VOLUME 28
FALL 1991
NUMBER 4

THE M.C.GILL DOORWAY

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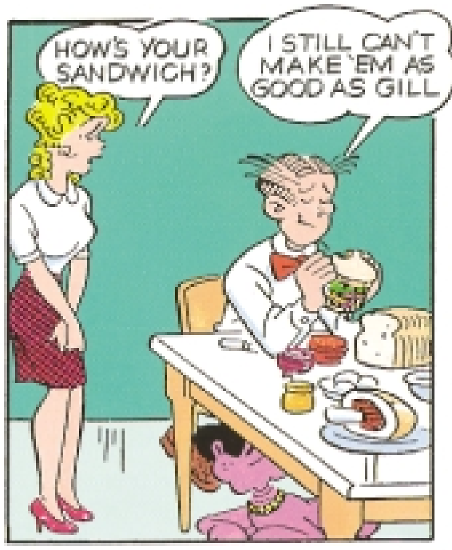
SANDWICH PANEL REVIEW…PART 3



Introduction: *This issue of the M. C. Gill Doorway is Part 3 of our Sandwich Panel Review updating a similar series issued in 1984 and 1985. Part 1 dealt with a general overview of sandwich panels and their components, and Part 2 covered similar subject matter but in greater depth. Part 3 advances preliminary design considerations for sandwich panel construction. Part 3 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 the address on the cover and we will be pleased to fill your request.*

Simplified Sandwich Panel Design

To our knowledge, sandwich panel design is not 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 the given problem.

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.

The side of the panel loaded in flexure (compression side) usually fails before the back side (tension side), so sometimes the compressive side is designed 20-30%

NOMENCLATURE

- 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 I.
- C_b — Coefficient for facing stress, from Figure I.
- d — Total panel thickness, inches.
- D — Panel ridigity.
- $E_{1,2}$ — Flexural modulus of either top or bottom facing in psi. (See Figure IV.)
- G_c — Shear modulus of the core, psi. (See Figure V.)
- h — $(t-t_f)$, thickness of panel between centroids of facings.
- K_b — Coefficients for panel bending. (See Figure I.)
- K_s — Coefficients for core shear.
- K_f — Coefficient to correct for flexural modulus of facing. (See Figure IV.)
- 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 III.)
- K_2 — Constant for facing stress for panel loaded as a plate.* (See Figure VI.)
- P — Load applied to panel, lbs./inch width.
- q — Uniform load, in 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.

stronger than the tension side. 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.

We do correct for foam cores which often have lower apparent facing stress. The reason for the correction is when the core compressive modulus is very much smaller that the facing modulus (250 x or more) it may allow the facing to wrinkle under flexural loading, which will result in premature failure of the facing.

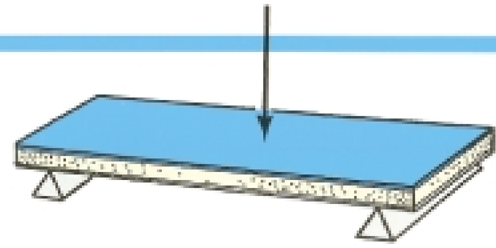
Panels obey these formulas when bonded with a thermoset adhesive (epoxy, phenolic, etc.), but if a contact adhesive is used the safety factor must be increased to perhaps 2.5-3.0.

Edge attachment, although not discussed here, can provide significant strength contribution. 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 cube of the panel thickness. Therefore, thicker panels are more rigid.



Sandwich Panels as Beams

The equations covering beam calculations for a sandwich panel are:

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

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

K_b = Coefficient From Figure I (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 I

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 Figure IV (page 7)

Step II:
Refer to Figure II (page 6) 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 I and $h = t_c + t_f$

Select core material that has core shear well above the value calculated, see Figure V (page 7). If it is decided to use a foam core, be sure to calculate D using $K_c = 2.2$.

Step IV:
Check Facing Stress

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

Where C_b if found from Figure I.

If calculated facing stress is over 75% of rated facing stress, re-select a thicker or stronger facing.

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 .075.″ 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

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

a = 48 in., the unsupported span

K_b = 0.013, from Figure I for simply supported beams

λ = 1.5, safety factor

We select 2024T3 aluminum facings in this example for high rigidity—$K_f = 1.0$ from Figure IV.

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

II. Referring to Figure II, we select:
$t_f = 0.025''$
$d = 2.25''$

III. Calculate Core Shear Stress

$$S = \frac{C_s P_c}{h} = \frac{(0.5)\,(240\ \text{lb./in.})}{(2.25\ \text{in.} - 0.025\ \text{in.})} = 54\ \text{psi}$$

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

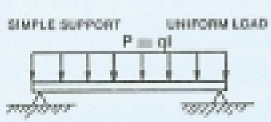
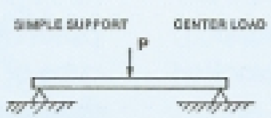
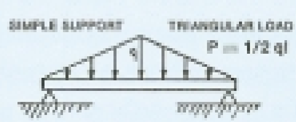
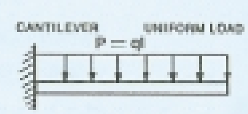
Referring to Figure II select a new value of t_f and d.

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.).

FIGURE I *Beam Chart* (P must be determined for a beam of unit width — b = 1″)

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

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

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

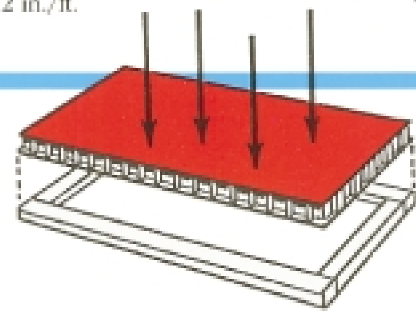
V. Additional Design

The core weighs 4 lb./ft.^{3} × $\frac{(2.15'')}{12\ \text{in./ft.}}$ = 0.72 lb./ft.^{2}

The skin weighs 2 × (0.050″) × 14 lb./in.-ft.^{2} = 1.40 lb./ft.^{2}

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

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



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.

