Baltek DuraKore™ Scantling Handbook

A Guide to Determining Suitable DuraKore™/FRP Laminate and Core Specifications for Application to Power and Sailing Vessel Construction

by

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The DuraKore™ System:

Baltek's DuraKore™ system combines the best features of wood strip plank construction with balsa-cored fiberglass construction. Although the core is balsa, this is not wood construction, but 100% modern cored fiberglass. DuraKore™ makes it possible for a boatbuilder to build a vessel that is both unusually light and strong with less labor than required with other boatbuilding methods. This booklet will provide the builder with the information necessary to determine the scantlings for most ordinary vessels when using the Baltek DuraKore™ system. (Scantlings are the sizes, shapes, and weights of the structural components of a boat.) All the necessary calculations can be made quickly and easily with an inexpensive, student-grade scientific calculator, or from the charts and graphs included.

The system that follows is known as a "scantling rule." Such a rule determines the required materials and dimensions based on a few simple numbers, such as length overall and displacement. Scantling rules have been one of the principal methods of specifying boat construction for well over a hundred years. They are used by classification societies like ABS and Lloyds, and many of the finest designers and builders such as Herreshoff and Nevins. Because of the simplicity of scantling rules—as compared with a detailed engineering analysis—many builders and designers prefer to work with them. It is important to keep in mind, however, that scantling rules only work for the specific type and size of boat intended by the initial rulemaker.

Boat Types and Sizes Covered by This Rule

This DuraKore scantling rule—developed by the author—is intended to cover all monohull vessels between 18 and 80 feet (5.4 and 24.4 m) length overall, power and sail, displacement and planing up to about 45 knots top speed. DuraKore is a superb material for larger and smaller vessels, and for higher-speed craft, but this scantling rule does not cover such boats. Builders contemplating projects like these must consult a qualified naval architect or marine engineer.

Multihulls are covered in the second, Multihull Section, Part II of this rule.

Materials:

There are four basic materials used in this rule:

1) fiberglass
2) balsa core
3) epoxy resin
4) solid wood: timber block, laminated wood, or plywood

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Fiberglass:

Fiberglass comes in a very wide array of styles from "traditional" woven roving and chopped strand mat E-glass to tri-axial S-glass (aircraft-grade fiberglass). Further, other fibers are used in modern boat construction such as Kevlar, graphite, Spectra™, polypropylene (Dynel™), and polyester (Xynole™).

This rule applies exclusively to uni-directional E-glass laid in epoxy. High-modulus Graphite, S-glass, Kevlar, etc. can offer additional weight savings or performance enhancement. DuraKore/uni-directional E-glass construction is so light and strong, however, that the additional expense of high-modulus fibers is seldom justified for most ordinary vessels.

Uni-directional E-glass has strength in only one direction (along the fibers). As a result, the uni-di E-glass is applied in varying orientations on the hull. The most common is at plus and minus 45° (bi-axial, like double diagonal planking) and/or at 0° and 90° (running fore-n-aft and athwartships). To save the builder time, uni-directional glass is available in bi-axial "knitted" or "stitched" styles. This simply means the fiberglass supplier has stitched two uni-di layers together in convenient-to-apply "cloth" rolls. A typical specification for fabric like this might be DB120. This stands for double-bias (bi-axial) 12 oz./sq.yd. (407 g/m^2) uni-di E-glass with no mat layer attached (the final "0"). CD180 would be 0°-90° fiber orientation. Different manufacturers use varying numbering systems, so it's important to check with your glass supplier.

Chopped strand mat is commonly used in conventional polyester FRP construction. It is very important that you *do not use ordinary mat with*

DuraKore epoxy construction. Standard fiberglass mat consists of short chopped strands of fiberglass squashed into a flat "cloth" that is further bound together with a chemical seizing or binder. The standard binder for mat is NOT compatible with epoxy resins. A few special mat products do have seizings compatible with epoxy (or have no seizing or binder). One such fabric style is Hexcell/Knytex C-24 knitted stitch-mat another is BTI CM2415. These are 24 oz./sq.yd. knitted bi-axial or 0°-90° fabrics with a 1.5 oz./sq.yd. (50.8 g/m^2) mat stitched on. The mat has no binder and is compatible with epoxy. Though considerably less expensive than knitted bi-axial fabric, both woven roving and mat have less strength for the same thickness and weight. Accordingly, woven roving and mat make little sense for use in lightweight cored construction with DuraKore. A fabric like C-24 or CM2415 knitted stitch mat, however, can be useful for building up local reinforcement at high load areas and/or where the DuraKore has been removed for hardware attachment or highly-loaded hull penetrations.

