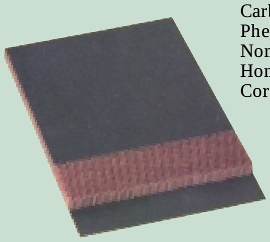
IV. Calculate Facing Stress

$$F_s = \frac{K^2 q_c b^2}{h t_f}$$

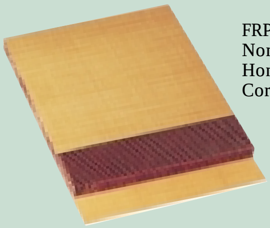
From Table 1 $K_2 = 0.066$ for a b/a = 0.80

$$F_s = \frac{(0.066)\,(5\ \text{psi})\,(40")^2}{(1.0")\,(0.025")} = 21{,}120\ \text{psi}$$

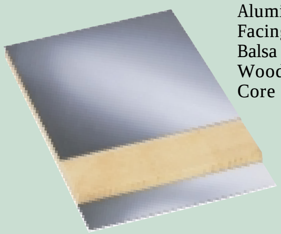
Since this is under 70% of the facing stress of an epoxy fiberglass composite (30,000 psi) our design calculations are done.



Carbon-Phenolic/Nomex Honeycomb Core



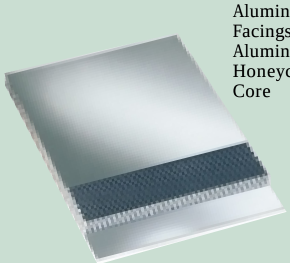
FRP Facings/Nomex Honeycomb Core



Aluminum Facings/Balsa Wood Core

FRP Facings/Balsa Wood Core

FRP-Epoxy Facings/Nomex Honeycomb Core



Aluminum Facings/Aluminum Honeycomb Core

TABLE 2 – MECHANICAL PROPERTIES OF TYPICAL SANDWICH FACING MATERIALS

Facing Material	Yield Strength f_f (psi x 10^3)	Modulus of Elasticity E_f (psi x 10^6)	Wt. per Mil Thickness (lb/ft^2)	K_f	Comments
Aluminum-2024-T3	42	10	0.014	1.0	Good strength, moderate cost
Aluminum-3003-H16	20	10	0.014	1.0	Moderate strength, good weathering when Alclad
Aluminum-5052-H32	23	10	0.014	NA	Coated for corrosion resistance
Aluminum-6061-T6	21	10	0.014	1.0	Workable, corrosion resistant
Aluminum-7075-T6	60	10	0.014	1.0	High tensile strength and dent resistant
Cold rolled carbon steel- 1.5% carbon content	50	28	0.040	.35	Low cost, high weight, hard to cut with hand tools
Stainless steel-316	60	29	0.040	.33	Heavy, expensive, hard to bond and fabricate with hand tools; high rigidity and strength
Titanium: Annealed Ti-75A	70	15	0.0235	.67	High cost, low corrosion, hard to bond, hard to machine
Fiberglass cloth laminates					
Epoxy-Gillfab 1040	30	3.3	0.01	3.0	Std. epoxy, 180°F service temp.
Epoxy-Gillfab 1045	30	3.3	0.01	3.0	High strength, 250°F service temp.
Phenolic-Gillfab 1002	30	3.0	0.01	3.0	Retains strength well at 350°F, most fire-resistant
Polyester-Gillfab 1074	33	3.0	0.01	3.0	Good strength
Polyimide-Gillfab 1028	22	2.5	0.01	3.3	Retains strength at 400°F
Polyester-glass-mat- Gillab 990C	16	1.8	0.01	5.0	Lowest cost, excellent corrosion, resistance, low flex strength and modulus
Polyester- woven rovings- Gillite 1027 (24oz.)	25	2.0	0.01	4.6	Low cost, general purpose laminate
Kevlar®-epoxy-Gillfab 1313	18	2.5	0.0068	6.0	Moderate strength, light weight
Kevlar®-phenolic-Gillfab 5055	16	2.0	0.0068	NA	Light weight, low smoke
Carbon-epoxy-Gillfab 1089	65	16.0	0.008	1.6	High cost, strength, stiffness; guard against galvanic corrosion
Carbon-phenolic-Z119	60	15.0	0.008	NA	High cost, strength, stiffness; guard against galvanic corrosion
Douglas fir plywood	2.6	1.5	0.003	7.3	Low cost, poor weathering, heavy
Tempered hardboard	2.0	0.6	0.0045	16.0	Low cost, low strength, heavy

NA= not available

TABLE 3 – PROPERTIES OF TYPICAL CORE MATERIALS

Core	Cell Size in.	Foil Th. in.	Density pcf	Shear Str. psi L/W Dir.*	Shear Mod. ksi L/W Dir.*	Stabilized Compress. Strength psi	Heat Transfer U = BTU/ hr/ft^2/°F
Aluminum Honeycomb	1/8	.0007	3.1	155/90	45/22	215	0.85
	1/8	.001	4.5	285/168	70/31	405	0.95
	1/8	.002	8.1	670/400	135/54	1100	0.95
	3/16	.002	5.7	410/244	90/38.5	600	0.95
	1/4	.001	2.3	100/57	32/16.2	130	1.00
	1/4	.002	4.3	265/155	66/29.8	370	1.00
	1/4	.003	6.0	445/265	96/40.5	660	1.00
	3/8	.003	4.2	255/150	65/29	355	1.00
Glass Cloth / Phenolic Honeycomb	3/16		4.0	210/110	11.5/5.0	480	0.45
	3/16		5.5	370/190	19.5/8.5	750	0.50
	1/4		3.5	170/100	9/3.5	400	0.50
	1 /4		4.5	250/140	14/6.0	560	0.50
Aramid Fiber Honeycomb (Nomex®)	1/8		1.8	65/36	3.7/2.0	85	0.42
	1/8		3.0	160/85	7.0/3.5	270	0.45
	1/8		5.0	235/175	11.1 /5.4	660	0.45
	1/8		9.0	370/240	17.0/9.0	1600	0.42
	1/4		3.0	135/60	7.0/3.0	240	0.50
	3/16		6.0	330/150	14.0/6.0	650	0.50
Paper Honeycomb	1/4		5.0	192/86	30.2/6.5	400	0.40
	1/2		2.2	79/41	11.9/4.4	140	0.60
Gillfoam® (Phenolic)			7	103	3.6	190	.257
			10	152	6.4	334	.293
			18	320	9.5	1257	.408
Polyurethane Foam			2.0	20	0.226	27	0.14
			4.0	48	0.750	80	0.14
			6.0	90	1.50	140	0.18
			20.0	450	15.00	850	0.40
PVC Foam Closed Cell			3.5	78	1.8	110	0.10
			6.2	120	2.2	200	0.18
End grain Balsawood (Ochroma pyramidale)			6.0	140	16.0	750	0.3
			9.5	220	28.0	1500	0.4