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

Where:

K_1 is obtained from Figure III (page 6)

K_f is obtained from Figure IV

$q_c = K_c q$

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

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

Where: K_3 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 tabulation:

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 Figures IV & V. If the load is not uniform, a uniform loading to simulate actual loading must be assumed for these equations to work.

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 III) for a b/a = 0.80, all edges fixed. As a first approximation choose $K_c = 1.0$.

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

$$D = \frac{(2.0)\ (0.0015)\ (3.0)\ (5\ \text{psi})\ (40'')^4}{(1.0\ \text{in.})}$$

$D = 1.2 \times 10^5$

II. Select d and t_f from Figure II

Checking Figure II 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 Figure VI $K_2 = 0.066$ for a b/a = 0.80

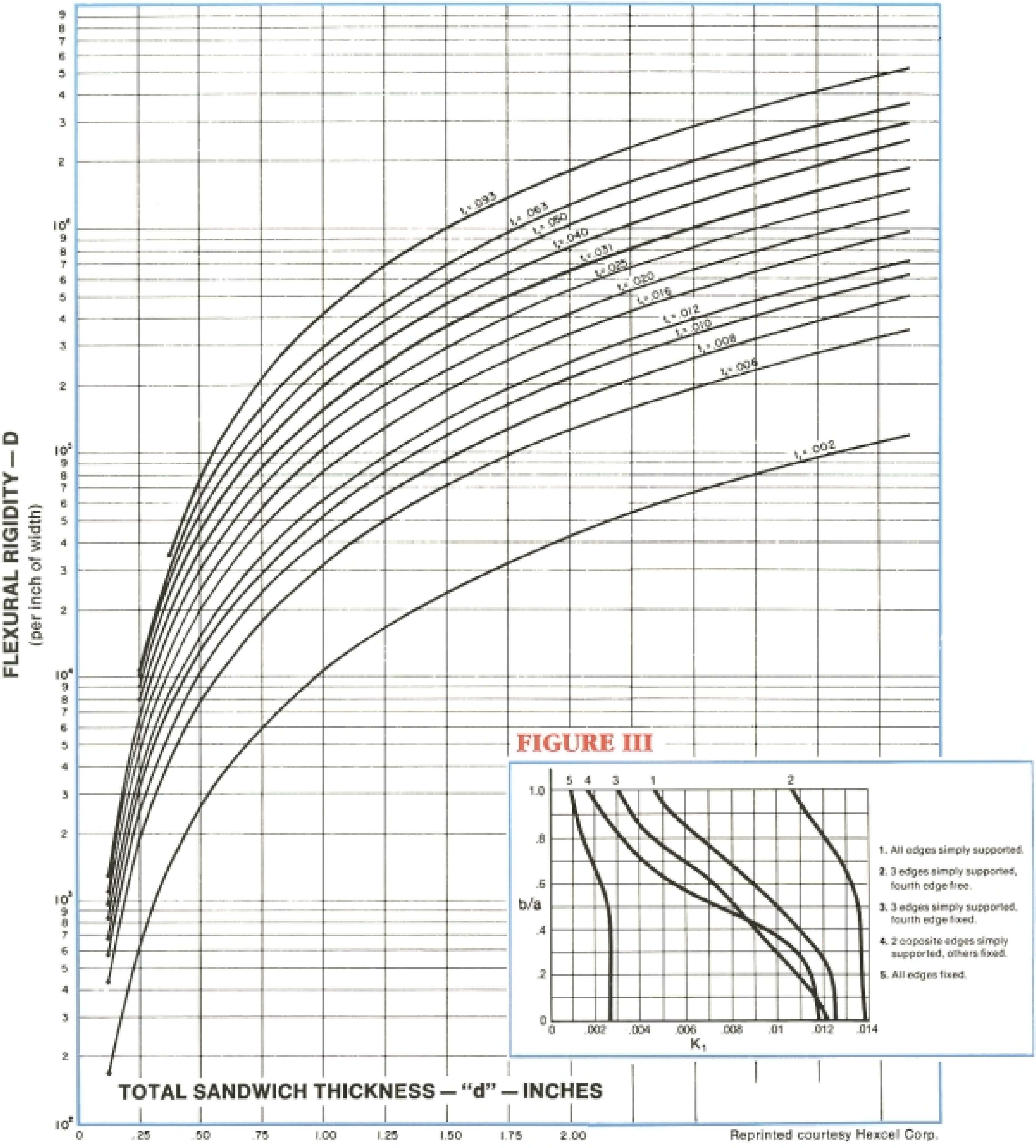
$$F_s = \frac{(0.066)\ (5\ \text{psi})\ (40'')^2}{(1.0'')\ (0.025'')} = 21{,}120\ \text{psi}$$

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

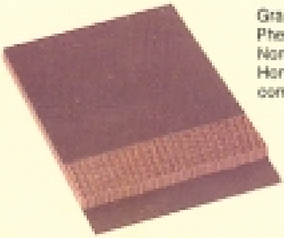
Note: Center load × 2 = uniform load.

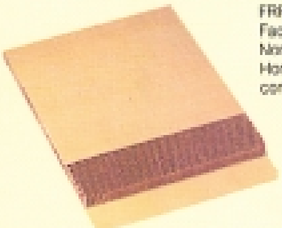
CANTILEVER — END LOAD — P	BOTH ENDS FIXED — UNIFORM LOAD — P = ql	BOTH ENDS FIXED — CENTER LOAD — P	ONE END SIMPLY SUPPORTED, ONE END FIXED — UNIFORM LOAD — P = ql	QUARTER POINT LOAD — SIMPLE SUPPORT — P/2, P/2
1/3	.0026	.0052	.0054	.0143
1	1/12	1/8	1/8	1/8
1	1/2	1/2	5/8	1/2

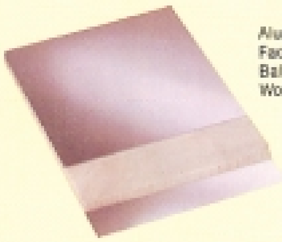
FIGURE II *Flexural Rigidity Curve for Aluminum Facings*

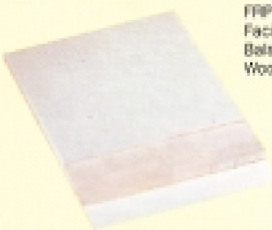


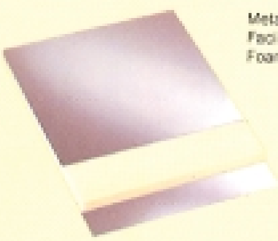
Reprinted courtesy Hexcel Corp.