DuraKore:

DuraKore is Baltek's standard AL-600/10 polymer pre-sealed end-grain balsa core faced, on the end-grain, with 1/16-inch (1.58 mm) hardwood veneers. The balsa has an average density of 9.5 lb./cu.ft. (0.14 g/cm^3). DuraKore's average shear strength (perpendicular to the grain) is 432 psi (2.97 mPa). It is available in thickness from 3/8 inch (9.5 mm) through 1 inch (25 mm). (Greater thickness are available on special order.)

Fabricated in strips like traditional solid-wood strip-plank, the hardwood faces permit bending the DuraKore strips to shape, without splitting the end-grain open. The end-grain balsa has no longitudinal strength, however, the hardwood facing or veneer has a tensile strength, in the laminate, of approximately 13,000 psi (89.6 mPa) and a modulus of elasticity (E) of 1.3 x 10^6 psi (8963 mPa). Because of this, the veneer (and only the veneer) can be treated as part of the laminate for strength purposes.

In combination with an FRP laminate bonded with epoxy, each veneer is very roughly equal to about 34 oz./sq.yd. (1150 g/m^2) fiberglass reinforcement in flexural characteristics or stiffness. In pure tension, the veneers are about equal to 7 oz./sq.yd. (237 g/m^2) of uni-directional E-glass. These characteristics allows the actual fiberglass laminate to be thinner than with standard cored construction. Keep in mind, that the veneers alone are not sufficient for strength. The DuraKore/FRP hull shell derives its strength *only* in combination with the FRP/epoxy laminate. It is also *vitally* important to avoid grinding away the mahogany veneers during preliminary fairing. If and when this happens the laminate must be increased by 34 oz./sq.yd. (1150 g/m^2) of fiberglass reinforcement.

Note: Some grinding of the veneers is unavoidable during preliminary fairing. As long as 75% of the veneer thickness, or so, remains there is no need to add additional glass. In small local regions, no more than, about 4% of beam overall in diameter, it is acceptable to grind the veneer nearly completely away—if necessary for fairing. This detracts from strength no more than a hole for a thru-hull fitting. Simply, saturate the area well with unthickened epoxy; let cure; and apply the laminate.

When larger areas have their DuraKore veneers ground completely away, these areas must be built up with additional glass. If the ground-off regions are no more than 15% of beam in diameter—and there are not many such areas—simply laminating on a "band-aid" of 7 oz./sq.yd. (237 g/m^2) uni-directional E-glass (extending onto the veneers for at least 6 inches (150 mm) beyond the exposed end-grain) will be sufficient. The uni-di must lie in the fore-n-aft direction. Should still larger areas of veneer be ground away, then a full 34 oz./sq.yd. (1150 g/m^2) of laminate (similar in composition to the balance of the hull shell laminate) must be added.

Epoxy:

Although polyester and vinylester resins are used in standard cored and single-skin FRP construction, DuraKore hulls *must* use *only* marine-grade epoxy, both for bonding and sealing the DuraKore strips and for laying up the FRP skin laminate. Epoxy is the most effective in protecting wood from moisture, it develops the highest mechanical properties in the laminate, and it has the highest peel strength when bonding a laminate to a core. This is because marine epoxies are highly elastometric—they stretch or elongate before cracking or breaking. Elongation absorbs considerable energy making a stronger and tougher structure.

Solid Wood:

Wood cores and reinforcement are used—in some form or other—on the majority of fiberglass vessels. All wood, without exception, must be presealed with epoxy before applying the fiberglass laminate. All wood that is not covered with laminate must be sealed with a minimum of 3 coats of marine epoxy. Plywood is frequently used as core for engine beds, transoms, and at high-load hardware attachments. All plywood *must* be fabricated from glue rated waterproof by boil test (not simply water-resistant). The ideal plywood is rated marine grade; however, ordinary exterior grade is usually acceptable for core construction.

Wherever wood cores are penetrated by fasteners great care must be taken to seal the edges with epoxy resin and/or a marine bedding compound.

