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"We try hard enough to make it happen"

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A Composite Sandwich Panel Review

In the Summer 1984, Fall 1984, and Winter 1985 issues of the Doorway, we published the first of our Home Study Courses. The subject matter was "sandwich panels" and it was very well received. We reprinted it in 1991 and we believe the time has come to update that series. We've moved up several notches on the sandwich panel learning curve in the past thirteen years and we wanted to share what we've learned with you. So, with this issue, we begin our Sandwich Panel Review Series.

The Making of a Sandwich Panel

For our purposes, a sandwich panel is a laminate of thin, high strength facings on each side of a much thicker, light weight core material. There is a third component that is often overlooked, all important and poorly understood—a tough, but rigid adhesive attaching the facings to the core. All three components must be present to qualify as a successful sandwich panel.

RATIOS OF THICKNESS TO STRENGTH AND WEIGHT 4T				
_	т	2T		
Relative rigidity	1.0	7.0	27.0	
Relative flex strength	1.0	3.5	9.2	
Relative weight	1.0	1.03	1.06	



Resistance to fire and toxic smoke is an advanced feature of Gill's graphitephenolic/Nomex® honeycomb panel.



Resistance to repeated heavily loaded caster wheels and high heels provides the durability feature.



Extreme light weight and strength combine to afford energy savings in aircraft and other transport vehicles.

As shown in the accompanying chart, the total thickness of the facing material(s) split in half andseparated by a core results in dramatic stiffness and strength improvements, with minimal weight increase.

This simple illustration also points out the value of making the sandwich panel as thick as possible. Since core materials are not only lighter than facings but also generally less costly **per unit of thickness**, a thicker panel with thinner faces will normally cost less and be more rigid. How thin they can be will be discussed in the third issue of this series.

All sandwich panels share certain advantages and drawbacks. They are all quite rigid and light in weight compared to alternative materials. On the minus side, sandwich panels sometimes must be sealed around their edges especially if a moist environment is anticipated; all are more costly than common comparable materials such as plywood or metal plate; honeycomb cells will hold moisture if a facing is punctured; and, attachments and inserts can be a problem.

Evaluation Criteria

There are considerations other than strength in evaluating sandwich panels, including:

SAFETY—Fire resistant; low toxic and smoke emissions in a fire.

WEIGHT—Low initial weight; minimal weight gain when exposed to moisture, or when fastening systems and edge sealing are added.

DURABILITY—Corrosion resistant; resistant to repetitive loading, e.g., fatigue from flexural stresses, point loads such as stiletto heels or rolling cart wheels; dent and puncture resistant; environmental resistance; no loss in strength from fabricating or from the addition of fasteners.

COST—Ease of fabrication from raw stock panel to "ready to install," e.g., simple installation of fasteners and rapid cutting with proper tools; inexpensive installation accessories such as inserts or other fasteners and edge sealant or close-out; high yield from raw stock panels, e.g., panel dimensions can be made compatible with finished sizes and resistant to edge damage during cutting using accepted cutting procedures.

POOR EARL

History tells us that the Earl of Sandwich is not but often credited with inventing the edible bearing his name. However, we would be remiss if we did not point out that the good Earl had it entirely backwards when considering a load bearing sandwich panel. Whereas the tasty center portion is the key to a successful sandwich (the eating kind), the load bearing kind has a center that is either mostly full of air or woody tasting, and the faces are tough and terribly chewy. The underlying principle of sandwich panel design is that the core, or the center part, serves primarily to hold the facings apart. The facings take the stress created when a load is placed on that panel and it is the facings which largely determine the sandwich panel's strength. In the final analysis, however, it is the adhesive that is the key element, because to function properly, the facings must adhere to the core. If they don't, all is lost.



The versatility of sandwich panels used in aircraft is illustrated by the pictures above. From left to right, the sides, top and bottom of a food service cart made by British Petroleum; carbon faced flooring panels that reduced weight in MD-11's by approximately 350 pounds; a stowage unit in a Daussalt Falcon jet; and a crew galley for the KC-10.

A Few of the More Common Configurations

Given the many different kinds of facings, core materials, and adhesives... the number of variations of different kinds of sandwich panels is almost endless. The following considers the more common configurations and their advantages and disadvantages.