Graphite-Phenolic/ Nomex Honey-comb Core


FRP Facings/ Nomex Honey-comb Core


Aluminum Facings/ Balsa Wood Core


FRP Facings/ Balsa Wood Core


Metal Facings/ Foam Core


FRP-Epoxy Facings/ Nomex Honey-comb Core


FRP Facings/ Foam Core

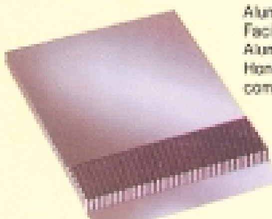

Aluminum Facings/ Aluminum Honey-comb Core

FIGURE IV *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
Aluminum-6061-T6	21	10	0.014	1.0	Workable
Aluminum-7075-T6	60	10	0.014	1.0	High strength
Mild carbon steel	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
Titanium: Annealed Ti-75A	70	15	0.0235	.67	Low corrosion, high cost
Fiberglass 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	Good strength, 350°F service temp.
Polyester-Gillfab 1074	33	3.0	0.01	3.0	Good strength, most fire-resistant
Polyimide-Gillfab 1028	22	2.5	0.01	3.3	400°F service temp.
Polyester-mat-Gillfab 999	16	1.8	0.01	5.0	Low cost
Polyester-woven rovings-Gillfab 1027	30	1.8	0.01	4.6	Low cost
Kevlar-epoxy-Gillfab 1313	20	2.5	0.0068	6.0	Moderate strength, light weight
Kevlar-phenolic-Gillfab 1170	16	2.0	0.0068	6.0	Light weight, low smoke
Carbon-epoxy-Gillfab 1089	65	16.0	0.008	1.6	Watch for galvanic corrosion, high cost, strength, stiffness
Carbon-phenolic-Gillfab 1186	60	16.0	0.008	1.6	Watch for galvanic corrosion, high stiffness, low smoke generation
Douglas fir plywood	2.6	1.6	0.003	7.3	Low cost, poor weathering, heavy
Tempered hardboard	2.0	0.6	0.0045	16.0	Low cost, low strength, heavy

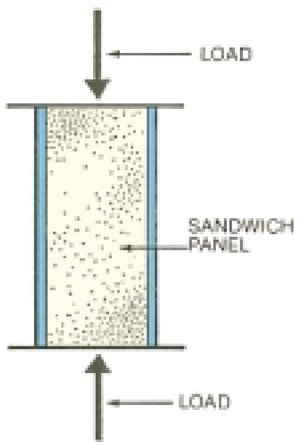
FIGURE V *Properties of Typical Core Materials*

CORE	Cell Size in.	Foil Th. in.	Density pcf	Shear Str. psi *R/W Dir.	Shear Mod. ksi *R/W Dir.	Stabilized Compress. Strength psi	Heat Transfer U = BTU/hr/ft^2/°F
Honeycomb Al-5052	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 Phenolic HRP	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
HRH-10 "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	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
Polystyrene Foam			1.8	30	1.0	25	0.23
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
Balsawood (Ochroma pyramidale)			6.0	140	16.0	750	0.3
			9.5	220	28.0	1500	0.4

*R = ribbon direction; W = warp direction

Testing

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.



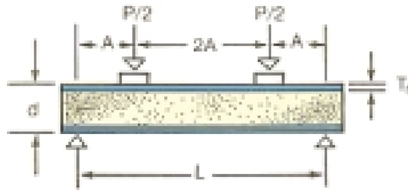
EDGEWISE COMPRESSIVE TEST
ASTM C364, MIL-STD 401B

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.

$$\text{Edge Compressive Strength} = \frac{P}{2t_f w}$$

Where:

- P = load
- w = panel width
- t_f = skin thickness



QUARTER-POINT LOADING

LONG BEAM FLEX TEST
ASTM C393, MIL-STD 401B

This is the standard test for determining the load bearing capability of a sandwich panel. It measures facing stress and panel rigidity. By using a span 30-50 times the panel thickness, the facing will fail before the core. If the panel rigidity, D, is desired then the deflection is also measured at given loadings.

$$F_s = \frac{C_b Pa}{ht_f}$$

$$D = \frac{K_b P_x a^3}{\Delta}$$

Where:

- a = span
- F_s = facing stress
- C_b = 1/8
- D = panel rigidity
- P_x = load to create Δ deflection

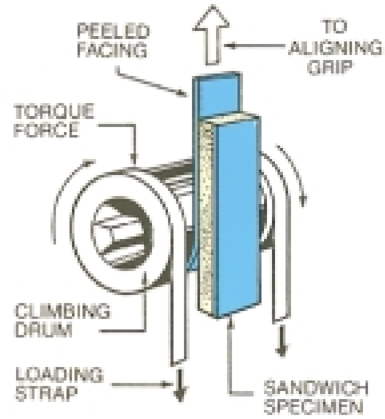
In actual practice the facing stress, F_s, is somewhat dependent upon type of core, adhesive, and thickness of the facing.

CORE SHEAR
ASTM C393, MIL-STD 401B

By reducing the span on a flex test to 15-30 times the panel thickness, the core will fail before the skins. This test measures the core shear stress.

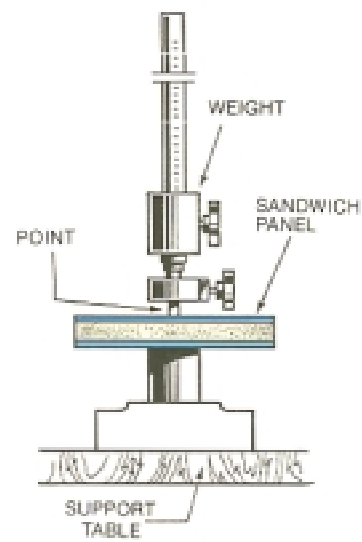
$$S = \frac{P}{2h}$$

In practice the value varies with thickness of facing, type of facing and strength of bond, but core shear strength is the dominant factor being measured.