*For Honeycomb cores: L = ribbon direction; W = transverse direction

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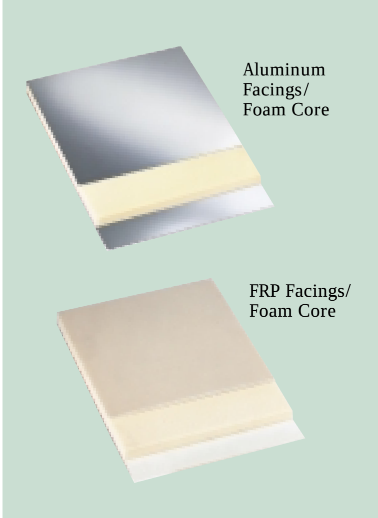


TABLE 4
PROPERTIES OF FOAMS, COMMONLY USED IN AIRCRAFT SANDWICH PANELS

Type of Foam	Density PCF	Compressive Strength, PSI	Compressive Modulus PSI	Shear Strength PSI	Shear Modulus PSI	K-Factor BTU/in hr ft² °F
Test Method	ASTM D-1622	ASTM D-1621	ASTM D-1621	ASTM C-273	ASTM C-273	ASTM C-518
Polyurethane	18	877	8,750	548	16,322	.34
PVC	7	128	2,591	199	8,553	.27
Rohacell	6.9	427	NA	341	22,700	NA
Gillfoam	7 10 18	190 334 1,257	3,799 6,741 22,935	103 152 320	3,647 6,408 9,488	.26 .29 NA