Metal Facings/Plywood Core (or Particle Board) Used in building construction and industrial applications, the metal (steel or aluminum) acts as a protective facing for the plywood core and greatly enhances the panel's strength.

Pluses: Low purchase price for core; high puncture resistance; readily available; inserts usually not needed; and much greater rigidity than raw plywood.

Minuses: Heavy; untreated metal facings can corrode; not truly fire-resistant; and moisture absorbent.



Metal Facings/Foam Core

Used in non-structural applications utilizing its low cost and thermal insulation, such as refrigerated carts.

Pluses: Low initial purchase price; low weight; excellent thermal insulation; good point load resistance; and, good impact values.

Minuses: Aluminum facings are subject to corrosion (this can be corrected by anodizing them); delamination; low service temperature ranges; core is friable and low fatigue, and has high smoke evolution.



Fiberglass Reinforced Plastic (FRP) Facings/Foam Core

Foam core panels are widely used in commercial refrigeration construction.

Pluses: Low purchase cost for commodity type foams; very low panel weights; excellent thermal insulation; low moisture absorption; and solid core, meaning good point load resistance; good corrosion resistance.

Minuses: Low resistance to repetitive flexure; delamination (facings separating from core) due to low core integrity; core has low tensile strength and is relatively brittle; and, high smoke evolution in a fire.

Aluminum Facings/Aluminum Honeycomb Core

A very common sandwich panel first used in the aircraft industry.

Pluses: Relatively low cost; high strength to weight ratio; excellent rigidity; and, many combinations of different core configurations and facing thicknesses and alloys.

Minuses: Aluminum corrodes without proper treatment; is subject to denting and permanent distortion; aluminum honeycomb is more prone to point load failure; honeycomb cells may fill with liquid if facing is punctured; and, although non-burning and non-smoking, aluminum panels have poor burn-through characteristics and high heat conduction.



Here's How M.C. Gill Makes Sandwich Panels

Nomex Honeycomb Core Production



This is where it begins. The aramid fiber paper (Nomex) feeds from the let-off reel into the printer oven.



The master control panel regulates print roller and cutter, paper humidity, and printing oven in the processing that follows.



Aluminum Honeycomb Core Production



Very thin aluminum foil feeds from the letoff reel into a horizontal tank where it is sprayed and cleaned prior to alodining.



Foil from the horizontal tank feeds into the alodiner and oven, preparing it for printing of glue lines. Other steps for aluminum are the same as for Nomex honeycomb core, except that aluminum core does not go through the dipping and baking processes.

Film Adhesive Process



Our film adhesive coating line produces for Gill consumption. Our proprietary formulations are used to bond facings to solid and honeycomb cores. We make our own adhesives and they meet the two common adhesive specs, MMM A 132, Type 1, Class 2 & 3, and MIL A 25463A. More important, they meet our own quality requirements, including uniformity, availability, lower cost, traceability, and long shelf life (in controlled storage to 0° F). The manufacture of sandwich panels is a specialized business with many variables to be considered. These include the integrity of the manufacturer, along with experience, types of equipment and quality control procedures. Paramount in importance is the laminator's experience.



A print roll applies glue lines to the Nomex paper. The glue is necessary for bonding the individual sheets together during the pressing process.



The printed paper comes out of the printer conveyor where it is automatically cut off in sheets and stacked, preparatory to inspection and loading into the press.



Paper sheets are inspected to ensure that adhesive lines on each are off-set (see inset) so that when bonded, hexagonal cells will be formed after the expanding process.



Stacks of Nomex paper fiberglass blankets for set under pressure to b at the adhesive lines. T increases capacity 21/2 sheets and loaves.



The M.C. Gill Corp. uses sandwich panel facings of reinforced fiberglass and carbon (woven or unidirectional) and aluminum; adhesives of epoxy, contact, phenolic and polyester; and cores of foam, end grain balsa wood, and aluminum and aramid honeycombs. Aramid and aluminum honeycomb are available in a variety of cell sizes and densities ranging from 1.8 pcf to 9 pcf and higher. Stabilized compressive strength ranges from 55 psi to 1700 psi, with plate shear values between 100 psi and 500 psi. Aluminum honeycomb likewise is available in several cell sizes and densities from 1.6 pcf to 8.1 pcf and higher; with compressive strengths of 70 psi to 1100 psi. Plate shear strength values test from 60 psi to 670 psi.



urrounded by ulation) are heatd sheets together new press mes, with larger



After pressing the sheets into loaves they are expanded to the proper length to achieve the dimensional cell size specified (see inset). The revamped expander turns out a larger finished loaf in the same amount of time.



