PIGS IS PIGS

Episode 2

Our story to date: Mr. Morehouse's attempt to take delivery of a pair of guinea pigs ordered for his son was thwarted by Mike Flannery, Westcote agent for the Interurban Express Company. Flannery insisted on freight charges for "pigs" (thirty cents apiece). Mr. Morehouse insisted the "pigs" were domestic pets (twenty-five cents each). When the encounter stalemated, Mr. Morehouse stormed out of the freight office to take the matter, by letter, to Interurban's President. The answer said all claims for overcharge be sent to the Claims Department and he immediately fired off a six page diatribe. Our story continues.

A few weeks later he received a reply from the Claims Department. Attached to it was his last letter.

" Dr. Sir," said the reply. "Your letter of the 16th inst., addressed to this Department, subject rate on guinea-pigs from Franklin to Westcote, rec'd. We have taken up the matter with our agent at Westcote, and his reply is attached herewith. He informs us that you refused to receive the consignment or to pay the charges. You have therefore no claim against this company, and your letter regarding the proper rate on the consignment should be addressed to our Tariff Department."

Mr Morehouse wrote to the Tariff Department. He stated his case clearly, and gave his arguments in full, quoting a page or two from the encyclopedia to prove that guinea-pigs were not common pigs.

"Flannery is right, pigs is pigs"

To assure himself that his report would be up to date, Flannery went to the rear of the office and looked into the cage. The pigs had been transferred to a larger box—a dry goods box.

"Wan,—two,—t'ree,—four,— foive,—six,—sivin,—eight!" he counted. "Sivin spotted an' wan all black. All well an' hearty an' all eatin' loike ragin' hippypotty-musses." He went back to his desk and wrote.

"Mr. Morgan, Head of Tariff Department," he wrote. " Why do I say pigs is pigs because they is pigs and will be til you say they ain't which is what the rule book says stop your jollying me you know it as well as I do. As to health they are all well and hoping you are the same. P. S. There are eight now the family increased all good eaters. P. S. I paid out so far two dollars for cabbage which they like shall I put in bill for same what ?"

With the care that characterizes corporations when they are systematically conducted, Mr. Morehouse's letter was numbered, O. K'd, and started through the regular channels. Duplicate copies of the bill of lading, manifest, Flannery's receipt for the package and several other pertinent papers were pinned to the letter, and they were passed to the head of the Tariff. Department.

The head of the Tariff.Department put his feet on his desk and yawned. He looked through the papers carelessly.

"Miss Kane, " he said to his stenographer, "take this letter. 'Agent, Westcote, N. J. Please advise why consignment referred to in attached papers was refused domestic pet rates."'

Miss Kane made a series of curves and angles on her note book and waited with pencil poised. The head of the department looked at the papers again.

"Huh! guinea pigs!" he said. "Probably starved to death by this time! Add this to that letter: 'Give condition of consignment at present,'"

He tossed the papers on to the stenographer's desk, took his feet from his own desk and went out to lunch.

When Mike Flannery received the letter he scratched his head.

"Give prisint condition," he repeated thoughtfully. "Now what do thim clerks be wantin' to know, I wonder! 'Prisint condition, 'is ut? Thim pigs, praise St. Patrick, do be in good health, so far as I know, but I niver was no veternairy surgeon to pigs. Mebby thim clerks wants me to call in the pig docther an' have their pulses took. Wan thing I do know, howiver, which is they've glorious appytites for pigs of their soize. Ate? They'd ate the brass padlocks off of a barn door! If the paddy pig, by the same token, ate as hearty as these Guinea pigs do, there'd be a famine in Ireland."

Morgan, head of the Tariff, Department, when he received this letter, laughed. He read it again and became serious.

" By Georgel" he said, "Flannery is right, 'pigs is pigs.' I'll have to get authority on this thing. Meanwhile, Miss Kane, take this letter: Agent, Westcote, N. J. Regarding shipment guinea-pigs, File No. A6754. Rule 83, General Instruction to Agents, clearly states that agents shall collect from consignee all costs of provender etc., etc., required for live stock while in transit or storage. You will proceed to collect same from consignee.

Flannery received this letter next morning, and when he read it he grinned.

"Proceed to collect,'' he said softly. "How thim clerks do loike to be talkin'! Me proceed to collect two dollars and twinty-foive cints off Misther Morehouse! I wonder do thim clerks know Misther Morehouse? I'll git it! Oh, yes! 'Misther Morehouse, two an' a quarter, plaze.' 'Cert'nly, me dear frind F'annery. Delighted!' Not!"

Flannery drove the express wagon to Mr. Morehouse's door. Mr. Morehouse answered the bell.

"Ah, ha!" he cried as soon as he saw it was Flannery. "So you've come to your senses at last, have you? I thought you would! Bring the box in."

"I hev no box," said Flannery coldly. "I hev a bill agin Misther John C. Morehouse for two dollars and twinty-foive cints for kebbages aten by his Guinea pigs. Wud you wish to pay ut ?"

Will Morehouse cough up the $2.25? Will Flannery have to adopt the pigs? Stay tuned for Episode 3 of the thrilling "Pigs Is Pigs" in the Summer issue of the Doorway appearing on the news stands the week of August 11, 1997.