FIGURE 2 *Flexural Rigidity Curve for Aluminum Facings*

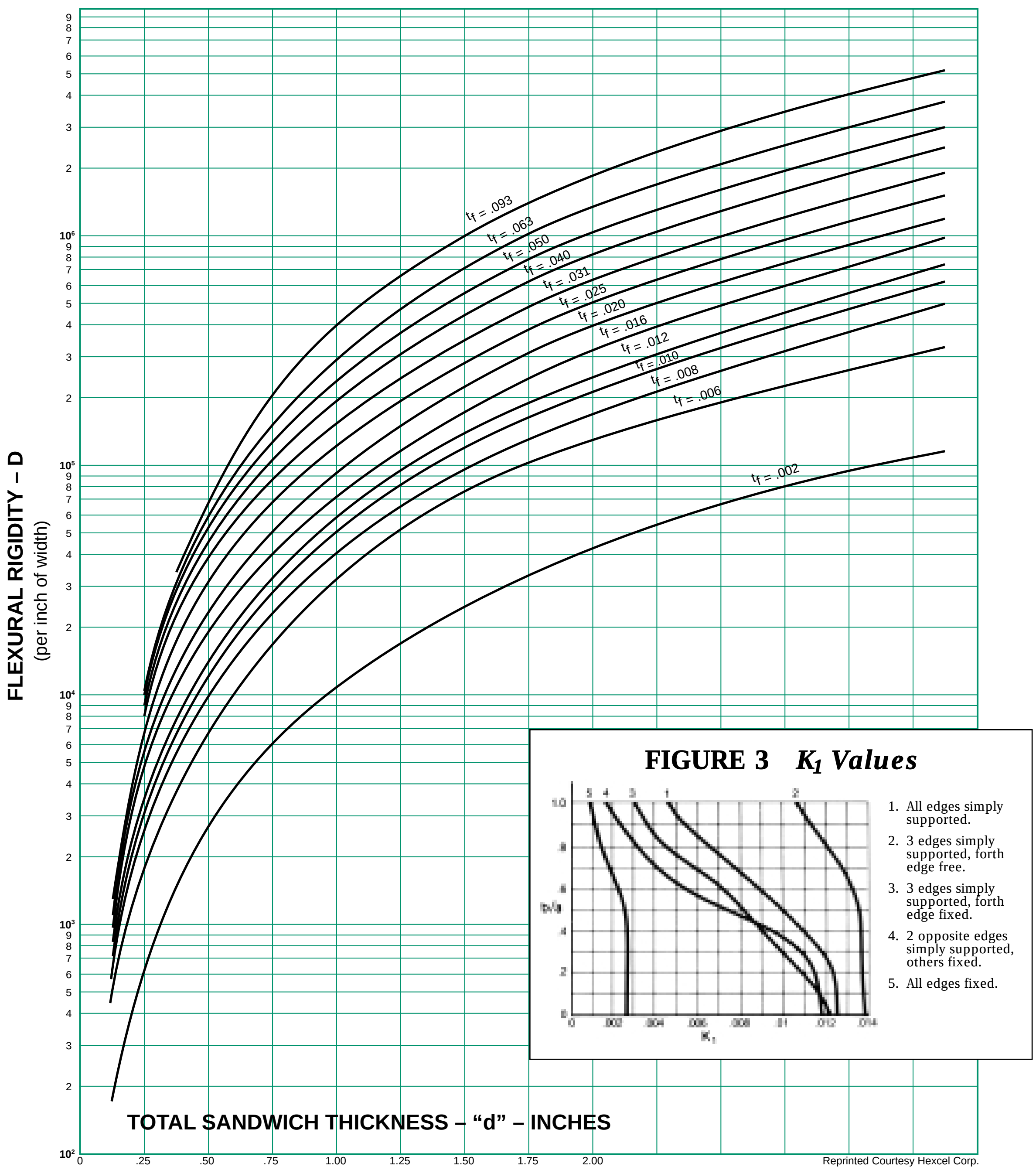


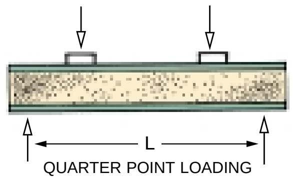
FIGURE 3 *K_1 Values*

1. All edges simply supported.
2. 3 edges simply supported, forth edge free.
3. 3 edges simply supported, forth edge fixed.
4. 2 opposite edges simply supported, others fixed.
5. All edges fixed.

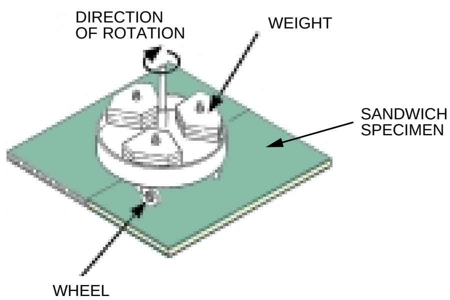
Reprinted Courtesy Hexcel Corp.

The Most Important Property

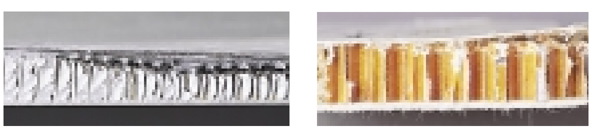
Based on our 50 plus years of experience, we believe the following



Long Beam Flex tests the facings (which should fail before the core in this test). It is the standard test for determining the load bearing capability of a sandwich panel. It tells you how much weight the panel will support and how much deflection you will experience.

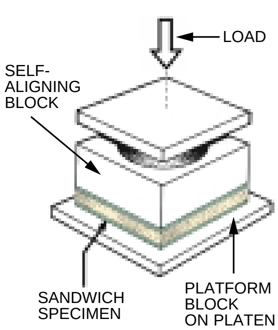


Roller Cart test determines the fatigue resistance of the core in an aircraft flooring panel. The test is a meaningful approximation of how flooring will stand up in-service in the aisles of commercial passenger aircraft. It simulates the wear and tear created by food and beverage carts in the aisleways and galleys of these aircraft.

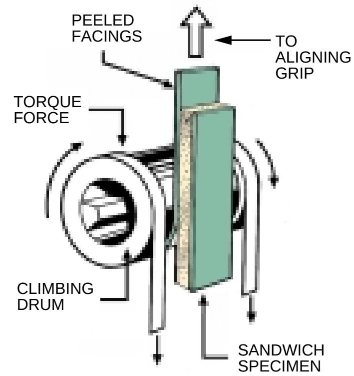


EXAMPLES OF CORE FAILURE IN AN ALUMINUM HONEYCOMB CORE PANEL (LEFT) AND A NOMEX HONEYCOMB CORE PANEL (RIGHT).

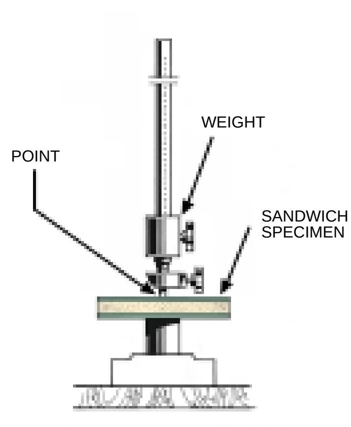
Core Shear tests the core (which should fail first in this test). It reduces the span on a flex test to 15-20 times the panel thickness to see where the core will fail before the facings. It tells you, using a different test method for another component of the panel, essentially the same thing long beam flex does.



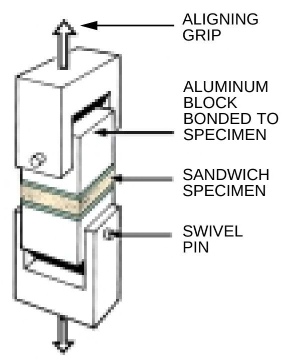
Flatwise Compressive measures the strength of the core in resisting compressive loads, such as women's spiked heels where loads might reach 4,100 psi.



Climbing Drum Peel measures the torque to peel the facing from the core. You don't want the facings pulling away from the core because it reduces the strength of the panel. However, experience has taught us that panels with quite low peel will serve quite well as flooring if the edges are not exposed to peel forces. For example, some of our 5007A panels with low peel values have lasted 20,000 hours in the aisles of jet aircraft. Delaminated flooring is spongy and tends to upset passengers.



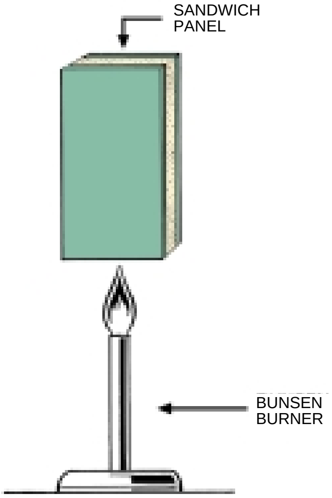
Impact measures the panel's resistance to damage from impact or puncture i.e., weights such as mechanics' tools dropping on an unprotected panel, as well as women's stiletto heels.



Flatwise Tensile measures the strength of the adhesive—a good indication of structural strength of core and adhesive, two very important contributors to the overall strength of the panel.

Tests of Sandwich Panels

property tests we perform in our labs are most important.