After each dip, the loaf is placed in this oven and carefully baked until the resin is cured. This process is repeated until the desired density is attained.



After the dipping and baking pro complete, the loaf is tagged as t size, density, and date of manuf information is vital for traceability inventory control.

Facings Production

(in this instance, the facings are unidirectional S-2® glass)



Technician prepares and tests viscosity of the cooked resin before it is placed in a holding drum and fed into the resin tray.



Rovings (durable untwisted strands of glass or carbon) come off the spool creel just prior to dipping in the resin bath.



Rovings going through the dip tr fed onto the creel just prior to th through the drying oven.



The bottom facing and film adhesive are already in place on the caul sheet. Honeycomb core slice is being placed on top.



Here, cross plies of the unidirectional facings are oriented at 0° and 90° on top of the honeycomb core.



The component panel goes into the electronically-controlled press capable of handling seven panels simultaneously.



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A loaf is sliced by the one of three computer controlled horizontal band saws. It cuts raw material up to 60" wide to virtually any thickness with a \pm .005" tolerance over the entire sheet.



The slice goes to a dial indicator table and thickness is measured along the entire width and length. Slices of the same thickness, density and cell size then await sandwich panel production. Each slice is tagged for traceability.



being ourney



M.C. Gill technician at one of the control panels checking the oven's temperature, which is critical and must be closely monitored.



The resin impregnated facing comes out of the B stage drying oven and is cut to pre-determined length. It then goes into refrigerated storage to await sandwich panel construction.





The cured and heat-set panels come out of the press, ready for final trimming.



This panel is being cut and trimmed to size. From here it goes into finished goods inventory or directly to shipping for packaging and delivery to customers.



Aluminum Facings/Balsa Wood Core

End grain balsa wood has performed well in the aircraft industry for almost 40 years.

Pluses: Very good stiffness and core shear (when the core fails before the facings); relatively low cost; good thermal insulation; simple edge sealing with liquid sealant; and, very good point load resistance.

Minuses: Relatively heavy with only two core weights of 6.5 lbs/ft³ and 9 lbs/ft³ available; aluminum corrodes without proper treatment; aluminum facings less dent resistant than FRP; and, panel will absorb some water unless edges are properly sealed and proper adhesive used.



FRP Facings/Nomex® Honeycomb Core

Nomex honeycomb is made from an aramid fiber paper and is a very resilient core material. Either unidirectional or woven fiberglass facings are used. This panel is often used for aircraft flooring and other interior panels, and is finding use in a few specialized non-aircraft markets.

Pluses: Highly fatigue resistant core; light, low smoke configuration possible; completely non-metallic, therefore corrosion resistant; very low density core available and when combined with various facing thicknesses provides good flexibility in design; radar transparent; can be formed into simple curves; and, core absorbs shock well

Minuses: Tendency for edge delamination when cutting if facings are unidirectional; high smoke emission level if epoxy adhesive and epoxy facing resin (lower smoke emission with phenolic resins); high initial cost; needs edge treatment; and, honeycomb cells may fill with liquid if facing is punctured.



FRP Facings/Balsa Wood Core

Introduced by M.C. Gill Corporation to the aviation industry more than 35 years ago this panel is made with woven fiberglass cloth as reinforcement in the facings. Very little adhesive as such is used – the facings are fused to the core.

Pluses: Solid core and FRP facings provide excellent dent and point load resistance; relatively low cost considering the panel's durability; completely non-metallic, therefore corrosion resistant; excellent fatigue resistance; and, radar transparent.

Minuses: Heavier than some newer types of panels with same mechanical strength properties; and, will absorb some water unless edges are properly sealed.