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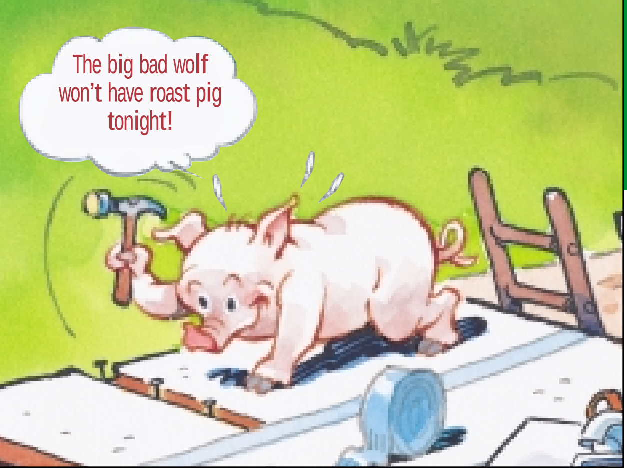
THE M.C. GILL DOORWAY

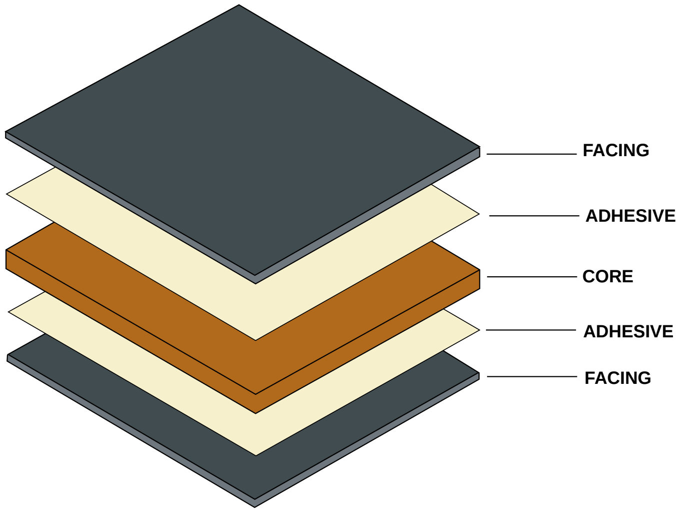
"We try hard enough to make it happen"

M.C. GILL CORP., 4056 EASY ST., EL MONTE, CA 91731 • PHONE (818) 443-4022 • FAX (818) 350-5880 • http://www.mcgillcorp.com

PART 2, SANDWICH PANEL SERIES



THE ANATOMY



A REVIEW, PART 2

Part 1 of this updated series dealt with a general overview of sandwich panels, a discussion of different constructions, a pictorial of how sandwich panels are made, and a listing of sandwich panels M. C.Gill has in stock and ready for shipment. If you did not receive Part 1 and would like a copy, please contact the Marketing Services Department at one of the numbers on the masthead.

In Part 1, we listed the three components of a sandwich panel, i.e., top and bottom facings, core, and adhesive. *Just as the three little pigs each selected materials for their houses that they hoped would keep the wolf outside their doors, we will cover the various types of sandwich panel materials in this issue.*

As will become apparent in the following pages, there are many variables as to which type of sandwich panel is the right one for a given end use application. Moreover, it is important to understand that simply having a hot platen press to bond components purchased elsewhere does not qualify one as a reliable and responsible sandwich panel laminator. It takes properly designed and controlled equipment, long time qualified personnel and rigid quality control, preferably conforming to D1-9000. There is no substitute for almost 52 years of experience.

Facings

In sandwich panel design, the facings are the main load-bearing element. Under top loading, the bottom facing is always in tension and the top facing in compression. (In most panels, the compression skin is the weaker and fails first.) The facings must be strong enough to carry the intended loads and have the proper characteristics to withstand the various service environments they encounter. However, strength is not the only consideration that plays a part in selecting types of faces. The end user must also think about such other factors as weight, corrosion resistance, cost, dent or puncture resistance, weatherability, fire resistance, smoke and toxic emissions, and appearance. Different types of facings include aluminum, fiber reinforced composites, steel, titanium, carbon, and plywood and pressed hardboard. The mechanical properties of typical facing materials are shown in Table 1 on page 4.

Aluminum Alloys
Aluminum alloys are primarily used in aircraft applications, utilizing their high rigidity-to-weight ratio. Each alloy has its advantages: generally the higher the yield strength, the lower the corrosion resistance. A 2024T3 alloy offers a good compromise between strength and susceptibility to corrosion for aircraft uses. We recommend an anodized corrosion treatment in preference to the Forest Product treatment. Aluminum offers good stiffness properties and core shear. However, it will corrode without proper treatment, and is subject to denting and permanent distortion. Although non-burning (except at very high temperatures) and non-smoking, aluminum does have high heat contribution and conduction.

OF A SANDWICH PANEL

Fiber Reinforced Plastics
FRP laminates are widely used as facing material for sandwich panels. They have lower specific gravity, greater corrosion resistance, and lower dielectric properties (low radar signature) than aluminum. Sandwich panel design using FRP faces is a rapidly changing field and S-2 Glass®, carbon, Kevlar® and E-Glass are all possible reinforcements.

The following are some of the more popular FRP facing materials. They can be unidirectional—where all fibers run in the same direction to provide higher impact resistance and specific strengths in specific directions. Or they can be woven—where fibers are woven in cloth patterns to provide ease of cutting and trimming, delamination resistance and bi-directional strengths.

E-glass
Originally called electrical glass, it produces the lowest cost, high strength glass-reinforced plastic. It has high mechanical strength properties combined with good chemical and heat resistance. Generally, when people say "fiberglass," they mean E-glass.

S-2 glass
Has high impact and high tensile strengths. It has the same rigidity as E-glass (modulus is less than 5×10^6) but has 50 percent higher tensile strength and puncture resistance. Hollow fiber versions are still in developmental stages.

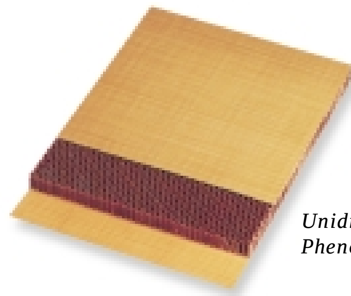
Carbon, or graphite
This is synonymous with the term "advanced composites." Although E-Glass and S-2 Glass are used in the vast majority of reinforced plastic applications, carbon has dominated the trade literature for the past few years. It is very stiff, light weight, and has low thermal expansion. Carbon composites are considered to have excellent fatigue strength. Its shortcomings are its poor impact strength and its high cost. Galvanic corrosion, particularly with aluminum, can be a big problem, especially with metal fastening systems. Carbon sets up an electronic couple with aluminum and is quickly corroded, unless special precautions are taken. Care must be exercised in cutting, drilling or sanding carbon panels because the dust produced will short circuit electrical motors.