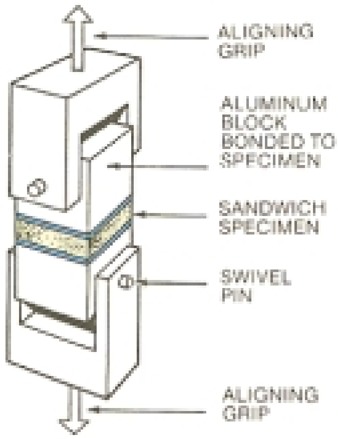
PEEL TEST
(Climbing Drum Peel)
ASTM D1781, MIL-STD 401B

The peel test measures the torque to peel the facing from the core. It depends on the resilience of the adhesive bond and on core strength. It is a good indicator of the tendency to delaminate during secondary cutting operations.



IMPACT TEST
(Gardner)
ASTM D3029

The impact test is a measure of a panel's resistance to damage by impact. The test is done by dropping a known weight a measured distance onto a specially built point, which is in contact with the panel's surface. Failure occurs when the point ruptures the panel facings. Units are inch-pounds.



FLATWISE TENSILE TEST

ASTM C297, MIL-STD 401B

This test measures the strength of the adhesive bond—a good indication of structural strength of core and adhesive.

$$F_t = \frac{P}{ab}$$

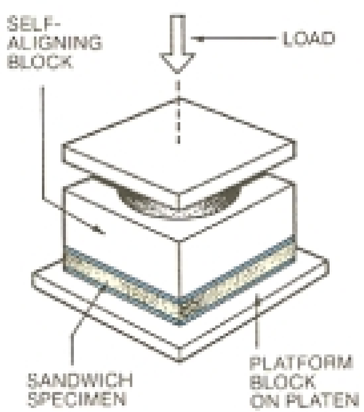
Where:

F_t = Flatwise tensile strength

a = length of specimen

b = width of specimen

If the core fails, the adhesive is considered to have passed.



FLATWISE COMPRESSIVE TEST

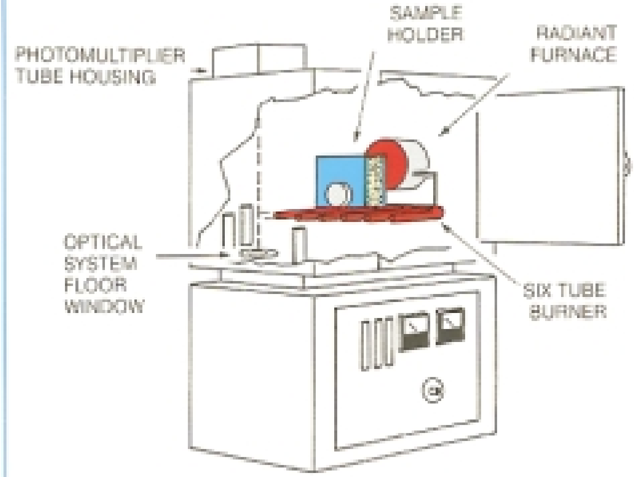
ASTM C365, MIL-STD 401B

Flatwise compressive test measures the strength of the core (stabilized and unstabilized) in resisting compressive load.

$$\text{Compressive Strength} = \frac{P}{ab}$$

Note: Stabilized—Facings bonded to core.

Unstabilized—Core alone is tested.



NIST (NBS) SMOKE CHAMBER TEST

ASTM 662

Specific Optical Density of Smoke Generated by Solid Material

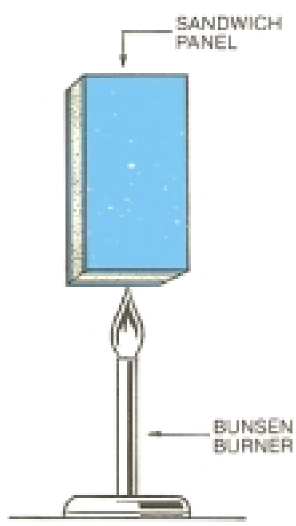
This method measures the smoke emitting properties of materials when exposed to heat and flame under two controlled conditions, flaming and non-flaming. A brief summary of the method is given below.

1. A radiant heater produces an irradiance level of 2.2 BTU/ft^2/sec. This is directed on average at the central 1.5″ diameter area of a vertically mounted sample. The sample size is 3″ x 3″ and the exposed area is 2-9/16″ x 2-9/16.″ This exposure provides the non-flaming condition of the test.

2. For the flaming condition, a six-tube burner is used to apply a row of equidistant flamelets across the lower edge of the exposed specimen area and into the specimen holder trough. The radiant heater is also used during this test.

3. The test samples are exposed to either flaming or non-flaming conditions within a closed chamber. Light transmission of the air within the chamber is measured. This value is used to determine Specific Optical Density (D_s) of the smoke generated during the time period.

Details of the calculation are given in the Standard; the values are on a logarithmic scale. A minimum of 6 samples is required: 3 non-flaming condition and 3 flaming condition.



FLAME TEST

(Vertical)

FAR 25.853

This test gives a rough indication of how the panel will perform in a fire. The panel thickness must be the minimum thickness to be qualified for use in the aircraft. An unprepared panel edge is subjected to a minimum of 1550°F flame for 60 seconds. The extinguishing time (time it takes for the panel to stop burning *after* the flame is removed) and the length of the burn are measured. This is a small scale test and performance in large fires can vary dramatically.

You Get What You Pay For, But…

Are you paying for what you really want? When you submit a request for quotation (RFQ) or order sandwich panels, especially those that must qualify to your specifications, do you automatically go to the lowest bidder? Or, do you dig a little deeper to find out why there may be price differentials? You should; it could save you money in the long run because no product specification can possibly cover every aspect of quality that goes into a product. Likewise, none has been written that didn't have some loophole that enabled someone to ignore functionality and make a product that was inferior and less expensive, yet passed the specifications. Your only defense is the integrity of the manufacturer who has the experience required to know what he is doing. But, if you order oranges and you want to make sure you don't get lemons you'll want to read the following recap of Gill's Home Study Course III, on "How to Select a Composites Laminator." If you would like a copy of the complete article, please contact our Marketing Services Department.