Carbon-Phenolic/Nomex Honeycomb Core

This panel, a relatively new configuration, is made from unidirectional or woven carbon facings bonded to a Nomex honeycomb core. Because of the high cost of the raw materials, its market is limited primarily to aircraft and aerospace applications.

Pluses: Light weight; much stiffer than other panels of the same weight; very low density core available and when combined with various facing thicknesses provides good flexibility in design; highly fatigue resistant core; more resistant to repeated high psi loading, such as caster wheels and stiletto heels; and, very low smoke emission levels due to phenolic facing resin.

Minuses: Carbon dust may short out electrical hand tools during fabrication; galvanic corrosion likely between carbon and adjacent metallic materials unless protected with fiberglass overlays and/or expensive titanium, stainless steel, or composite inserts are used; high initial cost; needs edge treatment; and, honeycomb cells may fill with liquid if facings are punctured.



Sandwich Panels in Inventory

The products shown in the following table are stocked for immediate shipment.

Because our customers all have differing specifications, sandwich panels are traditionally custom fabricated. With all the differing thicknesses, lengths, widths, facings, cores, and tolerances, the possible variations in sandwich panel construction are endless, and the M. C. Gill Corporation has historically manufactured panels produced specifically to customer callouts. Conversely, our corporation also has prided itself on prompt response to customer requests. In fact, it is the company's philosophy that **we do not lose orders because of delivery terms**. Therefore, based on sales history and to support those customers that regularly order the same panels, we do maintain an inventory of the more popular constructions. By doing so, we provide quicker turn around time and more economical pricing for most customers, no matter how big or small.

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M.C. GILL PART NUMBER	DIMENSIONS	CONSTRUCTION	COMMON END USES
Gillfloor 4017T	.400" x 48" x 144" Facings .015"/.015"	Unidirectional S-2 glass reinforced epoxy faces bonded to Nomex honey comb core with modified epoxy adhesive.	Aircraft flooring in passenger compartment of DC-9, MD-80, DC-10 aircraft. Qualifies to McDD Drawing BZZ 7002, Ty1.
Gillfab 4030	.500"x 48"x 96" Facings .020"/.020"	2024T3 aluminum faces, aluminum honeycomb core (1/4" cell size 5052/ .002" foil aluminum honeycomb), modified epoxy adhesive.	General purpose panels for shelving, cabinetry, partitions, bulkheads and multiple other uses.
Gillfab 4105B	.375" x 48" x144" Facings .025"/.025"	Woven E-glass/epoxy faces, 3/16" cell Nomex honeycomb core, modified expoxy adhesive.	Passenger compartment flooring.on A300/A310 and A330/A340 aircraft. Qualified to Airbus Industrie TL53/5000/79,Ty 2.
Gillfab 4205	.375" x 48" x 144" Facings .025"/.025"	FRP/unidirectional carbon fiber reinforced phenolic faces/Nomex honeycomb core with modified epoxy adhesive.	Passenger and cockpit flooring on A320/A321 aircraft. Qualified to Airbus DBAA 5360 M1B 000100.
Gillfab 4323	.496 x 60" x 96" Facings .030"/.020"	FRP reinforced phenolic faces/ Nomex honeycomb core with modified epoxy adhesive.	Bulk cargo flooring on A300/A310, A320/A321 and A330/A340 aircraft. Qualified to Airbus DBAA 5360 M1B 000100.
Gillfab 4417 Ty II	.400" x 48" x 144" Facings .015"/.015"	Unidirectional FRP epoxy facings/Nomex honeycomb core with modified epoxy adhesive.	Cabin flooring on all 700 series aircraft. Qualified to Boeing BMS 4-17, Ty II.
Gillfloor 5007A	.400" x 48" x 144" Facings .030/.020, .030" /.030" and .040"/.020"	FRP faces, 9 pcf end grain balsa wood core. Also 7 PCF on special orders.	Aircraft passenger compartment replacement flooring, galleys, cabinetry and pallets.
Gillfloor 5007B	.400"x 48"x 144" Facings .040"/.020"	Same as 5007A except for modified resin for high peel.	Aircraft replacement flooring in high traffic areas. Qualified to United Airlines SHE 2902.
Gillfloor 5007C	.400" x 48" x 144" Facings of wear- resistant FRP, one side, .045"/.025" and facings of wear resistant FRP, both sides, .045"/.045"	FRP with mat overlay facings/9 pcf end grain balsa wood core, modified polyester adhesive. Mat overlay consisits of random glass fiber overlay. Facings are fused to core.	Bulk and containerized cargo compartment replacement flooring. Proprietary to the M.C. Gill Corporation.
Gillfab 5040	.400 x 48" x 144" Facings .020"/.012"	2024T3 aluminum faces, 9 pcf end grain balsa wood core, heat setting elastomer adhesive.	Passenger and cargo container compartment replacement flooring. Used as general purpose panel to replace plywood.
Gillfab 5242	.390" x 48" x 144" Facings .020"/.012"	Glass cloth overlay of reinforced epoxy/aluminum and .012" aluminum facings/end grain balsa wood core with modified epoxy adhesive.	Cargo flooring on DC-9, MD-80 aircraft. Qualified to McDD Dwg S00096, Revision C (2024-T3 aluminum).
Gillfab 5424 Ty II	.400" x 48" x 144" Facings .018"/.018"	Unidirectional epoxy facings/ aluminum honeycomb core	Passenger cabin flooring on 737, 757 aircraft. Qualified to Boeing 4-23, Ty II.