Steels and Titanium
Low carbon steels are low cost and very stiff, but are heavy and prone to corrosion. Titanium is strong and light, but expensive and hard to bond. Stainless steel has high strength and rigidity, but bonding to core material is difficult.

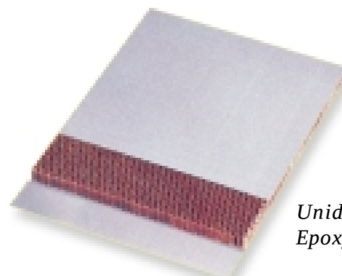
Plywood and Pressed Hardboard
These materials are used in low-cost vertical or non-load bearing architectural applications, not so much to improve properties as to keep costs to a minimum, and for rigidity and flatness in undemanding applications.

The M. C. Gill Corporation uses primarily aluminum and composite facings but if our customers request we will use any conventional materials as facings for sandwich panel requirements.

Woven FRP-Polyester Facings

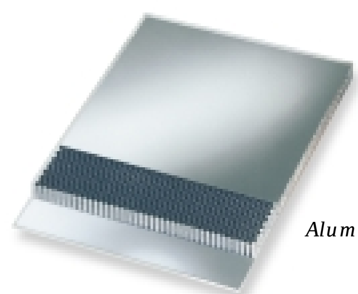


Unidirectional FRP-Phenolic Facings



Unidirectional FRP-Epoxy facings

Unidirectional Carbon-Phenolic Facings



Aluminum Facings

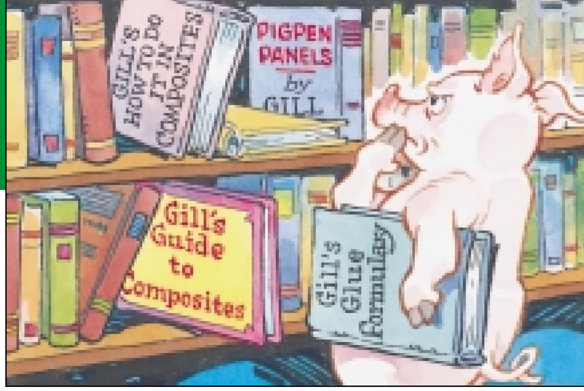
TABLE 1—MECHANICAL PROPERTIES OF TYPICAL SANDWICH FACING MATERIALS

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)	Comments
Aluminum-2024-T3	42	10	0.014	Good strength, moderate cost
Aluminum-3003-H16	20	10	0.014	Moderate strength, good weathering
Aluminum-5052-H32	23	10	0.014	Coated for corrosion resistance
Aluminum-6061-T6	21	10	0.014	Workable, corrosion resistant
Aluminum-7075-T6	60	10	0.014	High tensile strength and dent resistant
Rolled carbon steel- 1.5% carbon content	50	28	0.040	Low cost, high weight, hard to cut with hand tools
Stainless steel-316	60	29	0.040	Heavy, expensive, hard to bond and fabricate with hand tools
Titanium: Annealed Ti-75A	70	15	0.0235	High cost, low corrosion, hard to bond
Fiberglass laminates				
Epoxy-Gillfab 1040	30	3.3	0.01	Std. epoxy, 180°F service temp.
Epoxy-Gillfab 1045	30	3.3	0.01	High strength, 250°F service temp.
Phenolic-Gillfab 1002	30	3.0	0.01	Retains strength well at 350°F, most fire-resistant
Polyester-Gillfab 1074	33	3.0	0.01	Good strength
Polyimide-Gillfab 1028	22	2.5	0.01	Retains strength at 400°F
Polyester-mat-Gillab 990C	16	1.8	0.01	Lowest cost, excellent impact, low flex strength and modulus
Polyester- woven rovings - Gillfab 1027 (24oz.)	25	2.0	0.01	Low cost, general purpose laminate
Kevlar-epoxy-Gillfab 1313	18	2.5	0.0068	Moderate strength, light weight
Kevlar-phenolic-Gillfab 5055	16	2.0	0.0068	Light weight, low smoke
Carbon-epoxy-Gillfab 1089	65	16.0	0.008	High cost, strength, stiffness; guard against galvanic corrosion,
Carbon-phenolic-Z119	60	15.0	0.008	High cost, strength, stiffness; guard against galvanic corrosion,
Douglas fir plywood	2.6	1.5	0.003	Low cost, poor weathering, heavy
Tempered hardboard	2.0	0.6	0.0045	Low cost, low strength, heavy

McDonnell Douglas switched from fiberglass-faced flooring panels to carbon and reduced weight in each MD-11 by approx. 350 lbs.

Fiberglass faced/balsa core 5007C sandwich panels for flooring resist high abuse in Federal Express 747 cargo compartments.

British Aerospace employee installing carbon faced/Nomex honeycomb flooring in the BAe 146 passenger area.



Cores

In the aircraft and aerospace industries *end-grain balsa wood, honeycomb and foam are the core materials of choice. Each has its advantages and disadvantages. The end user must weigh the pros and cons of the core material with the specific end use before specifying type. If the user is unsure, we can assist in the selection.*

END-GRAIN BALSA WOOD

Because of its light weight and competitive low cost, balsa wood is widely used as core material for sandwich panels in the aircraft and marine industries. Balsa can be considered a cellulose aligned foam, with cylindrical cells 95 percent closed and 100 percent aligned.

"End grain" simply means that the grain of the wood is perpendicular to the panel surface—like a butcher's cutting block. Thus, the compressive strength of the wood achieves its optimum utilization with this configuration. Under a microscope, balsa is seen to have a vertical, 95 percent closed-cell structure that is much better aligned than foams.

Not all balsa is the same and it is imperative that the panel fabricator is experienced in specifying and inspecting the balsa used in sandwich panels. The balsa we use comes from central Ecuador and we buy the finest available. The trees are harvested, and the wood dried and cut into "sticks" which are glued together in a layer where all sticks are the same thickness. The layers are then glued together with a high strength adhesive, forming the block which is then shipped to our fabricating facility.