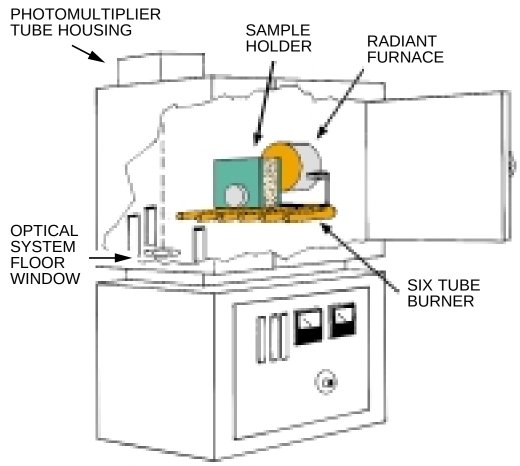


Flame Test (vertical). This test indicates how a panel will perform in a fire. Thickness is the same as that qualified for use in an aircraft. The raw panel edge is subjected to a minimum 1550° F flame for 60 seconds. Extinguishing time (time it takes for the panel to stop burning *after* the flame is removed) and burn length are measured. This is a small scale test and performance in large fires can vary dramatically.

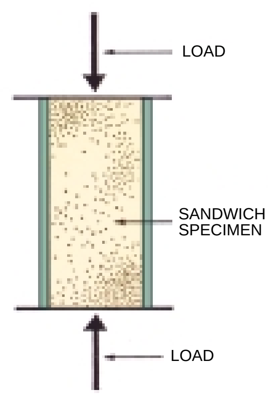
Smoke, Toxic Emissions and Heat Release. Low smoke and toxic emissions, and low heat release are arguably the most important properties from a safety standpoint. One result of the tragic aircraft crashes during the 80s and 90s is increasing concern related to passenger hazards caused by post crash conditions, namely fire, smoke and heat.

Heat release values are reported in terms of kilowatts of heat per square meter for the peak heat release and in terms of kilowatt-minutes per square meter for a two minute integrated heat release. The FAA's maximum values are 65 and 65 for peak and total heat release.

A one square foot piece of red oak flooring one-half inch thick yields readings of 130 and 130 – twice that currently allowed by the FAA.



NIST (NBS) Smoke Chamber measures the smoke emitting properties of materials when exposed to heat and flame under flaming and non-flaming conditions. In other words, if there is a fire, how much smoke will the panel emit and how will passenger and crew visibility be affected.



Edgewise Compressive Test
This test measures the load carrying capacity of the sandwich panel when loaded as a column. Specimens should be at least 2" wide and the unsupported length should be 4-8 times the panel thickness.

These are only a few of the tests normally used to measure the properties of sandwich panels. We describe them here to allow the reader to better visualize what the numbers represent. The formulations for calculating the values of each of these tests are available on request to the Marketing Services Department.

Some of the newer flooring panels we have recently

TABLE 5 – PHYSICAL AND MECHANICAL PROPERTIES
SELECTED M.C. GILL SANDWICH PANELS – BOEING & DOUGLAS AIRCRAFT

Product	Core Type and density	Adhesive	Top facing	Bottom facing	Panel thickness (inches)	Panel weight (lb/ft^2)	Flex strength 20" span 2 pt. load Ult. load (lbs)	Defl. @ 100 lbs (inches)	Climbing drum peel strength (in-lbs/3" width) Top	Bottom
Test Method							Mil Std 401B		Mil Std 401B	
4409 Ty II	1/8" cell, 9 pcf, Aramid honeycomb	Modified phenolic	.010" Unidir carbon/ phenolic	.010" Unidir carbon/ phenolic	0.402	0.55	346	0.406	21.7	21.7
4409 Ty III	1/8" cell, 5 pcf, Aramid honeycomb	Modified phenolic	.010" Unidir carbon/ phenolic	.010" Unidir carbon/ phenolic	0.403	0.44	269	0.419	22.1	22.1
4417 Ty I	1/8" cell, 5 pcf, Aramid honeycomb	Modified epoxy	.015" Unidir FRP/epoxy	.015" Unidir FRP/epoxy	0.396	0.515	273	0.796	32	32
4417 Ty II	1/8" cell, 9 pcf, Aramid honeycomb	Modified epoxy	.015" Unidir FRP/epoxy	.015" Unidir FRP/epoxy	0.397	0.628	291	0.792	35	35
4417 Ty III	1/8" cell, 9 pcf, Aramid honeycomb	Modified epoxy	.022" Unidir FRP/epoxy	.022" Unidir FRP/epoxy	0.400	0.758	382	0.540	31	31
4417 Ty IV	1/8" cell, 5 pcf, Aramid honeycomb	Modified epoxy	.015" Unidir FRP/epoxy	.015" Unidir FRP/epoxy	0.659	0.637	518	0.261	32	32
4509 Ty 1	1/8" cell, 8 pcf, Aramid honeycomb	Modified phenolic	.012" Unidir carbon/ phenolic	.012" Unidir carbon/ phenolic	0.393	0.521	500	0.265	25.5	25.5
4509 Ty 2	1/8" cell, 4 pcf, Aramid honeycomb	Modified phenolic	.012" Unidir carbon/ phenolic	.012" Unidir carbon/ phenolic	0.3883	0.418	434	0.291	23.6	23.6
5424 Ty I	1/8" cell, 6.1 pcf, 5052 alloy, aluminum honeycomb	Modified epoxy	.015" Unidir FRP/epoxy	.015" Unidir FRP/epoxy	0.400	0.543	283	0.739	40	40
5424 Ty II	1/8" cell, 8.5 pcf, 5052 alloy, aluminum honeycomb	Modified epoxy	.015" Unidir FRP/epoxy	.015" Unidir FRP/epoxy	0.400	0.633	314	0.679	42	42
5433C	Fire retardant epoxy woven FRP	Epoxy	.016" aluminum alloy 2024T3	.020" aluminum alloy 2024T3	0.058	0.75	NR	NR	40	40

Note: NR means not required by customer specification. * Called insert membrane.