Virtually all of the sandwich panels we inventory were originally developed for use in commercial passenger aircraft and, depending on the date they were introduced, have a minimum of 10 to 25 years of proven in-service history. Since their development, most of these raw stock panels have found many other uses. For example, Gillfloor 5007A has been used since 1966 by the Jet Propulsion Laboratory (JPL) in Pasadena, CA as the flooring material of choice for their unmanned gondolas that carry scientific instrumentation into the stratosphere . . . to measure everything from changes in the weather to studying closely the effects of the self-destruction of a type 11 supernova in a neighboring galaxy. Gillfab 4030 type (Gillfab 4101) panels have been used by Ron Jones Marine, Kent, WA, in the design and construction of unlimited hydroplane racing boats, notably the Miss Budweiser, the most successful unlimited hydroplane in the history of the sport. Gillfab 5040 is used as the mounting boards for photographing printing plate negatives in graphic arts cameras. In short, raw stock panels can be used to fabricate parts for a wide variety of end uses.

Some of the above end uses require variations from the configurations of the panels we normally stock. In either case, we make every effort to ensure that the customer is aware of the construction of the panel, its tolerances and load-bearing properties.

A Myriad of Uses for Sandwich Panels

...where requirements call for significant reductions in weight, impact strength, rigidity, insulation, fire resistance and low smoke.

> Insulated food cart uses Gillfab 5019 panels with fiberglass facings and polyurethane foam core.









The flooring in this FedEx 747 bulk cargo compartment is Gillfloor 5007C with abrasion resistant fiberglass top facing.

An air duct assembly and a pilot's side console storage unit (ready for final detailing) for the British Aerospace BAe 146-200. M.C. Gill's flat stock is cut, formed, and assembled for both units. The air duct assembly jig is shown in the background at the left.



Episode 1

In keeping with our cover theme, the following is Episode 1 of a short story that dates back to the turn of the last century. However, as we prepare for the turn of the next century, its content is as fresh as today's newspaper and we believe many, if not all, of our readers can relate to the frustrations experienced by each of the main characters.

Mike Flannery, the Westcote agent of the Interurban Express Company, leaned over the counter of the express office and shook his fist. Mr. Morehouse, angry and red, stood on the other side of the counter, trembling with rage. The argument had been long and heated, and at last Mr. Morehouse had talked himself speechless. It was a soap box across the top of which were nailed a number of strips, forming a rough but service-able cage. In it two spotted guinea-pigs were greedily eating lettuce leaves.

"Do as you loike, then!" shouted Flannery, "pay for thim an' take thim, or don't pay for thim an' take thim, or don't pay for thim and leave thim be. Rules is rules, Misther Morehouse, an' Mike Flannery's not goin' to be called down fer breakin' of thim."