M. C. Gill has long recognized the many advantages of balsa wood: high strength, low cost and remarkable endurance in heavy duty, high abuse applications.

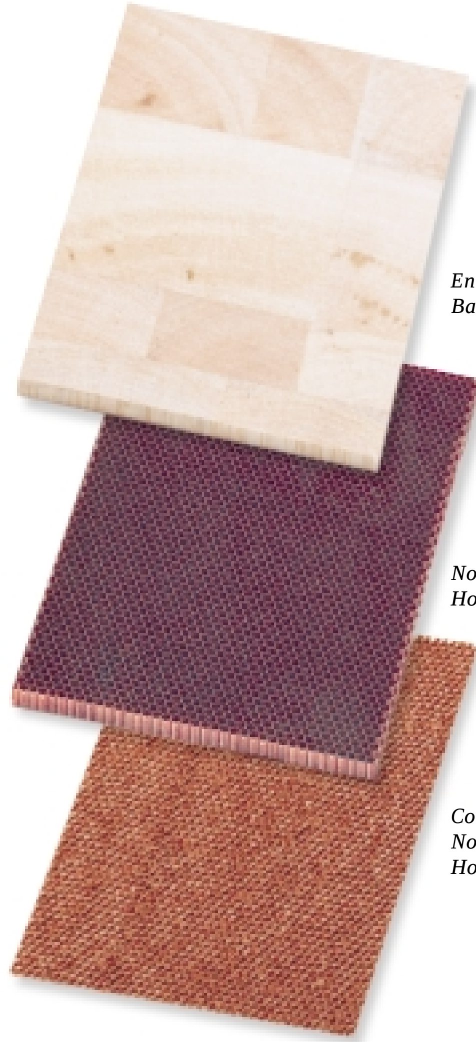
End-grain balsa wood is available in either 9.5 pcf (pounds per cubic foot) or 6.25 pcf density. Because balsa wood is a natural product these densities are averages. For example, at 9.5 pcf, densities of individual sticks may range between 7 and 14 pcf. The 6.25 pcf density is normally used where the panel is in a vertical position or where loads are less severe.

Among balsa wood's many features are:

- *High compressive strength—over 1500 psi (pounds per square inch) for 9.5 pcf balsa and over 900 psi for 6.25 pcf balsa*
- *Resilient, high fatigue nature—is resistant to point loading, and is not brittle*
- *Good core shear strength—200 psi for 9.5 pcf balsa and 160 psi for 6.25 pcf balsa*

To illustrate the strength difference between 6 and 9 pcf balsa, tests on identical panels showed the 6 pcf balsa had 16 percent greater deflection under load, 6 percent lower ultimate load, but the overall panel weight was reduced by 15 percent.

M.C. Gill's end-grain balsa floor panels have achieved a service life in commercial aircraft of well over 20,000 hours flight time as center aisle flooring on flights of short duration and, therefore, more demanding service.



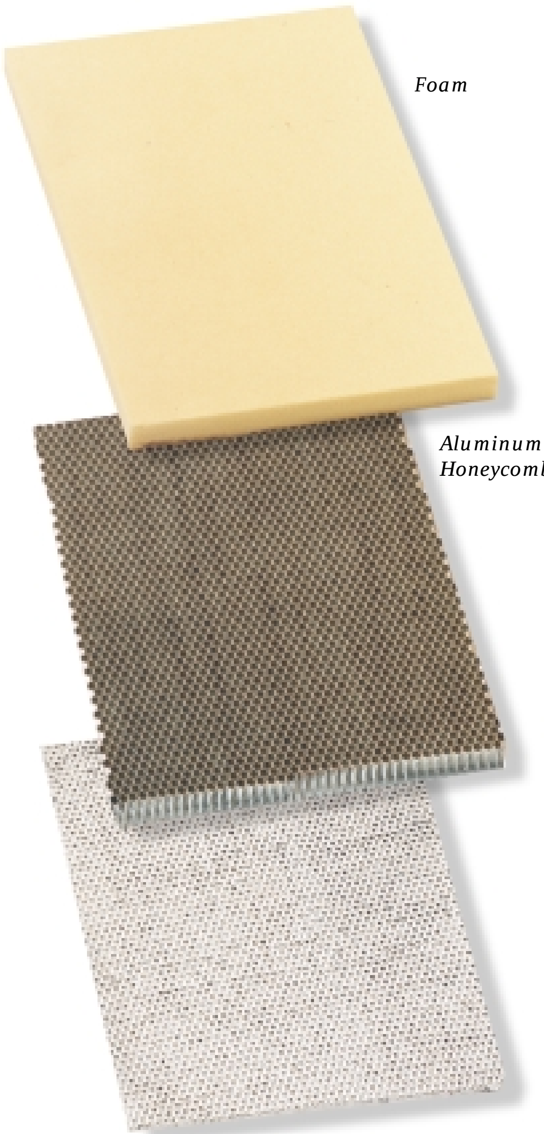
End grain Balsa wood

Nomex® Honeycomb

Compressed Nomex® Honeycomb

HONEYCOMB

Honeycomb is the core material that first comes to most people's minds when thinking of sandwich panels. Its initial applications came in the aircraft industry during World War II where it provided a panel with high stiffness-to-weight ratio. Having processed honeycomb core for sandwich panels since 1955, the M.C. Gill Corporation knows what makes for good quality and proper use.



Compressed Aluminum Honeycomb

Honeycomb core can be made from fiber reinforced plastic, aramid paper, carbon, metallic foils such as aluminum and stainless steel, or Kraft paper. The strength and stiffness of honeycomb is determined by its density; that is, its cell size, cell wall thickness and the material used in the honeycomb. High density produces higher mechanical strength, especially compressive strength, coupled with a greater weight increase.

Resin impregnated Kraft paper honeycomb is the least expensive and is used where high strength and moisture resistance are not so important. Aramid (or Nomex), FRP and honeycomb are most widely used in high performance applications. A wide range of cell size configurations and densities can be produced to meet varying performance levels.