You have every right to expect that what you purchase is a product that will satisfy your requirements, but such is not always the case. An informed decision requires more than simply reading down the right side of the menu and selecting the least expensive entree. Key supplier evaluation points include the following:

- *Physical plant components including capability to manufacture subcomponent raw materials;*
- *Trained, experienced, and conscientious work force;*
- *Quality-assurance program encompassing approved raw material suppliers, inspection of raw materials on receipt and work-in-process; and, on-premise testing facilities;*
- *Research and development facilities and experienced personnel; and,*
- *Important intangibles such as integrity, financial strength and a customer-service driven attitude.*

Once the buyer is satisfied that composites vendors meet these criteria there are the following basics concerning sandwich panel orders or RFQ's.

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 number or specification 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 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 or polyvinyl chloride (PVC).

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 perforation 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. Often, less is known about the adhesive required than other sandwich panel components. 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 which is slower and more costly.

Dimensional Tolerances. For raw stock panels, length and width tolerances are normally +1/4" -0" with diagonal measurements matching with 3/32 (0.0938) x width in feet. Thickness tolerance is to ±.015." 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 fax 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.

FIGURE VI *Properties of Selected M. C. Gill Sandwich Panels*

This table is reprinted from the Summer 1991 issue (Part 2 of this series). However, we have added selected results from tests conducted on plywood to give our readers a frame of reference in interpreting and evaluating results from the same tests on composite materials.

PRODUCT	Core type and density	Adhesive	Top facing	Bottom facing	Panel thickness (inches)	Panel weight (lb/ft²)	Flex strength 20" span 2 pt. load: Ult. load (lbs)	Flex strength 20" span 2 pt. load: Defl. @ 100 lbs (inches)	Heat Release (Total kw/min/m² Peak kw/m²)	Climbing drum peel strength (in-lbs/3" width): Top	Climbing drum peel strength (in-lbs/3" width): Bottom
TEST METHOD ►							Mil Std 4018		FAR 25.853 (a-1) App F, Part 4	Mil Std 4018	
4004	1/8" cell, 9 pcf Aramid honeycomb	Modified epoxy	.015" Unidir. FRP phenolic	.015" Unidir. FRP phenolic	.390	.70	325	.85	24/21	21	21
4017 Ty 1	1/8" cell, 9 pcf Aramid honeycomb	.030 psf epoxy	.015" epoxy Unidir. FRP	.015" epoxy Unidir. FRP	.400	.64	260	.85	53/59	30	30
4017 Ty 2	1/8" cell, 5 pcf Aramid honeycomb	.030 psf epoxy	.015" epoxy Unidir. FRP	.015" epoxy Unidir. FRP	.400	.52	240	.85	53/59	30	30
4022	1/8" cell, 8 pcf Aramid honeycomb	Modified epoxy	.020" FRP phenolic	.020" FRP phenolic	.400	.84	306	.72	14/19	25	25
4030	3/16" cell, 5.7 pcf Aluminum honeycomb	Modified epoxy	.020" 2024T3 aluminum	.020" 2024T3 aluminum	.500	.90	484	.15	0.5/0	40	40
4105	3/16" cell, 6 pcf Aramid honeycomb	Modified epoxy	.025" woven FRP epoxy	.025" woven FRP epoxy	.375	.67	371	.681	58/58	27	27
4109 Ty 1	1/8" cell, 8 pcf Aramid honeycomb	Modified epoxy	.014" Unidir. GRP phenolic	.014" Unidir. GRP phenolic	.390	.52	325	.40	40/49	21	21
4109 Ty 2	1/8" cell, 4 pcf Aramid honeycomb	Modified epoxy	.014" Unidir. GRP phenolic	.014" Unidir. GRP phenolic	.390	.42	325	.40	41/50	18	18
5007A	End grain balsa 9.5 pcf	Modified polyester	.040" woven FRP polyester	.020" woven FRP polyester	.400	1.05	400	.41	78/62	18	10
5007B	End grain balsa 9.5 pcf	Modified polyester	.040" woven FRP polyester	.020" woven FRP polyester	.400	1.05	420	.43	N/A	28	20
5007C	End grain balsa 9.5 pcf	Modified polyester	.045" woven FRP polyester	.030" woven FRP polyester	.400	1.3	525	.36	N/A	30	22
5040	End grain balsa 9.5 pcf	Phenolic Mod. elastomer	.020" 2024T3 aluminum	.012" 2024T3 aluminum	.400	.75	295	.31	3.6/0	50	50
Plywood	5-ply solid core Douglas Fir 37.4 pcf	N/A	.080" Douglas Fir	.080" Douglas Fir	.500	1.58	295	.48	N/A	N/A	N/A