"But, you everlastingly stupid idiot!" shouted Mr. Morehouse, madly shaking a flimsy printed book beneath the agent's nose, "can't you read it here-in your own plain printed rates? "Pets, domestic, Franklin to Westcote, if properly boxed, twenty-five cents each.' " He threw the book on the counter in disgust. "What more do you want? Aren't they pets? Aren't they domestic? Aren't they properly boxed? What?"

He turned and walked back and forth rapidly; frowning ferociously.

Suddenly he turned to Flannery, and forcing his voice to an artificial calmness spoke slowly but with intense sarcasm.

"Pets," he said "P-e-t-s! Twenty-five cents each. There are two of them. One! Two! Two times twenty-five are fifty! Can you understand that? I offer you fifty cents."

Flannery reached for the book.

He ran his hand through the pages and stopped at page sixty four.

"An' I don't take fifty cints," he whipered in mockery, "Here's the rule for ut. 'Whin the agint be in anny doubt regardin' which of two rates applies to a shipment, he shall charge the larger. The consign-ey may file a claim for the overcharge.' In this case, Misther Morehouse, I be in doubt. Pets thim animals may be, an' domestic they be, but pigs I'm blame sure they do be, an' me rules says plain as the nose on yer face, 'Pigs Franklin to Westcote, thirty cints each.' An' Mister Morehouse, by me arithmetical knowledge two times thurty comes to sixty cints."

Mr. Morehouse shook his head savagely. "Nonsense! "he shouted, "confounded nonsense, I tell you! Why, you poor ignorant foreigner, that rule means common pigs, domestic pigs, not guinea-pigs!"

Flannery was stubborn.

"Pigs is pigs, " he declared firmly. "Guinea-pigs or Irish pigs is all the same to the Interurban Express Company an' to Mike Flannery. Th' nationality of the pig creates no differentiality in the rate, Misther Morehouse! Twould be the same was they Dutch pigs or Rooshun pigs. Mike Flannery, " he added, "is here to tind to the expriss business and not to hould conversation wid pigs in sivinteen languages fer to discover be they Chinese or Tipperary by birth an' nativity. "

Mr. Morehouse hesitated. He bit his lip and then flung out his arms wildly.

"Very well!" he shouted, "you shall hear of this! Your president shall hear of this! It is an outrage! I have offered you fifty cents. You refuse it! Keep the pigs until you are ready to take the fifty cents, but, by George, sir, if one hair of those pigs' heads is harmed I will have the law on you!"

He turned and stalked out, slamming the door. Flannery carefully lifted the soap box from the counter and placed it in a corner. He was not worried. He felt the peace that comes to a faithful servant who has done his duty and done it well.

Mr. Morehouse went home raging. His boy, who had been awaiting the guinea-pigs, knew better than to ask him for them. He was a normal boy and therefore always had a guilty conscience when his father was angry. So the boy slipped quietly around the house. There is nothing so soothing to a guilty conscience as to be out of the path of the avenger.

Mr. Morehouse stormed into the house. "Where's the ink?" he shouted at his wife as soon as his foot was across the doorsill.

Mrs. Morehouse jumped, guiltily. She never used ink. She had not seen the ink, nor moved the ink, nor thought of the ink, but her husband's tone convicted her of the guilt of having borne and reared a boy, and she knew that whenever her husband wanted anything in a loud voice the boy had been at it.

"I'll find Sammy," she said meekly.

When the ink was found Mr. Morehouse wrote rapidly, and he read the completed letter and smiled a triumphant smile.

"That will settle that crazy Irishman!" he exclaimed. "When they get that letter he will hunt another job, all right!"

A week later Mr. Morehouse received a long official envelope with the card of the Interurban Express Company in the upper left corner. He tore it open eagerly and drew out a sheet of paper. At the top it bore the number A6754. The letter was short. "Subject–Rate on Guinea-pigs," it said, "Dr. Sir–We are in receipt of your letter regarding rate on guinea-pigs between Franklin and Westcote, addressed to the president of this company. All claims for overcharge should be addressed to the Claims Department."

Mr. Morehouse wrote to the Claims Department. He wrote six pages of choice sarcasm, vituperation and argument, and sent them to the Claims Department.

Will Flannery prevail over Morehouse's pig-headed parsimonious resistance? Stay tuned, don't miss Episode 2 of the exciting "Pigs Is Pigs" in the next issue of the Doorway.