The Scantling Number — "Sn":

The principal reference point for this scantling rule is a Scantling Number (Sn). To determine core, laminate, other structural component dimensions and weights, it is necessary to determine the scantling number for the vessel being built.

The Scantling Number (Sn):

Sn = LOA (ft.) x Beam (ft.) x Depth of Hull (ft.) ÷ 1,000 [English]

Sn = LOA (m) x Beam (m) x Depth of Hull (m) ÷ 28.32 [Metric]

Where:

LOA = Length overall

Beam = Beam overall

Depth of Hull = Depth of hull at midships from the sheer to the top of the keel inside the boat.

Note: Midships is exactly half the waterline length, not half the length overall.

Example:

If your new vessel, *Swift'n Swank,* were:

LOA	40.00 ft.	12.19 m
Waterline	37.20 ft.	11.34 m
Beam	12.56 ft.	3.83 m
Depth of Hull	5.91 ft.	1.80 m

She would have a Scantling Number (Sn) of 2.97.

40 ft. LOA x 12.56 ft. Beam x 5.91 ft. depth of hull ÷ 1,000 = 2.969, use 2.97 Sn

12.19 m LOA x 3.83 m Beam x 1.80 m depth of hull ÷ 28.3 = 2.969, use 2.97 Sn

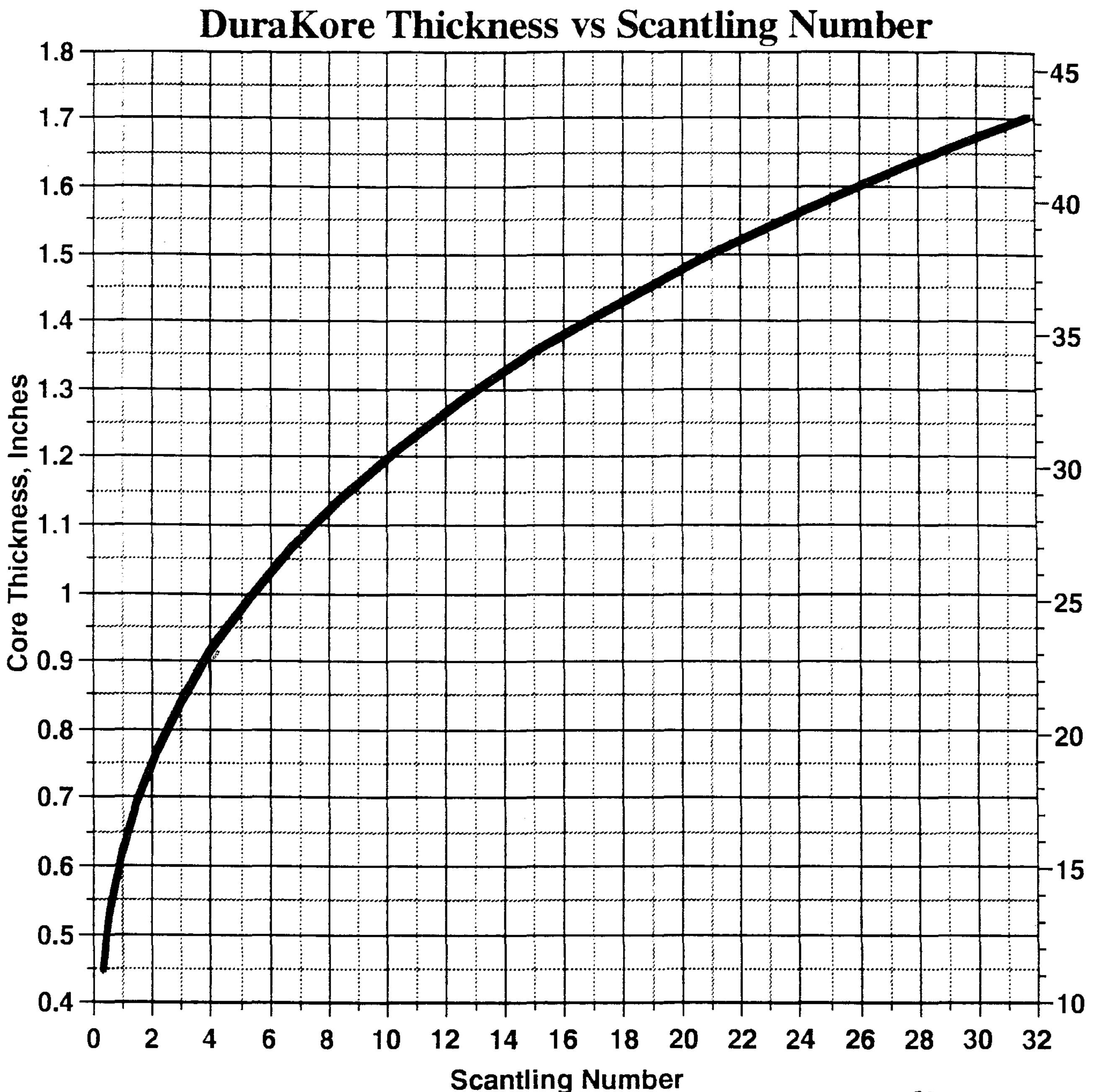
Adjustment for long overhangs:

When LOA divided by WL (Waterline Length) is greater than 108%, find corrected LOA:

Corrected LOA = (Length Overall + Waterline Length) ÷ 2

CALCULATING DURAKORE THICKNESS:

DuraKore Thickness:



DuraKore thickness (inches) = $0.12 + \left(\frac{\sqrt[3]{Sn}}{2}\right)$

DuraKore thickness (mm) = $15.75 \times Sn^{0.285}$

Where: Sn = Scantling Number

Example:

Swift'n Swank's Sn of 2.97 gives a DuraKore thickness of 0.84 inches or 21.4 mm.

$$\left(\frac{\sqrt[3]{2.97}}{2}\right) + 0.12 = 0.838,\ 0.84 \text{ in.}$$

$$15.75 \times 2.97^{0.285} = 21.47 \text{ mm}$$

ADJUSTING DURAKORE THICKNESS AT HULL BOTTOM FOR BOAT SPEED:

The above thickness is suitable for both the bottom and topsides of vessels with a top speed of 10 knots or less. This same thickness should be used on the topsides of higher speed craft, but the bottom thickness (from the turn of the bilge or from the chine down) should be adjusted as follows:

Speed-Adjusted DuraKore Bottom Thickness:

Increase DuraKore thickness 1% for every knot over 10 knots

Example:

Our 40-foot (12.19 m) *Swift'n Swank*'s scantling number (Sn) is 2.97, thus her core thickness should be 0.84 or 21.4 mm (use 3/4-in. or 1-in. — 19 mm or 25 mm DuraKore) for speed under 10 knots. (The thicker core will increase stiffness, but the thinner core will be less expensive and easier to apply.) If *Swift'n Swank* were a 25-knot planing hull:

25 knots - 10 knots = 15, or increase thickness 15%

0.84 in. x 1.15 = 0.966 in. (use 1.0-in. DuraKore, in hull bottom — 3/4-in would be too thin.)

21.4 mm x 1.15 = 24.6 mm (use 25 mm DuraKore, in hull bottom — 3/4-in would be too thin.)

ADJUSTING DURAKORE THICKNESS FOR HEAVY DISPLACEMENT:

The basic scantling rule assumes the vessel has a displacement-length ratio of 275 or less. For displacement-length ratios under 100, additional weight savings can be achieved by keeping similar DuraKore thickness and going to higher-modulus laminate reinforcements (graphite, S-glass, Kevlar, etc.). This is not required but will produce a lighter hull at somewhat greater cost. Such laminates fall outside this scantling rule.

Heavy-displacement boats—with displacement length ratios greater than 275—place additional strain on their hulls. The DuraKore thickness (both bottom and topsides) should be adjusted as follows:

Percent Increase of DuraKore for Heavy Displacement = 0.89 + (DL Ratio ÷ 2,500)

Where:

DL Ratio = Displacement-Length Ratio

DL Ratio = Tons ÷ $(0.01 \times WL\ ft.)^3$ [English]

DL Ratio = (Mtons ÷ 1267) ÷ $(WL\ m \div 328)^3$ [Metric]

Tons = full-loaded displacement, in long tons of 2,240 lbs.