PRODUCT	Flatwise compressive strength (psi)	Flatwise tensile strength (psi)	Core shear 4" span 2 pt. load (psi)	In-plane shear strength (psi)	2 lb. Gardner impact (in-lbs)	Insert shear strength (lbs)	Roller cart (test cycles to failure)	30 day 100% humidity soak (% of dry results): 20" flex strength	30 day 100% humidity soak (% of dry results): Climbing drum peel	Specifications
TEST METHOD ►	Mil Std 4018	Mil Std 4018	Mil Std 4018	BMS 4-17D	Model 11K3	Shurlok 5107-A3	BMS 4-17D	Mil Std 4018	Mil Std 4018	
4004	1600	N/A	N/A	N/A	100	N/A	N/A	100%[1]	100%[1]	McDonnell Douglas DWG 7954401
4017 Ty 1	1500	700	700	4,140	65	950	128 lbs — 120,000 158 lbs — 35,000	80%[1]	80%[1]	McDonnell Douglas DWG BZZ 7002 Lockheed LAC-C-28-1386
4017 Ty 2	600	550	430	4,140	65	980	98 lbs — 80,000	80%[1]	80%[1]	McDonnell Douglas DWG BZZ 7002 Lockheed LAC-C-28-1386
4022	1200	350	437	7,200	26	N/A	N/A	N/A	N/A	McDonnell Douglas 9D0059 Lockheed LAC-C-22-1339 & LAC-C-28-1041
4030	600	700	198/128[2]	N/A	40	N/A	N/A	N/A	100%	Lockheed LAC-C-28-1145 Ty 5, 7, 9, 10 E-systems TMS 11-903
4105	916	501	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Airbus Industrie TL53/5000/79
4109 Ty 1	1200	N/A	355/190[2]	N/A	20	650	100 lbs. — 100,000	100%[1]	100%[1]	McDonnell Douglas DWG 7954400 BAER 3231
4109 Ty 2	470	N/A	235/120[2]	N/A	20	650	N/A	100%[1]	100%[1]	McDonnell Douglas DWG 7954400 BAER 3231
5007A	1500	900	240[3]	12,200	44	1200	128 lbs — 120,000 158 lbs — 35,000	70%	80%	Airbus Industrie TL53/5000/79
5007B	1500	1000	250[3]	9,200	40	1000	128 lbs — 120,000 158 lbs — 50,000+	70%	80%	United Airlines SHE 2902
5007C	1500	1000	260[3]	14,700	54	1150	128 lbs — 120,000 158 lbs — 35,000	70%	80%	
5040	1500	275	185[3]	14,000	34	1200	128 lbs — 40,000	85%	70%	
Plywood	1025	120	N/A	8,500	35	N/A	N/A	N/A	N/A	

NOTES: N/A means not available.
FRP means glass reinforced plastic.
GRP means graphite reinforced plastic.

1. Tested after 30 days at 140°F and 95-100% relative humidity.
2. First number is ribbon direction/second number is transverse direction.
3. 12" span.

Gilldiet

One of Swissair's new MD-11's. We were quite taken that the aircraft's "G" designation was the first MD-11 to use Gillfloor 4109.

McDonnell Douglas employees Jeff Bartlett (left) and Reggie Hill installing one of the very first 4109 flooring panels in an aisle.

Thursday, September 5, 1991, was a red letter day for Swissair, McDonnell Douglas, and the M.C. Gill Corporation. It marked the first flight of an MD-11 using a new lightweight sandwich panel for passenger compartment and cockpit flooring.

Customer Satisfaction Is Job One

Since the mid-1980's, McDonnell Douglas engineers have been striving to reduce weight in the company's MD-90's. When Swissair (M.C. Gill's first airline customer) wanted to realize even greater weight savings in the MD-11's they had an order, Douglas engineers were quick to respond. Using the technology acquired from their work on the MD-90, they determined that one area where a savings could be effected was flooring in the passenger compartment and cockpit.

Having worked with the M.C. Gill Corp. since 1985 on a lighter weight flooring, the decision was made to utilize the same panel developed earlier for use in the MD-90. That decision resulted in a contract award to M.C. Gill in February 1990 for the new flooring. The contract was awarded by General Dynamics, prime contractor to McDonnell Douglas for fuselage construction and fabrication (including passenger compartment and cockpit flooring).

Oldies Are Still Goodies — Just A Little Unpleasingly Plump

It must be noted that Douglas' efforts and Swissair's request for less weight was just that. That consideration aside, there was little quarrel with the original flooring for the MD-90 or MD-11 — unidirectional fiberglass reinforced epoxy facings bonded to an aramid honeycomb core. In fact, that flooring has long been used in the MD-80 and MD-90 series' and the early MD-11 aircraft, and is also manufactured by M.C. Gill — Gillfab 4017. A proven flooring panel workhorse from the day it qualified to McDonnell Douglas' DWG BZZ 7002 in the late 1970's, 4017 has gained acceptance in the McDonnell Douglas operators' community with the record it has achieved from in-service testing for more than a decade.

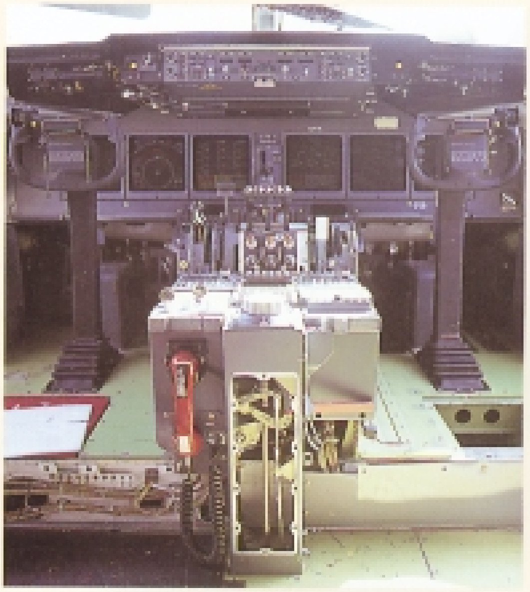
Enter Gillfloor 4109

Nevertheless, Swissair wanted less weight but not at the expense of sacrificing other desirable properties. Their specifications were tough and exacting, and literally thousands of man-hours were spent developing a product that would meet them.

Constructed of unidirectional graphite rowings reinforced phenolic resin bonded to an aramid fiber honeycomb core, Gillfloor 4109 proved to be the flooring panel of choice for the passenger compartment and cockpit. Graphite was selected for the facing

Helps the MD-11 Shed 350 Pounds

Sealing a forward flooring panel using polysulfone applied with an air powered caulking gun.



A view of the cockpit interior showing the avionics and 4109 flooring. (The green primer on some of the panels was applied by McDonnell Douglas, but is not required.)

Douglas employees Mark Hansen, Senior Engineer, Product Support (left) and Bob Whitbeck, Ship Captain, inspecting the completed installation.

material because of its very light weight (approximately 20 percent less than other conventional flooring materials). Rigidity was also of prime importance and with a flexural modulus of 18 x 10^6, Gillfloor 4109 meets that criterion.