Honeycomb core is truly a versatile, high performance core material. Cell sizes vary from 1/8" to 1.0" or more and overall densities may range from 1.8 pcf to more than 12.0 pcf. Slice thicknesses can be specified up to 12" and more down to .080" It can also be milled, crushed, or the cells over-expanded for contoured panels. Generally, the smaller the cell size, the higher the cost at a given density. Conversely, smaller cell sizes provide 1) less honey-comb mark-off (dimpling of the facings), 2) a greater bonding area, and 3) under heavy loads, less wrinkling of facings, giving higher facing stress.

Aluminum honeycomb features good temperature resistance, low water absorption and relatively low cost. However, aluminum honeycomb is poor in burn-through resistance and unless properly treated, will corrode. Nomex honeycomb is higher in cost and has low resistance to water absorption, but offers superior fatigue resistance and radar transparency. Panel strength is influenced by the particular honeycomb configuration used.

We have produced both aluminum and Nomex honeycomb core materials with our own equipment since 1983, thus providing better verifiable quality control and availability.

Compressed (Crushed) Honeycomb

Compressed honeycomb panels can be roll-formed, routed, sawed, drilled, or riveted using standard metal shop practices. General aviation uses these thin sandwich panels as flooring and interior sidewalls. In larger commercial jets they are used as flooring in containerized baggage compartments. Crushed core panels can be substituted for solid sheet, thickness for thickness, at a weight saving of one-third and no sacrifice in mechanical properties.

As Thin As .080"

Our 60" span horizontal band saws have enabled us to develop the capability to provide honeycomb as thin as .080" without crushing it. The computer controlled saw slices Nomex honeycomb and foam to within a .005" tolerance across each slice. The ability to produce very thin slices results in a lighter weight lower cost panel that can be substituted for crushed honeycomb in applications such as shelving and flooring, or where the panels do not have to be formed.

FOAMS

Foam core sandwich panels have been used as thermal insulation materials in the construction industry. Their use has been restricted by flammability and smoke emission requirements, low tensile strength and core shear, fatigue failure and their friable (crumbly) nature. These drawbacks have been overcome to varying degrees with new types of foam, such as Gillfoam®, although most other foams produce high smoke generation in a fire which greatly reduces their use in transportation vehicles. Foam core panels are used almost exclusively in vertical non-structural surfaces due to their lower mechanical strength.

Polymethacrylimide

This relative newcomer to the field of high performance rigid foam exhibits mechanical properties well above PVC or urethane in the same densities. Available in densities as low as 1.9 pcf, it is resistant to most solvents and chemicals, and has good structural properties at temperatures up to 350°F However, it is much more water absorbent than other foams mentioned here. It is highly toxic in a fire, is more expensive, and is difficult to bond.

Poly Vinyl Chloride (PVC)

These foams are actually half PVC and half urethane, with the urethane providing cross-linking and increased temperature stability. The PVC decreases brittleness and increases fire resistance, but increases smoke emissions. Densities range from 2.5 pcf to 17 pcf. PVC foams exhibit somewhat stronger characteristics than urethane foams of the same density, particularly friability.

Polystyrene Foam

High density styrofoam as a core material is acceptable for some applications. Although low in cost, it is soluble in many solvents. Its high flammability and smoke emissions make it unsuitable for aviation related applications.

TABLE 2
SELECTED FIRE-RELATED PHYSICAL PROPERTIES OF GILLFOAM BY DENSITY IN POUNDS PER CUBIC FOOT (PCF)

Property ▼	4.5	7	10	18	18 pcf polyurethane	FAA Maximum
60 second vertical Burn, length, in.	1.70	1.30	0.47	2.30	3.30	8.0
Extinguishing time, sec.	1.10	0.67	0.87	1.20	1.70	15.0
Drip extinguishing time, sec.	0	0	0	0	0	5.0
45° Flame Penetration Exting. time, sec.	NA	0.70	0.90	1.20	NA	15.0
Afterglow, sec.	NA	0	0	0	NA	10.0
Penetration	NA	0	0	0	NA	0
OSU heat release Total at 2 min., KW-min/M2	NA	53.9	57.5	64.6	164	65.0
Peak, KW/M2	NA	38.6	43.7	54.4	144	65.0

TABLE 3
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 hrft^2°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	N/A	341	22,700	N/A
Gillfoam® 2019	7 10 18	190 334 1,257	3,799 6,741 22,935	103 152 320	3,647 6,408 9,488	.26 .29 N/A

Gillfoam

Gillfoam, developed by M.C. Gill Corp., is a phenolic resin based blown cellular, gas-filled polymeric thermosetting foam. Although the cells contain micro-sized holes they are essentially closed (the holes are so small that water molecules have difficulty penetrating them).

The foam is non-structural, has very good bondability characteristics, high compression values, and very low moisture absorption (edge potting is not necessary in most applications). Only at densities lower than 8 to 10 pcf is Gillfoam somewhat friable. Vis-a-vis foams previously described, Gillfoam is extremely fire retardant, low smoke producing and low toxic emissisions. Smoke density is 17.0 D_S. By contrast, an 18 pcf polyurethane foam produces a smoke density of 263.0, more than 15 times greater than the same density Gillfoam. The FAA's standard for use in commercial aircraft is 200.0 D_S maximum.

Gillfoam is ideally suited as the product of choice where foam is specified in commercial aviation applications—either as the core material in a sandwich panel or as a stand alone component. The data in Table 2 show Gillfoam's fire related properties and Table 3 compares it to other foams.

Adhesives

Because a sandwich panel is no better than the reliability of the adhesive that bonds it together, it should command the buyer's serious attention. The adhesive is the one sandwich panel component that must not be compromised.

For purposes of this discussion there are five high performance general adhesive types available.