TABLE 6 – PHYSICAL AND MECHANICAL PROPERTIES
SELECTED M.C. GILL SANDWICH PANELS – AIRBUS INDUSTRIE AIRCRAFT

Product	Core type and density	Adhesive	Top facing	Bottom facing	Panel thickness (inches)	Panel weight (lb/ft^2)	Distributed surface load (lbs) 0.43" load (lbs)	0.67" 100 lbs (inches)	Ultimate load	Concentrated load without deformation (lbs)	Impact strength (ft lbs)
Test Method							Airbus Industrie TL 63/5000/79 (Gillfab 4105) DAA/MBB/A1 5360 M16 000100 (Gillfab 4205, 4322, and 4323)				
4105	3/16" cell, 6 pcf Aramid honeycomb	Modified epoxy	.025" woven FRP epoxy	.025" woven FRP epoxy	.374	.676	NA	NA	5000	>200	NA
4205	3/16" cell, 6 pcf Aramid honeycomb	Modified epoxy	.025" Fiberglass fabric/carbon fiber	.025" Fiberglass fabric/carbon fiber	.374	.705	1000	1750	4500	>192	NA
4322	3/16" cell, 6 pcf Aramid honeycomb	Modified epoxy	.024" Fiberglass/ phenolic	.022" Fiberglass/ phenolic	.374	.697	NA	>1414(3)	3800	>200	7.0
4323	3/16" cell, 6 pcf Aramid honeycomb	Modified epoxy	.030" Fiberglass/ phenolic	.020" Fiberglass/ phenolic	.496	.756	NA	>2434(3)	5567	>200	18.0

Notes: FRP means glass reinforced plastic.
NA means not applicable.

(1) Per DAA/AI Specification ATS 1000.001.
(2) Per FAR Part 25, Appendix F, Part III.
(3) Minimum load without permanent deformation.

qualified at Boeing, McDonnell Douglas, and Airbus

TABLE 5 – CONTINUED – PHYSICAL AND MECHANICAL PROPERTIES
SELECTED M.C. GILL SANDWICH PANELS – BOEING & DOUGLAS AIRCRAFT

Product	Stabilized compressive strength (psi)	Flatwise tensile strength (psi)	In-plane shear strength (psi)	2 lb. Gardner impact (in-lbs)	Insert shear strength (lbs)	Roller cart (test cycles to failure)	30 day 97% humidity soak		
							20" flex strength	climbing drum peel	Specifications
Test Method	Mil Std 401B	Mil Std 401B	BMS 4-17D	Model 11K3	Shur-Lok 5107-A3	Mil Std and DAC Dwg 7954400	Mil Std 401B	Mil Std 401B	
4409 Ty II	1943	NR	358	19.7	1431	120,076/ 36,781	302	18.0	Boeing BMS 4-20
4409 Ty III	814	NR	340	20.0	1322	82,300	279	19.0	Boeing BMS 4-20
4417 Ty I	846	NR	385	131	1839	83,964	244	39.0	Boeing BMS 4-17
4417 Ty II	2030	NR	444	108	1957	121,020/ 38,427	252	52.0	Boeing BMS 4-17
4417 Ty III	2236	NR	382	166	1931	120,001/ 35,083	298	49.0	Boeing BMS 4-17
4417 Ty IV	771	NR	408	127	1719	83,804	460	50.0	Boeing BMS 4-17
4509 Ty 1	1568	NR	412	26	1329*	111,002	482	25.8	Douglas DAC Dwg 7954400, Ty 1
4509 Ty 2	574	NR	404	24	1132*	NR	410	22.2	Douglas DAC Dwg 7954400, Ty 2
5424 Ty I	1086	NR	455	111	1952	83,570 (No failure)	246	50	Boeing BMS 4-23
5424 Ty II	1777	NR	451	172	2023	121,652 (No failure)	267	54	Boeing BMS 4-23
5433C	NR	L (0) 85 Lt (90) 83	NR	31	NR	NR	NR	NR	Boeing BMS 7-326 Ty VII, Cl 2/1

Note: NR means not required by customer specification. * Called insert membrane.

TABLE 6 – CONTINUED – PHYSICAL AND MECHANICAL PROPERTIES
SELECTED M.C. GILL SANDWICH PANELS – AIRBUS INDUSTRIE AIRCRAFT

Product	Compressive fatigue 2 x 10^6 cycles	In-Plane panel shear (lbs force)	Building fatigue lower limit 34 lbs upper limit 337 lbs 2 x 10^6 cycles	Roller cart (test cycles to failure)	Insert pull-out lbs)	Flammability	Smoke D, flaming 240 sec Non-flaming 240 sec	Toxic gas emission(1)	Heat release	Oil Burner(2)
Test Method	Airbus Industrie TL 53/5000/79 (Gillfab 4105) DAA/MBB/A1 5360 M1B 000100 (Gillfab 4205, 4322, and 4323)					DAA/ATS 1000.001			FAR 25.853/FAR 26.855	
4105	NA	29,000	NA	>128lbs – 120,000 >158lbs – 35,000	1700	PASS	NA	NA	NA	NA
4205	PASS	24,100	PASS	>128lbs – 120,000 >158lbs – 35,000	2300	PASS	34 2	PASS	44.4/ 44.3	NA
4322	NA	NA	NA	NA	1700	PASS	60 3	PASS	45/45	PASS
4323	NA	NA	NA	NA	1679	PASS	83 7	PASS	43.6/ 37.0	PASS

Notes: FRP means glass reinforced plastic.
NA means not applicable.

(1) Per DAA/AI Specification ATS 1000.001.
(2) Per FAR Part 25, Appendix F, Part III.
(3) Minimum load without permanent deformation.

How To Order Sandwich Panels

Calling out a specific Gill part number or a customer specification along with length, width, thickness, and quantity should provide the information we need. If no part numbers or specifications are available, the facings, core and adhesive must be specified.