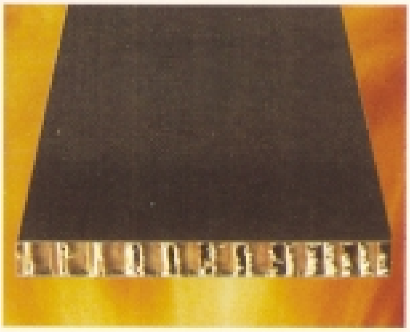
Phenolic resin was specified because it is inherently non-burning and has very low smoke and toxic emissions in a fire — two qualities that are increasingly important in today's aircraft safety requirements.

Finally, the panel qualifies to McDonnell Douglas DWG 7954400 Ty 1 & 2. Certainly, some of our competitors will no doubt qualify their products to this specification in time. Meanwhile, the M.C. Gill Corp. will be working on improved versions. The task is formidable, but then we were somewhat skeptical the current version of 4109 would do as well as it has.

A Little More Than An Ounce Off An Elephant

Throughout this article, the focus has been on weight savings. The world's airlines place a great degree of emphasis on this issue because of the direct relationship between weight and fuel requirements, i.e., light weight = less fuel = lower operating costs. An indication of how seriously the airlines consider this is that the weight saved by switching from fiberglass to graphite faced panels is less than two ounces per square foot! However, to put this in perspective, the total weight reduction per aircraft is approximately 350 pounds — a minuscule amount compared to the total weight of the aircraft but it shows the importance airlines place on this factor.

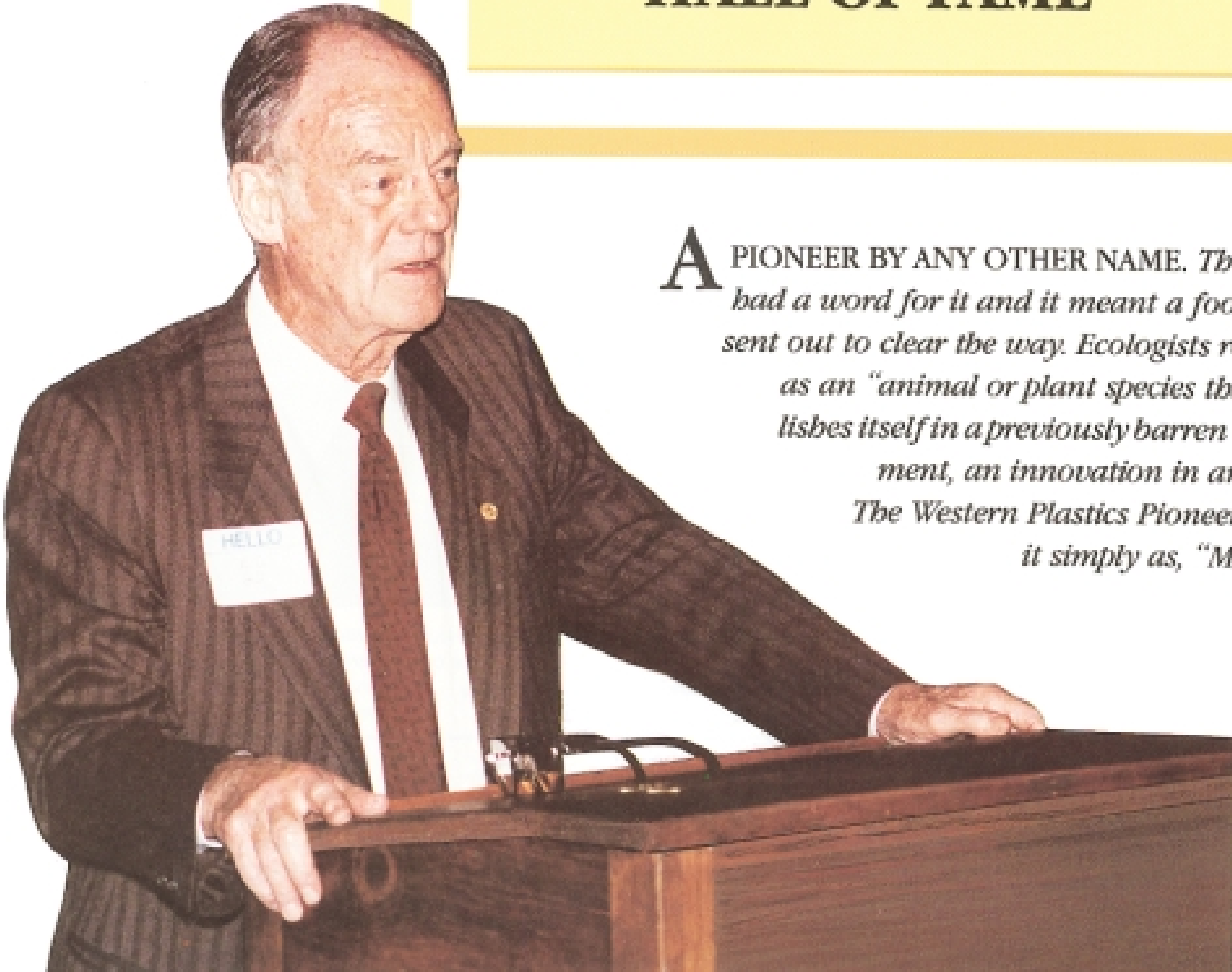
What is also demonstrated is the willingness by all parties concerned to satisfy a customer need. Certainly, quick response is necessary in today's competitive environment, but a sincere desire to make the extra effort typifies the spirit of cooperation that exists among the MD-11 team members and the pride they share in a job well done.



The Featherweight Champion: Gillfloor 4109. Unidirectional graphite rovings in reinforced phenolic resin, bonded to an aramid honeycomb core, results in lightweight and low smoke emission in a fire.

PLASTICS PIONEER INDUCTED INTO HALL OF FAME

A PIONEER BY ANY OTHER NAME. *The French had a word for it and it meant a foot soldier sent out to clear the way. Ecologists refer to it as an "animal or plant species that establishes itself in a previously barren environment, an innovation in any field." The Western Plastics Pioneers define it simply as, "M.C. Gill."*



M. C. Gill offered a few words of thanks for his induction into the Western Plastics Pioneers Hall of Fame.

Flanking M. C. are retired Pioneers Les Swanson (left), VP, Electrical Specialties, and Bob Halliday, VP, Eastman Chemical, on the day they told M. C. of his nomination to the WPP Hall of Fame.