- *Modified Epoxy.* Usually the best choice and many formulations are available for different end uses.
- *Vinyl Phenolic.* Very durable with good property values but has environmental drawbacks in pressing.
- *Contact Elastomeric (rubber-like base).* May be satisfactory in non-structural applications but must be evaluated for cold flow, or creep, and solvent moisture and heat resistance.
- *Urethane.* Normally used in construction but has water resistance problems.
- *300°F to 350°F Service Epoxy.* Expensive, but produces durable bonds to 350°F

Urethane and contact-type bonding adhesives are used with lower cost, continuous surface core materials while modified epoxies are used with honeycomb and the higher performance cores required by the aircraft and aerospace industries. The M.C. Gill Corp. uses all types, depending on the compatibility of adhesive with core and facings, the bond and peel strengths required and customer preference or end use.

Elastomeric contact adhesives are applied to both facings and core, then laminated, or pressed, at low pressures and low temperatures.

Epoxy adhesives are best applied as heat-curing films and are placed between core and facings when the panel components are laid up. Initial heating of the press momentarily softens the epoxy. As the press continues to heat, the epoxy is cured to a tough rigid film mass, bonding core and facings together. Epoxies may be used in liquid or paste form when appropriate.

Panels that look and feel the same may have flatwise tensile strength variations that range from 40 to 1200 psi. Because of the difficulty of "inspecting quality," M.C. Gill concluded in 1977 that we would make our own epoxy adhesives to ensure that every inch of every roll of adhesive would exceed minimum requirements. The company's epoxy adhesives are formulated to satisfy customers' needs, and our consistently uniform quality is the result of 20 years' experience.

Adhesive Specifications

All M.C. Gill epoxy adhesives necessarily meet the two most common adhesive specifications: MMM A 132, Type 1, Class 2 and 3, and Mil A 25463 A. We test our adhesives to the most current durability tests as well as methodically spot checking during each run to ensure consistency.

The data in Table 4 on page 9 show the more commonly used adhesives (all modified epoxies except A-123 which is phenolic) that we manufacture, and is included here to assist our customers in deciding which adhesive they might choose to specify.

Factors Affecting Epoxy Adhesive Bond Strengths

Sometimes a customer has a certain honeycomb sandwich panel configuration in mind, but doesn't know what to expect in terms of bond strengths. When bonding a honeycomb sandwich panel there are a number of factors that will affect its bond strength. Foremost among these are 1) type of adhesive, 2) adhesive weight, 3) type of core, 4) cell size, 5) surface preparation of the facings, 6) processing techniques, and 7) variations in processing.

Adhesive Weight

A key variable in selecting epoxy adhesives is the weight of the adhesive per square foot. For purposes of illustration, we have taken an aluminum honeycomb core/aluminum faced panel. The core is 1/4" 5052 cell, .003N 6.0 pcf density; facings are each .020" 2024T3 aluminum; adhesive is Gillbond® A-193. The .045 psf adhesive is usually enough to bond fiberglass or carbon facings to honeycomb core, but experience has taught us that it will not provide a dependable bond for aluminum faces bonded to aluminum honeycomb core; therefore, we use an .060 psf epoxy. Where superior strength is required, we recommend using the .085 psf adhesive. The strength and reliability increase dramatically, but with some weight penalty. (See following tabulation.)

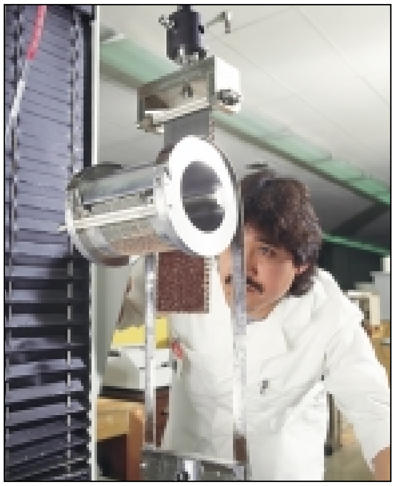
Adhesive Weight	Flatwise Tensile (psi)	Climbing Drum Peel (in-lbs/3")
.045	650	35
.060	1000	60
.085	1200	90

Type of Core

The type of core influences the bond strength. Unless the core has good flatwise tensile strength, the panel will not have high bond strength. For example, foam core has minimal strength, regardless of type; balsa core will bond satisfactorily if processed properly; and bondability of honeycomb core varies with type, paper or foil gauge, and cell size.

Surface Preparation and Workmanship

Surface preparation and workmanship are essential to high quality bonding. Like a chain, a bonded panel is no better than its weakest link and



The climbing drum peel test measures force required to separate facing from core; also strength of the adhesive.

processing techniques must be maintained at a high level. Seemingly insignificant changes can cause drastic changes in the bond. Therefore, uniformity is paramount. No one can do a good job without adequate equipment, procedures, and controls. Many "adhesive failures" are really inadequate surface preparations (it must be 100% clean) or uncontrolled process variations .

Although many materials can be used as facings, four of the more common are aluminum, FRP, carbon and stainless steel. For aluminum panel facings, chemical treatment is the only reliable preparation technique. As opposed to solvent or mechanical cleaning, chemical treatment changes the nature of the aluminum's surface to make it more receptive to adhesion. Aluminum is usually acid-etched or flash anodized.

Generally, in two step bonding, fiberglass reinforced plastic facings are pressed with a peel ply which keeps the bonding surface clean until it is removed just prior to lay up of the panel. If there is no peel

TABLE 4 – M.C. GILL MANUFACTURED ADHESIVES

Part Number	Weight (psf)	Uses/Features
A-187 and	.031	For one-step or primary bonding of FRP facings to Nomex honeycomb core.
A-197	.038	Fire resistant.
A-198	.045	Qualified to McDonnell Douglas DPS 1.99-9.15. Fire resistant.
A-193	.060	Standard for aluminum honeycomb core panels. Not fire resistant.
A-175	.085	Very high peel strengths. Not fire resistant.
A-176	.068	Light weight version of A-175. Not fire resistant.
A-123	.041	One-step cure; thus less expensive to process.

ply, the surface can be wiped clean with a solvent such as MEK; lightly abraded or sandblasted, and then wiped clean.

One method of preparing stainless steel is to sandblast it and then dip it in a solution of sulfuric acid to clean it, but the material must be carefully inspected after sandblasting for kinks or other possible damage. A second method is to dip it in a solution of nitric acid. Primers are sometimes used to coat faying surfaces to improve bondability.