FACINGS. Generally, they are aluminum or reinforced plastic. For these, we need thickness, length and width, and if splicing the facings is necessary, is that acceptable? If so, how is it designated? If the facings are metal we need to know alloy and surface treatment, e.g., Alclad or anodized.

CORE. Usually end grain balsa wood; aluminum or Nomex honeycomb; or foam—polyurethane, acrylic, phenolic, polyvinyl chloride (PVC), or Gillfoam.

END GRAIN BALSA. Our standard core is 6 or 9 pcf (pounds per cubic foot) average density, produced to our proprietary specification. If your requirements differ, please be sure to specify them.

ALUMINUM HONEYCOMB. Typically called out by cell size, alloy, cell wall thickness, and perforated or not.

NOMEX HONEYCOMB. Usually specified by cell size, wall thickness, and density in pcf.

FOAM. Can be ordered by type and density in pcf; or material specification.

ADHESIVE. This is the crucial sandwich panel component and yet less is known about the adhesive required than other parts of the sandwich panel. Our adhesives meet the two common adhesive specifications—MMMA 132 Type 1, Class 2 and 3, and MIL-A-25463A. If you have special adhesive requirements, please advise our Customer Service Department when placing an order or RFQ.

QUANTITY TOLERANCES. Shipping tolerance can vary from ± 10% to ± 0%. Zero quantity tolerance requires more intricate scheduling, but can be slower and will be more costly.

DIMENSIONAL TOLERANCES. For raw stock panels, length and width tolerances are normally + 1/2" – 0" with diagonal squareness measurements equal to 3/32 (0.0938) x width in feet. Thickness tolerance is to ±.010." If specific tolerances are required, they must be specified with the order or RFQ. Tolerances will meet the material specification if called out.

If you are formally requesting a quotation, we will fax you our standard Quotation Sheet to document the exact description of the product and our unit price. That Quotation Sheet is our precise understanding of what you expect us to supply. We have prepared a six-page bulletin on "How To Order Gill Products" If you would like a copy, please contact the Marketing Services Department.

When I go out to eat I go where the cook owns the restaurant, the wife keeps the books and the waiter knows my name.

How good the cook, how gracious the hostess and how consistent the quality and service, determines how often I return.

If there is a parallel between cooking prime rib and laminating sandwich panels, the big difference would be that the cook often is secretive about his recipe and process, whereas with sandwich panels the opposite is true.

I don't feel confident in recommending a chef, but where laminators are concerned I can give you some helpful hints because you have every right to expect that what you pay for will consistently satisfy your requirements.

First, laminating should be your supplier's principle activity—not just a sideline.

Second, determine how long they have been pressing sandwich panels. There is no substitute for experience.

Third, look at their largest customers, dollarwise.

Next, ascertain the nature of the products pressed for these customers—are they similar to yours?

Then, to best control quality they should make their own adhesives, facings, and core.

Find out if they have a Quality Assurance Program that approves raw material suppliers, inspects raw materials on receipt and work-in-progress, and has on-premises testing facilities.

And, know if they have an R & D Department that supports production and whose personnel are qualified in sandwich panel laminating.

Also, consider integrity, financial strength, and reputation for customer service.

There never has been a specification written that covers all aspects of quality nor one that guarantees it will meet your end use. "First-articles" are a must!

As for ourselves, we've been pressing laminates for 42 years and continue to improve and fine-tune materials and processes—this comes with specialization and dedication. That will be hard to duplicate.

Excellence in the Quality Assurance Process

A NEW STREAMLINED PROCEDURE... ANOTHER M.C.GILL MILESTONE

Stephen Gill, President and CEO, accepts the "Superior Quality and Sustained Excellence" Certificate from Rick Peyatt, Northrop Grumman.

"This award goes to the employees of the M.C.Gill Corporation because they're the ones that earned it– not just the Quality Assurance Department, but the entire company."

And with that, Rick Peyatt, Administrator of Supplier Variability Reduction of Northrop Grumman, presented a certificate "In Recognition of Superior Quality and Sustained Excellence" to Stephen Gill on behalf of all M.C. Gill Corp. employees.

What it means is that Northrop Grumman accepts the results of M.C. Gill's quality inspection instead of sending one of their source inspectors to our plant to approve a part(s) already inspected and accepted by us. Moreover, our approval obviates the necessity of another inspection when the part(s) arrive at Northrop Grumman's receiving area–from our dock to their stock, so to speak.

This new procedure eliminates redundant inspection both at our site and theirs. It further saves time for us because our QC personnel do not have to schedule an appointment for their source inspector, wait for his arrival, and accompany him as he performs his inspection.

Likewise, Northrop Grumman doesn't arbitrarily pick one of their suppliers and say, "Okay, now you do the quality inspection instead of us." The selections are based on vendor quality history, e.g., number and frequency of rejections. Once a supplier is selected, one or more of its QC staff attends a certification class at Northrop Grumman and learns how to fill out and process forms required for traceability, and the procedures for coordinating a smooth transition of completed parts from here to there.

Currently, M.C. Gill's Quality Director, a QC Manager, and a QC Inspector are certified to act as Northrop Grumman's source inspectors. We know what we expect from our top suppliers and we are guided by those expectations when it comes to our performance. Quality and customer service is at the top of our emphasis chart and our certification from Northrop Grumman indicates that philosophy is working.

M.C. Gill Expands to Europe....

"As reported in a News Flash in the Spring 1997 issue, the M.C. Gill Corporation has purchased the assets of Insoleq Ltd. of Belfast, Northern Ireland.