Mtons = full-loaded displacement, in metric tons of 2000 kg

WL = Waterline length, in feet

Example:

If *Swift'n Swank,*with a waterline of 37.2 feet had a displacement of 18 long tons, her DL Ratio would be 349; or with a waterline of 11.34 m and a displacement of 18.28 metric tons her DL Ratio would be 349. This would increase her DuraKore thickness as follows:

%Increase = 0.89 + (349 DL Ratio ÷ 2,500) = 1.029, use 3%

COMBINING SPEED ADJUSTMENT AND DISPLACEMENT ADJUSTMENT FOR DURAKORE:

On larger heavy work boats (for instance an offshore crewboat) both the speed and displacement adjustments would apply. First find the increase for displacement and apply that to both bottom and topsides. Next, find the increase for the speed and multiply the displacement-adjusted DuraKore thickness by that for the bottom core thickness.

Standard DuraKore Thicknesses

INCHES	3/8	1/2	5/8	3/4	1
MM	9.5	12.7	15.9	19	25.4

Other thickness available on special order. Consult Baltek Crop.

CALCULATING HULL SHELL LAMINATE:

The required total thickness of fiberglass (FRP) laminate skins, on both the inside and the outside of the DuraKore combined, is:

Total Laminate Thickness (in.) = 0.03 + (Sn ÷ 44) [English]

Total Laminate Thickness (mm) = 0.76 + (Sn ÷ 1.73) [Metric]

Where:

Sn = Scantling Number

Results apply only to knitted bi-axial or 0°–90° glass styles, with no mat. These styles—when properly laid up—produce a laminate which is approximately 55% glass content by weight.

Example:

For *Swift 'n Swanky*, with a Sn or 2.97:

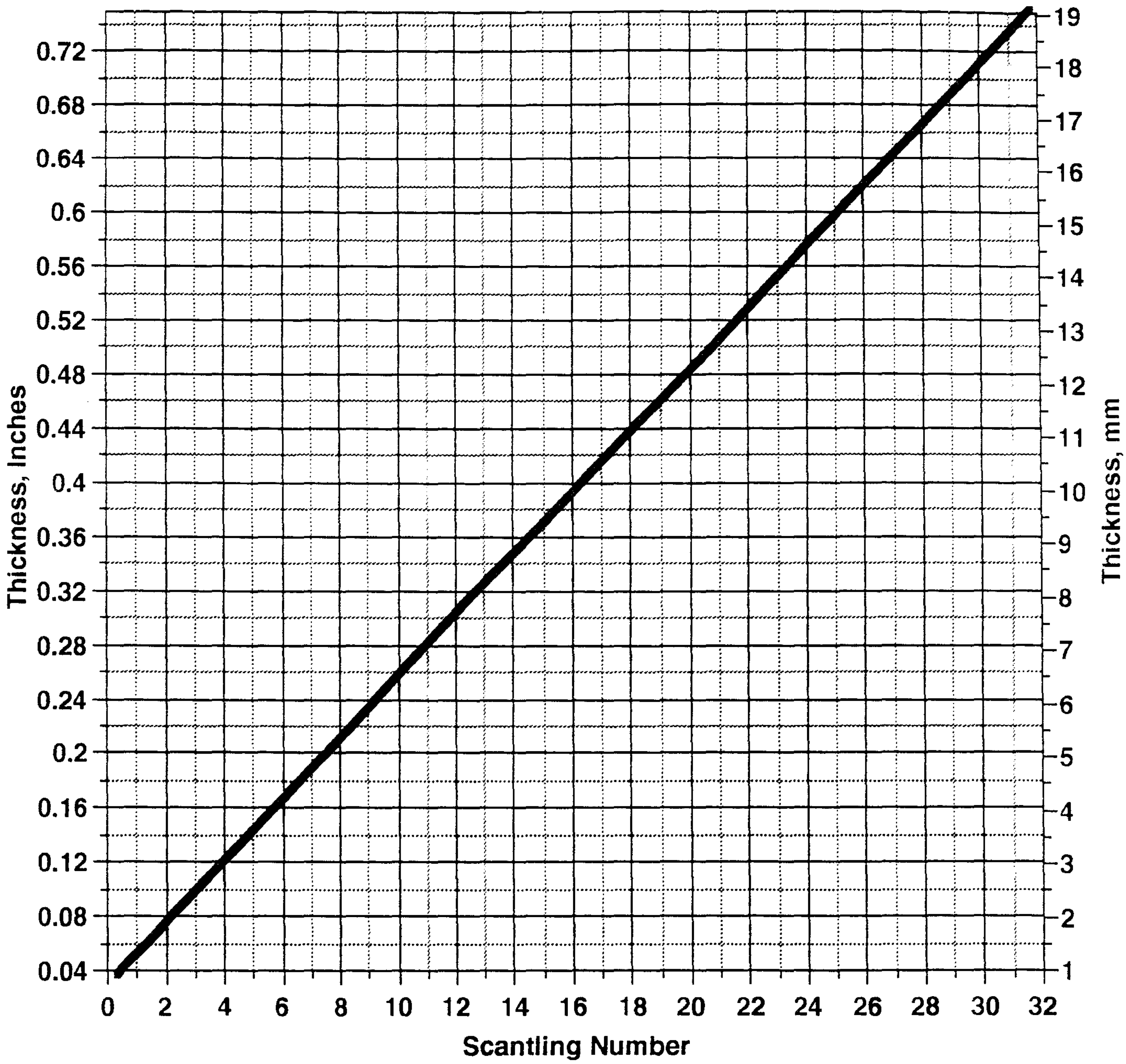
Laminate thickness (in.) = 0.03 + (2.97 Sn ÷ 44) = 0.097 in.