Titanium is a difficult facing material to bond, but one method is to dip it in a mixture of hydrofluoric, hydrochloric, and nitric acids. Another is to prime the surface to facilitate bonding.

The subject of surface preparation is only touched on here primarily to alert the reader to its importance and to emphasize that only an experienced laminator with the proper equipment and experienced personnel is qualified to do it properly.

SUMMARY

The information in Table 5 on page 11 summarizes the pluses and minuses of sandwich panel components. It serves as a quick reference to our readers and is not meant to be all encompassing. No one has ever designed a sandwich panel that has been considered "best" for all or even "best" for a single application. That is the reason our research efforts to develop and test new flooring panels for the commercial aviation industry are on-going. In Part 3 we will present selected physical and mechanical property values (comparable to those in Table 6 on page 12) of some of the newer panels we have developed since this series was last published in 1991.

A few words about fire and related hazards.

As noted in the introductory remarks in Part 1 of this series, we felt it necessary to update our earlier series on panels, in part because we've moved up several notches on the sandwich panel learning curve. Many of those notches have been related to heat release, smoke evolution, and toxic emission characteristics in a post-crash fire.

Given the tragic aircraft crashes that occurred during the 1980's and thus far in the 1990's the drawbacks related to the incorporation of epoxy resin systems in sandwich panels have become the increasing concern to the FAA, airframe manufacturers, airlines and the M.C. Gill Corporation.

Hazards to airplane passengers and crews caused by fire in post-crash conditions have drawn increasing public attention and congressional scrutiny. New standards were established by the FAA in 1988 for heat release rates of certain aircraft components.

Smoke and toxic emmisions are fire-associated dangers in a post-crash environment, but as of this writing the FAA has not yet established test procedures and minimum standards, as it has with heat release rates.

Note: Currently, flooring panels are not required to pass heat release tests. Nevertheless, in response to customer interests, and for the sake of aircraft safety, the M.C. Gill Corp. has developed and tested a number of panels that meet or exceed the following standards.

Heat release values for samples tested are reported in terms of kilowatts (kw) of heat per square meter (m^2) for the peak heat release and in terms of kilowatt-minutes (kw-min) per square meter for the two-minute integrated heat release. In 1986, the FAA established, as criteria, heat release rates of 100 kw/m^2 for the peak test and 100 kw/min/m^2 for the integrated test (usually expressed as 100/100). These standards became effective August 20, 1988, and became even more stringent in 1990 when they dropped to 65/65. To put this measurement in perspective, a one square foot piece of red oak flooring one inch thick will yield readings of 130/130 under identical test conditions—twice the maximum values currently allowed by the FAA.

To enable airlines and airframe manufacturers to comply with these standards, M.C. Gill Corp. has developed new products and "reformulated" existing ones to utilize phenolic resin systems in their construction. Phenolic resins are inherently non-burning and exhibit very low smoke evolution and toxicity in a fire compared to virtually any other organic polymer. Phenolics do have drawbacks but many are manufacturing oriented and not related to end use. As shown in Table 6, page 12, many M.C. Gill products are well within the FAA's 1990 guidelines, and likely would pass any future standards the FAA might adopt. The information in Table 6 identifies the construction and selected properties of some of our better selling sandwich panels.

TABLE 5 – SANDWICH PANEL COMPONENTS – PLUSES AND MINUSES

FACINGS

Aluminum Alloys
- High rigidity-to-weight
- Good stiffness
- Good core shear
- Non burning and smoking
- Low corrosion when treated
- Dents easily
- High heat contribution and conduction

Steels

Low carbon:
- Low cost
- Very stiff
- Heavy
- Prone to corrosion

Stainless:
- High strength and rigidity
- Difficult to bond

Titanium
- Strong and light
- Difficult to bond
- High cost

Plywood/Pressed Hardboard
- Low cost
- Non structural
- Heavy
- Burns easily
- Smoke is toxic
- Absorbs moisture

Fiber Reinforced Plastics

All are:
- Corrosion resistant

Most Are:
- Radar transparent
- Low specific gravity

Unidirectional:
- High puncture resistance
- High specific strengths in specific directions
- Good abrasion resistance

Woven:
- Easy to cut and trim
- Resists delamination
- Good bi-directional properties

Fiber Reinforced Plastics (continued)

E-Glass:
- High mechanical properties
- Good chemical, heat and moisture resistance
- Moderate price

S-2 Glass:
- Very high tensile strength
- Very good puncture
- Higher cost than E-Glass

Carbon:
- Very light weight
- Very good stiffness
- Excellent fatigue strength and wear resistant
- Low density and thermal expansion
- Poor impact strength
- Galvanic corrosion with aluminum unless latter is properly insulated
- High cost
- Dust from cutting conducts electricity

CORES

Rigid Foams

Phenolic:
- Low smoke and toxic emissions
- Low heat release values
- Good compression strength
- Good shear strength
- Wide density range

Polymethacrylamide:
- Good mechanical properties
- Water absorbent
- Burns easily
- High cost
- Difficult to bond

Poly Vinyl Chloride (PVC):
(half PVC/half urethane)
- Temperature stability
- Low brittleness
- Fair fire resistance

High Density Polystyrene:
- Fair mechanical values
- Low cost
- High flammability and smoke emission
- Low temperature resistance

Rigid Foams (continued)
- Soluble in many solvents which makes it difficult to bond with rubber based adhesives

Polyurethane:
- Solvent and chemical resistant
- Best thermal insulation
- Relatively fire retardant
- High smoke and toxic emission
- Fairly friable

End Grain Balsa Wood
- High endurance– hard use, much abuse
- High compressive strength
- Good core shear strength
- Resistant to point loading
- Good thermal insulation
- Low cost
- Limited density choices

Honeycomb

Aramid fiber (Nomex):
- High fatigue and impact resistance
- Radar transparent
- High strength-to-weight ratio
- Resilient