M. C. Gill employees; from left: Paul DeGood (Manager, Marketing Services), Kathie and Mel Kantz (Director, Research and Development), and Dan Guerrero (Manager, Human Resources).

M. C. gets congratulations from Jim Sbarbaugh, outgoing President of Western Plastics Pioneers, and Hester Bester, M. C. Gill Corporation Internal Auditor.

OCTOBER 20, 1991—A VERY SPECIAL DAY

On October 20, 1991, M.C. Gill was inducted into the Western Plastics Pioneers Hall of Fame in Long Beach, CA. This very special honor was accorded M.C. in recognition of his many contributions to the plastics industry over the past 46 years and is an achievement shared by very few.

The story of the son of an Iowa pharmacist who started his own "Peerless Plastics Products, Inc." in a Montebello, CA, garage in 1945 and ultimately ended up as the M.C. Gill Corporation on Easy Street has been well chronicled in past Doorways. What might not be so familiar are the many ups and downs, successes and failures, and wins and losses experienced by M.C. in the intervening years. Throughout it all, one of M.C.'s overriding concerns was that some part of whatever success he attained be given back to the plastics industry. And he has.

A LONG HISTORY OF SUCCESS AND INNOVATION

M.C. Gill products can be found on virtually every major commercial aircraft developed in the past 40 years; they've been part of the space program for years; and they even play a role as integral components on high speed racing boats. All of these product applications were at the forefront of applicable technology when they were introduced. However, to take advantage of this technology, new equipment was required to manufacture these state of the art products, but it had to be designed and developed. So, M.C. did that, too.

PAY-BACK TIME FOR M.C.

Perhaps two of M.C.'s most gratifying "pay-backs" were the endowment of the M.C. Gill Chair of Composite Materials at his alma mater, the University of Southern California and a donation to the economic development fund of his hometown of Terril, Iowa. That seed money resulted in the financing of a facility that would ultimately become the home of the Terril Plastic Molders Company.

Three generations of Gills flanking M.C.'s portrait that will hang in the WPP Hall of Fame in Long Beach, CA. From left: Stephen (CEO), daughter Debaney, Phillip (VP, Operations), M.C., and grandson Jimmy.

LET THE INDUCTION BEGIN

These and other accomplishments were recounted at ceremonies hosted at the La Mirada Country Club at the Western Plastics Pioneers annual dinner meeting that is held for the purpose of honoring one Hall of Fame inductee. The WPP was founded about 15 years ago specifically to recognize contributions to the plastics industry by pioneer/entrepreneurs in the 13 Western states. There are currently 19 members in the Hall of Fame. Four were inducted the first year and two the second. Since then, induction has been limited to only one pioneer per year.

Bob Poet, retired Vice President and General Manager, Silmar Division, BP of America, as he made his introductory remarks.

No one said it better than Bob Poet, longtime friend of M.C.'s, during his introductory remarks, "...this is one of the most deserving of the recipients of the honor of entering the Western Plastics Pioneers Hall of Fame. He joins a small, exclusive and highly esteemed group and I'm sure he is welcomed by his Hall of Fame peers.

"This honor covers a lifetime of work where, year after year for 46 years, the M.C. Gill Corporation has been on the leading edge of the industry it serves. We congratulate you, M.C. and wish you continued success at the work to which you have given such devotion—and we thank you for all you have done for the plastics industry."

Well spoken, Bob.

Trivia

Men recall what they read better than women do. Some researchers credit superior male concentration. One, a woman, said, "Lip readers always remember better."

★ ★ ★ ★

The average mature oak tree drops 700,000 leaves a year.

★ ★ ★ ★

The sailfish is the world's fastest swimming creature, capable of reaching speeds of 68 m.p.h., about the same as the cheetah, the fastest land animal.

★ ★ ★ ★

The trout is the official fish in 10 states. The bass is in second place with 7.

★ ★ ★ ★

About only one woman in 50 can stand on her head without help.

★ ★ ★ ★

42 percent of Americans can't name an Asian country near the Pacific Ocean.

★ ★ ★ ★

Nineteen percent of voters list their spouses as a "very important" source of information about political candidates.

★ ★ ★ ★

25,000 U.S. students are studying Russian. 4,000,000 Russian students are studying English.

M.C. GILL CORP. • SINCE 1945

The M. C. Gill Corporation is saddened to report the passing of Grady Toney, Quality Control Manager since 1985. He was one of those persons of whom it truly can be said that he was respected by all who knew him. "We'll miss you, Grady!"

The Funny Side

Some people are born on third base and go through life thinking they've hit a triple.

★ ★ ★ ★

"I read your manuscript, young lady," said the snooty publisher. "It has some merit but many parts are obscure. You must learn to write so that the most ignorant of readers can understand you." "I will," the authoress said coolly, "which parts gave you most difficulty?"

★ ★ ★ ★

Medical science has yet to discover an ailment that will arouse the interest of friends and neighbors as much as a black eye.

★ ★ ★ ★

Stunned by the beauty of a new secretary, two executives resolved to make her adjustment to the firm their personal business. "It's up to us to teach her what's right and what's wrong," said one. "Agreed," replied the other. "You teach her what's right and I'll teach her what's wrong."

★ ★ ★ ★

After ordering a drink, the man asked the bartender if he enjoyed dumb athlete jokes. "Listen," growled the bartender, "see those two big guys over there? They're starting tackles for the 49ers. The guy on your right is a pro wrestler. That guy in the corner is a champion weight lifter and I lettered in three sports at USC. Now, are you sure you want to tell dumb jock jokes?" "Naw, I guess not," the man replied, "I wouldn't want to have to explain it five times."

★ ★ ★ ★

Travel service: Flee market.
Budget: Quantity control.
Plastic surgeon: Scar gazer.
Gossip: Tale wind.
Nostalgia: Life in the past lane.

★ ★ ★ ★

The headwaiter of a posh restaurant noticed that a diner had tucked a napkin into his shirt collar as he seated himself at a table. Horrified, he rushed over to the table to correct the breach of etiquette without offending the customer. Bowing, he asked quietly, "Sir, will you have a shave or a haircut?"