Laminate thickness (mm) = 0.76 + (2.97 Sn ÷ 1.73) = 2.47 mm

INCREASING LAMINATE THICKNESS FOR HEAVY DISPLACEMENT:

The laminate thickness for vessels with DL Ratios over 275 should be increased by the same percentage of the core increase for displacement.

Total Layup Thickness (Inside & Out) vs Scantling Number



WEIGHT OF DRY GLASS CLOTH FOR REQUIRED THICKNESS:

You can refer to manufacturer's style sheets for laminate thickness per layer; however, the following formula will give a close estimate, for bi-axial or 0°–90° knitted glass styles, with no mat:

[English]

Weight of Dry Glass (oz./sq.yd.) = (Laminate Thickness (in.) x 610) - 0.3

Laminate Thickness (in.) = (Weight of Dry Glass (oz./sq.yd.) – 0.3) ÷ 610

[Metric]

Weight of Dry Glass (g/m^2) = (Laminate Thickness (mm) x 813) - 9.7

Laminate Thickness (mm) = (Weight of Dry Glass (g/m^2) – 9.7) ÷ 813

Example:

Swift'n Swank's 0.097-inch laminate would require 59 ounces of cloth laid in epoxy; or *Swift'n Swank*'s 2.47-mm laminate would require 1998 grams of cloth laid in epoxy

(0.097 in. laminate x 610) - 0.3 = 59.1, use 59 oz./sq.yd.