Honeycomb (continued)
- Corrosion resistant
- Low smoke and toxic emissions
- Absorbs moisture
- High cost
- Open cells collect liquids

Aluminum:
- Good temperature, corrosion, and moisture resistance if properly treated
- High strength-to-weight ratio
- Excellent rigidity
- No toxic and smoke emissions
- Lower cost than Nomex
- Poor burn through resistance
- Low corrosion and water resistance if not properly treated
- Open cells collect liquids

Crushed (Nomex or aluminum):
- Can be roll formed
- Can be substituted for solid sheet aluminum, thickness for thickness, with 1/3 weight savings and no sacrifice in most mechanical properties
- Higher cost than solid aluminum

ADHESIVES

Epoxy

Modified:
- Many formulations available for different end uses
- Relatively low cost

High temperature:
- Produces durable bonds to 350°F
- Moderately expensive

Vinyl Phenolic
- Excellent peel
- Environmental drawbacks
- Applications limited by environmental laws

Urethane
- Low cost
- Used with continuous surface material
- Low water resistance

Contact Elastomeric (rubber-like base)
- Satisfactory for non-structural applications
- Should be applied to facings and core
- Should be evaluated for cold flow, creep, etc.
- Application limited by environmental laws
- Inexpensive

TABLE 6 – PROPERTIES OF SELECTED M.C. GILL SANDWICH PANELS

Product ▼	Core type and density	Adhesive	Top facing	Bottom facing	Panel thickness (inches)	Panel weight (lb/f²)	Flex strength 20" span 2 pt. load: Ult. load (lbs)	Flex strength 20" span 2 pt. load: Defl. @ 100lbs 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 401B App F, Part 4		FAR 25.853 (a-1) Mil Std 401B		
4017T Ty 1	1/8" cell, 9pcf Aramid honeycomb	.030 psf epoxy	.015" epoxy Unidir. FRP	.015" epoxy Unidir. FRP	.400	.64	260	.85	53/59	30	30
4017T Ty 2	1/8" cell, 5pcf Aramid honeycomb	.030 epoxy	.015" epoxy Unidir. FRP	.015" epoxy Unidir. FRP	.400 .400	.52 .52	240 240	.85 .85	53/59 53/59	30 30	30 30
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
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	Modified elastomer	.020" 2024T3 Aluminum	.012" 2024T3 Aluminum	.400	.75	292	.31	3.6/0	50	50
5042B	End grain balsa 9.5 pcf	Modified epoxy	7075-T6* Aluminum	7075-T6* Aluminum	.400	.73	426	.35	N/A	49	49
5242	End grain balsa 9.5 pcf	Thermoset epoxy	.020" Gillfab 1040 bonded to .020" 7015-T6 Aluminum	.012" 7015-T6 Aluminum	.400	1.04	301	.35	N/A	N/A	N/A
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	

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 401B	Mil Std 401B	Mil Std 401B	BMS 4-17D	Model 11K3	Shurlok 5107-A3	BMS 4-17D	Mil Std 401B	Mil Std 401B	
4017T 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
4017T Ty2	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
4030	600	700	198/128[2]	N/A	40	N/A	N/A	N/A	100%	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
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%	Proprietary
5040	1500	275	185[3]	14,000	34	1200	128 lbs – 40,000	85%	70%	Embraer MEP 02-011
5042B	2198	1408	447	N/A	60	N/A	N/A	N/A	49	McDonnell Douglas DWG's 3932193 S3932195 S4931863
5242	1587	1522	220	N/A	118	N/A	N/A	N/A	92%	McDonnell Douglas DWG. S00096
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.
CRP means carbon 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.

*Facings' thicknesses depend on drawing call-out.

NEWS FLASH

In response to customers' requests that the company establish a physical presence in Europe, M.C. Gill has purchased the assets of Insoleq Ltd. of Belfast Northern Ireland. We will establish a warehouse and distribution facility for our products to serve our European customers more efficiently. Also, Insoleq will be fabricating Gill's flooring panels for BAe projects as well as manufacturing insulation packages. Further details will appear in the next Doorway.

THE FUNNY SIDE

You know childhood has passed you by when...
...the toys you played with as a kid are now being sold by antique dealers.
...the music a teenager listens to sounds like noise—unlike what you listened to.
...there's no longer any humor in hair replacement commercials.
...the only jeans that are comfortable are advertised as "relaxed fit".

★★★★

Small boy to his father, "I don't know why you call this an allowance. It doesn't allow me to do much of anything."

★★★★

"My boyfriend and I have a personality conflict," she said to a friend. "I have one and he doesn't."

★★★★

Products not worth patenting: Can opener in a can. Inflatable dartboard. Nuclear hand grenades. Lobster helper.

★★★★

"Sorry," said the man to the panhandler, "but my investments lost a great deal of money last week."
"Just because you had a bad week," replied the bum, "why should I suffer?"

★★★★

Prayer of Patience:
Lord, grant me patience. And, I want it NOW!

★★★★

Nothing makes a person more productive than the last minute.

★★★★

Trivia

The chances are 1 in 4 that an American will fall asleep with the TV on at least three nights a week.

★★★★

50 La-Z-Boy recliners were delivered to the CIA in January 1996.

★★★★

Aardvarks can get leprosy.

★★★★

An average of 12,877 dog bites are sustained daily by Americans, but no record of number of dogs bitten by Americans.

★★★★

Americans spend an average of $2,000 per second on legal drugs.

★★★★

There are 1.3 cows in Britain for each unexploded land mine in Cambodia.

★★★★

For an annual donation of $100 the Salesian Sisters of St. John Illosco will reserve a place for you in one of their nun's daily prayers.

★★★★

The Los Angeles Lakers professional basketball team signed Shaquille O'Neal to a $120 million contract. For the same amount they could have purchased the entire Pittsburgh Pirates baseball team and the Hartford Whalers hockey team; or, paid President Clinton's salary for the next 600 years; or, bought 1,200 fast food franchises. Do our values seem skewed?

★★★★

One ant weighs 1/10,000 of an ounce but collectively they weigh more than all the human beings on earth.

★★★★