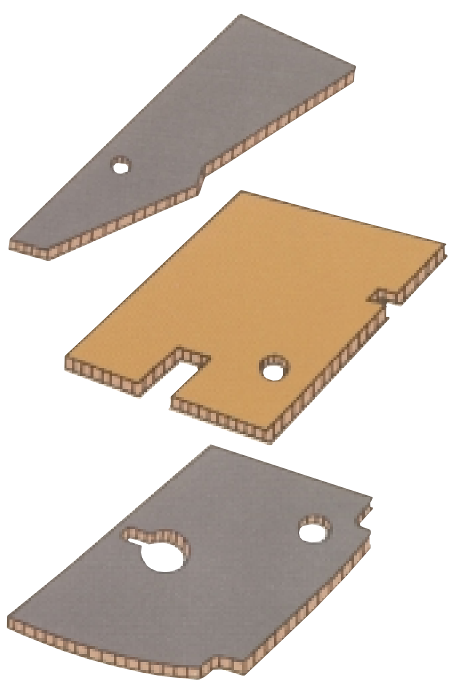
The driving force behind the purchase was a long standing desire to establish a physical presence in Europe to better serve our many European customers. In addition to Insoleq's existing manufacturing activities, M.C. Gill will establish a warehouse and distribution center for the company's products.

Establishment of a European distribution facility has long been high on the Corporation's list of priorities; so high, in fact, that Stephen Gill, president and CEO flew to Belfast personally to close the deal.

"Our customers have been requesting for some time that we locate in Europe and now we can say to them, 'Here we are,'" said Gill in making the announcement. "In addition to serving our customers in a more efficient and expeditious manner, this purchase will help us build on the market we have catered to in Europe since the early 1960's," Gill concluded.

Insoleq was founded in 1983 as a manufacturer of thermal and acoustic insulation packages for commercial aircraft. Its first customer was Shorts PLC for their SD330 and 360 aircraft.

Insoleq technician monitors the CNC fabrication of parts similar to those in the drawings below.



Capabilities for fabricating to any specified configuration.

Approvals and contracts with British Aerospace (BAe) soon followed. In 1988, the company expanded its product line and operations to include the fabrication of aircraft flooring panels for BAe's 146, ATP and 125 100 aircraft.

Using M.C. Gill's raw stock panels and a computer numerically controlled (CNC) profiler, Insoleq provided finished "drop-in-ready" flooring for the afore-mentioned aircraft.

"With the Insoleq facilities already in place, we can warehouse and ship our products from a point thousands of miles closer to our customers than in the past and broaden our product line at the same time," stated Mr. Gill. "This move is simply a logical step in the M.C. Gill Corporation's long range plan of orderly and systematic growth throughout the world. Most assuredly, we will retain Insoleq's employees because it just makes good sense to keep that experience and expertise in place," he concluded.

Frank Thompson will serve in the capacity of Insoleq's Managing Director and Gary Morrison will act as its Operations Manager. Messrs Thompson and Morrison can be reached at Insoleq–Semafour Ltd, Quarry Heights, North Road, Newtownards, NORTHERN IRELAND BT23 3SZ; by phone at 44 1247 822 800; or fax at 44 1247 822 811.

..and Grows in Seattle.

To commemorate that opening, the quarterly Board of Directors meeting was held in Seattle this past July 18th. The night before, the Board and several guests from Boeing celebrated with a reception and dinner at the Rainier Club.

"The company has grown to the point where we do not have to base our entire domestic sales organization in Southern California. We've reached a stage where some decentralization makes sense and the Seattle area was a logical step for us to take." So said Stephen E. Gill, President and CEO of the M.C. Gill Corp., in announcing the opening of the company's Seattle, Washington area office in Issaquah.

The move to Washington is simply one in a series of planned expansions that will allow the M.C. Gill Corp. to better serve its customer base—in this case Boeing and other customers in and around the Seattle area.

The office will be manned by Larry Russell, Director of OEM Sales and is located at 545 Rainier Blvd. N., Suite 12 in Issaquah (98027); phone 425-392-1434; fax 425-392-1437; or e-mail at lrussell@cyberspace.com.

Please note our new area code in El Monte, California

It applies to both our telephone numbers and fax numbers as follows:
Telephone: 626-443-6094 or 626-443-4022
Fax: 626-350-5880 or 626-279-6051

Stephen Gill and Larry Russell–M.C. Gill Corp.

M.C. Gill; David Fry–Boeing; Gil-Speed–an M.C. Gill Director

Sharon Volk–Boeing; Mrs. Phillip Gill; and Sharon Romero–Boeing

Paul Lee–CPA; Howard Alphson, and Stephen Gill–Directors of M.C. Gill Corp.

Phillip Gill–Royal Plastic and an M.C. Gill Director; Tim Meskill–Boeing; Don Clark–corporate attorney and Jack Steele–M.C. Gill Director

Bill Lee–Boeing with Larry Russell

Lee Ellis–Boeing; Howard Alphson with M.C. Gill

Lou Schwind–Boeing and Mrs. M.C. Gill

PLEASE NOTE
OUR NEW AREA CODE

It applies to both our telephone numbers and our fax numbers as follows:

Telephone: 626-443-6094 or 626-443-4022
Fax: 626-350-5880 or 626-279-6051

THE FUNNY SIDE

Many problems don't exist until a government agency is created to solve them.

★★★★

Middle age: When your children tell you you're driving too slowly and your parents tell you you're driving too fast.

★★★★

IRS auditor to taxpayer, "the secret is to stop thinking of it as your money."

★★★★

A picture is worth a megabyte.

★★★★

If at first you don't succeed, find out if the loser gets anything.

★★★★

A bachelor is a guy who thinks Twinkies and beef jerky are two of the major food groups.

★★★★

Then there was the guy who tried to convince his wife that "polyester" was the scientific name for "mink."

★★★★

Adam and Eve had the ideal marriage. He never compared her cooking to his mother's and she never talked about all the men she could have married.

★★★★

If the world is getting smaller why do postal rates keep increasing?

★★★★

If necessity is the mother of invention, how come so much unnecessary stuff gets invented?

Trivia

Mankind could survive a maximum of six months if there were no more invertebrates.

★★★★

At age 14 Ralph Waldo Emerson entered Harvard, Alfred Hitchcock quit school, and Joseph Stalin entered Theological Seminary.