(2.47 mm laminate x 813) - 9.7 = 1998, use 2000 g/m^2

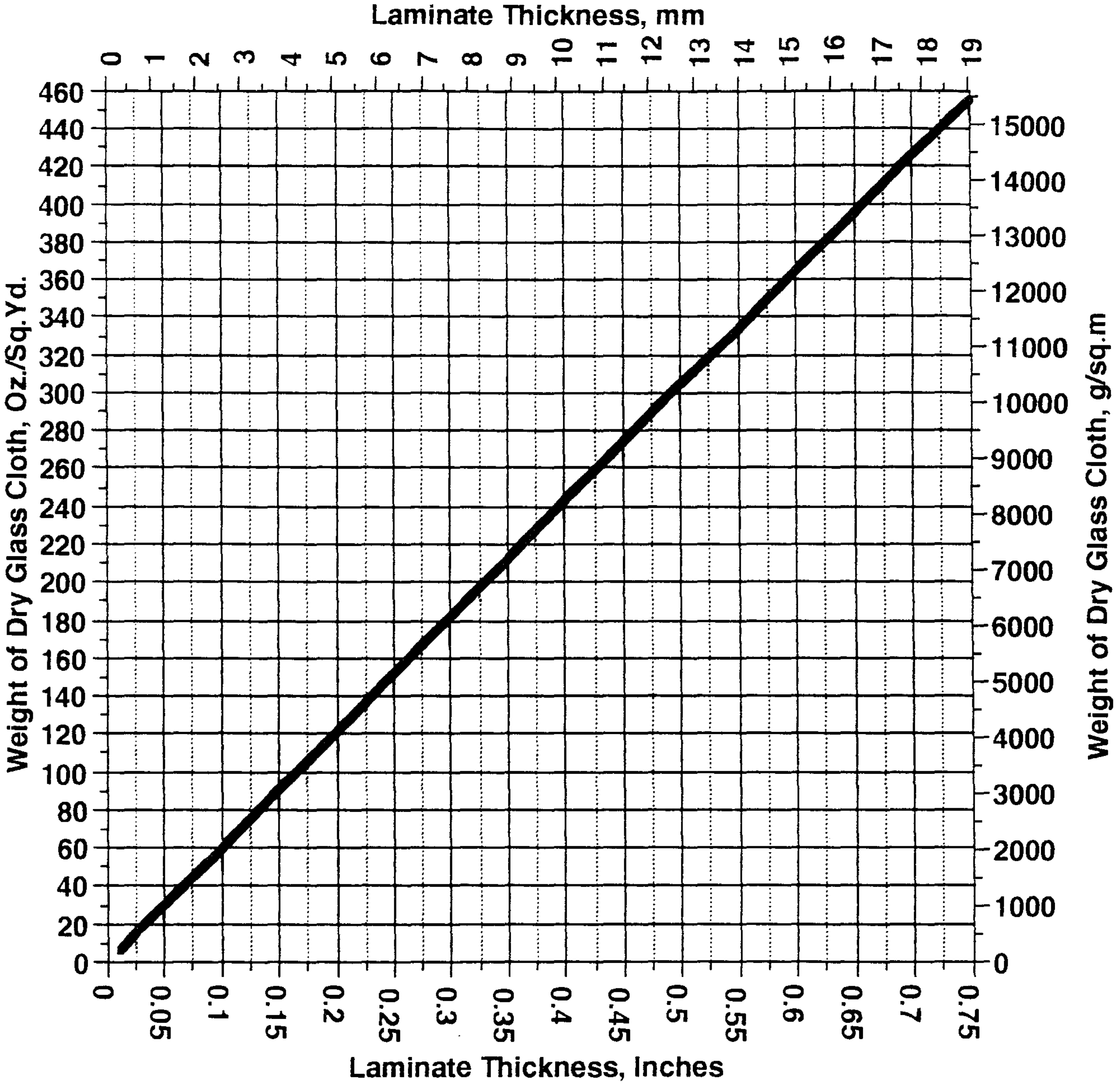
PERCENTAGE OF LAMINATE ON THE INSIDE AND THE OUTSIDE:

When possible, it is best to place 60 percent of the laminate thickness on the outside of the hull, and 40 percent on the inside. This gives better abrasion resistance, and provides somewhat greater laminate strength on the outside face which is in compression. (Most FRP laminates have greater strength in tension than in compression.)

As a practical matter it is necessary to select from the fabric styles readily available from manufacturers. For this reason, it is difficult to divide the laminate 60%-40% on a smaller vessel which may only have a total glass content (inside and out) of 25 to 40 oz./sq.yd [845 to 1360 g/m^2], or less. Such craft can have a balanced laminate (the same thickness inside and out). On larger vessels (a typical 60 footer [18.2 m] would have around 135 oz. [4600 g/m^2] of fabric in the laminate) it is easier to adjust to the 60%-outside 40%-inside rule.

Dry Glass Cloth Weight vs Finished Laminate Thickness

Knitted Bi-Axial & 0°–90° Glass Styles Only (No Mat Attached)



AVOID HEAVY OR THICK FABRIC STYLES:

Bi-axial and tri-axial fabrics are available in a wide variety of styles and weights.

Some are as heavy as 48 oz./sq.yd. [1650 g/m^2]. Builders without extensive experience laying up heavy-weight fabrics are *strongly* advised *not* to use any cloth more than 18 to 24 oz./sq.yd. [610 to 820 g/m^2]. Heavier cloth styles are difficult to wet out thoroughly, to drape in place, and to check for voids or dry spots. Without special equipment and know-how there will be little if any time savings from using heavier fabric styles.

THICKER LAMINATE ON HULL BOTTOM OUTSIDE:

The DuraKore scantlings above will produce a rugged hull that is lighter than most other forms of construction. For small day boats, trailer boats, racing craft, and the like no additional layup is required. On larger craft, however, it is recommended that the laminate on the hull bottom only be increased in thickness (on the outside only) by 5 to 10%. This provides additional protection during grounding and when hitting floating objects.

Example:

Swift'n Swank's 0.097 inch laminate would require 59 ounces or 2000 grams of cloth laid in epoxy.