★★★★

It was once said of Vince Lombardi that he possessed minimal football knowledge and lacked motivation.

★★★★

"J" is the newest letter in the English alphabet; "O" is the oldest; "Y" and "Z" were added in the 1st century.

★★★★

Boeing used to be called Pacific Aero Products, Nike was first known as Blue Ribbon Sports, the M.C. Gill Corp started as Peerless Plastic Products, Inc., and Maytag was once the Parsons Bandcutter and Self Feeder Co.

★★★★

Only an ostrich has larger eyes than a horse.

★★★★

600 million watched the first moon landing on television; 700 million watched Prince Charles' and Princess Di's wedding; one billion watch Bay Watch—everyday.

★★★★

M&M's were introduced in the 40s and the only color available was violet.

★★★★

30 million gallons of wine were lost in the 1906 San Francisco earthquake.

★★★★

The line of Chun King Chinese foods was founded by an Italian-American.

We apologize for not including Jokes and Trivia
but you'll get a few chuckles from this episode 3 of "Pigs is Pigs."

PIGS IS PIGS

Episode 3

The story thus far: Mr. Morehouse balked at paying Mike Flannery (agent for the Interurban Express Company) "livestock" freight charges for two guinea pigs ordered for his son, claiming the should be billed at the lower rate for "pets" and explained this by letter to Interurban's CEO, who advised he take the matter up with the Claims Department. Claims referred Morehouse's letter to the Tariff Department who, in turn, queried Agent Flannery as to a) why he had refused the pet rate, and b) the pigs' condition. He replied a) "Pigs is Pigs" and they (all EIGHT of them by now) are "well and hearty and who will repay the $2 O'ive spent spent on cabbages which they like?" Tariff suggested Flannery present the bill to Morehouse, which he did. Our story continues.

"Pay— Cabbages—!" gasped Mr. Morehouse. "Do you mean to say that two little guinea-pigs-"

"Eight!"said Flannery. "Papa an' mamma an' the six childer. Eight!"

For answer Mr. Morehouse slammed the door in Flannery's face. Flannery looked at the door reproachfully,

"I take ut the con-sign-y don't want to pay for thim kebbages," he said. "If I know signs of refusal, the con - sign - y refuses to pay for wan dang kebbage leaf an' be hanged to me!"

Mr. Morgan, the head of the Tariff' Department, consulted the president of the Interurban Express Company regarding guinea-pigs, as to whether they were pigs or not pigs. The president was inclined to treat the matter lightly.

"What is the rate on pigs and on pets ?" he asked.

"I take ut the con-sign-y don't want to pay."

"Pigs thirty cents, pets twentyfive," said Morgan.

"Then of course guinea-pigs are pigs," said the president.

"Yes," agreed Morgan, "I look at it that way, too. A thing that can come under two rates is naturally due to be classed as the higher.

But are guinea-pigs, pigs ? Aren't they rabbits?"

"Come to think of it, "said the president, "I believe they are more like rabbits. Sort of half-way station between pig and rabbit. I think the question is this—are guinea pigs of the domestic pig family? I'll ask professor Gordon. He is authority on such things. Leave the papers with me. "

The president put the papers on his desk and wrote a letter to Professor Gordon. Unfortunately the Professor was in South America collecting zoological specimens, and the letter was forwarded to him by his wife. As the Professor was in the highest Andes, where no outsider, had ever penetrated, the letter was many months in reaching him. The president forgot the guinea-pigs, Morgan forgot them, Mr. Morehouse forgot them, but Flannery did not. One-half of his time he gave to the duties of his agency; the other half was devoted to the guinea-pigs. Long before Professor Gordon received the president's letter Morgan received one from Flannery.

"About them Guinea-pigs, "it said, "what shall I do they are great in family life, no race suicide for them, there are thirty-two now shall I sell them do you take this express office for a menagerie, answer quick."

Morgan reached for a telegraph blank and wrote:

"Agent, Westcote. Don't sell pigs."

He then wrote Flannery a letter calling his attention to the fact that the pigs were not the property of the company but were merely being held during a settlement of a dispute regarding rates. He advised Flannery to take the best possible care of them.

Flannery, letter in hand, looked at the pigs and sighed. The drygoods box cage had become too small. He boarded up twenty feet of the rear of the express office to make a large and airy home for them, and went about his business. He worked with feverish intensity when out on his rounds, for the pigs required attention and took most of his time. Some months later, in desperation, he seized a sheet of paper and wrote "160" across it and mailed it to Morgan. Morgan returned it asking for explanation. Flannery replied:

"There be now one hundred sixty of them pigs, for heavens sake let me sell off some, do you want me to go crazy, what."

"Sell no pigs," Morgan wired.

Not long after this the president of the express company received a letter from Professor Gordon. It was a long and scholarly letter, but the point was that the guinea-pig was the Cavia aparoea while the common pig was the genius Sus of the family Suidae. He remarked that they were prolific and multiplied rapidly.

"They are not pigs," said the president, decidedly, to Morgan. "The twenty-five cent rate applies."

Morgan made the proper notation on the papers that had accumulated in File A 6754, and turned them over to the Audit Department. The Audit Department took some time to look the matter up, and after the usual delay wrote Flannery that as he had on hand one hundred and sixty guinea-pigs, the property of consignee, he should deliver them and collect charges at the rate of twenty-five cents each.

Flannery spent a day herding his charges through a narrow opening in their cage so that he might count them.

"Audit Dept." he wrote, when he had finished the count, "you are way off there may be was one hundred and sixty pigs once, but wake up don't be a back number. I've got even eight hundred, now shall I collect for eight hundred or what, how about sixty-four dollars I paid out for cabbages."

Will Morehouse readily accept and pay for 800 guinea pigs and hand over the $64 for cabbage? Will Flannery become the pigs' surrogate father? These and other burning questions will be answered in the final episode of "Pigs is Pigs" in the Fall issue of the Doorway on a website (www.mcgillcorp.com) near you the week of November 10, 1997.