60% on the outside = 35.4 oz./sq.yd., or 1200 g/m^2

40% on the inside = 23.6 oz./sq.yd., or 800 g/m^2

Increase outside layup on bottom by 10%:

3.54 oz./sq.yd. x 1.1 = 38.9 oz./sq.yd.

1200 g/m^2 x 1.1 = 1320 g/m^2

On topsides:

INSIDE: Use 2 layers Hexcell/Knytex DB120 (12 oz./sq.yd. [407 g/m^2] each)

OUTSIDE: Use 2 layers Hexcell/Knytex DB120 (12 oz./sq.yd. [407 g/m^2] each), plus 1 layer Hexcell/Knytex DB090 (9 oz./sq.yd. [305 g/m^2])

Total total topsides cloth weight = 57 oz./sq.yd. [1933 g/m^2]

On bottom:

Replace the layer of DB090 with a layer of DB180.

Total bottom cloth weight = 66 oz./sq.yd., or 2237 g/m^2

Total bottom cloth weight (on outside only) = 42 oz./sq.yd., or 1423 g/m^2

ADDITIONAL LAMINATE ON KEEL AND STEM:

To protect from grounding, impact, and hauling damage, the outside laminate on the keel and stem should be increased by 15% over the above outside bottom laminate. The additional laminate should extend to protect the projecting portions of the keel and skeg, or for 8% of the beam, which ever is greater.

Example:

Swift'n Swanky's 42 oz./sq.yd. [1423 g/m^2] exterior bottom should be about 48 oz./sq.yd. [1630 g/m^2] at the keel and stem. Add a layer of DB090 at the keel, which brings the total glass content of the laminate at the keel to 51 oz./sq.yd. [1728 g/m^2].

Note: The added build-up at the keel and stem can often be achieved by overlapping layers of laminate alternately as they run from one side of the hull to the other.

ADDITIONAL LAMINATE AT HIGH STRESS AREAS;

High-speed power boats should increase the laminate above the propellers on the hull bottom underside to the same thickness as recommended at the keel and stem. The area of additional thickness should run from the struts aft to the transom, and should extend for a width of at least 2 times the propeller diameter, centered over the propeller shaft.

Sailboats should increase the laminate thickness at the chainplates and under and around the mast step by 10% on both the inside and the outside laminates.

ADJUSTING THICKNESS FOR TYPE OF SERVICE:

Racing boats, and light trailerable dayboats can omit the additional bottom thickness for impact resistance and can use just 95% of the glass thickness or laminate thickness given above. You can achieve a further decrease in weight by using only uni-directional fabrics laid on one at a time in multiple axis orientations (rather than pre-manufactured knitted bi-axial fabrics).

Workboats such as patrol and pilot boats, fishing vessels, etc. should increase all laminate and core thicknesses by 5 to 10 percent.

FIBER ORIENTATION:

The DuraKore veneers provide uni-directional strength on the longitudinal (fore-n-aft) axis. For most smaller boats, bi-axial fabric orientation will provide the needed laminate strength. (Transverse strength is provided by bulkheads and ring frames.) When the laminate thickness becomes greater than 70 oz., [2300 g/m^2] or so, (35 to 40 oz. [1100 to 1400 g/m^2] on either the inside or the outside) it is necessary to add additional fibers along the fore-n-aft axis to supplement the DuraKore veneers. All layups over 70 oz./sq.yd. [2300 g/m^2] require at least 30% of the cloth weight to be 0°-90° styles.

DECK AND CABIN STRUCTURE:

The deck laminate should be the same as the topsides, *with a core 40 percent thicker*. The cabin and wheelhouse sides should be the same as the topsides both in core and laminate thickness.

Example:

We've found that the 40-foot (12.19 m) *Swift'n Swanky* required a topsides laminate 0.097 inches (2.47 mm) thick and a DuraKore thickness of 0.84 inches (24.6 mm). Her deck laminate would be the same 0.097 inches (2.47 mm) thick (inside and outside combined) but the deck core should be 1.18 inches (30 mm). This is between 1- and 1-1/4-inch DuraKore [25 and 30 mm]. One inch (25 mm) would probably be adequate, and would be easier to bend to complex shapes. One-and-a-quarter inch DuraKore is available on special order, and would increase deck strength for serious ocean voyaging or for workboat or charter-boat service.

NOTE:

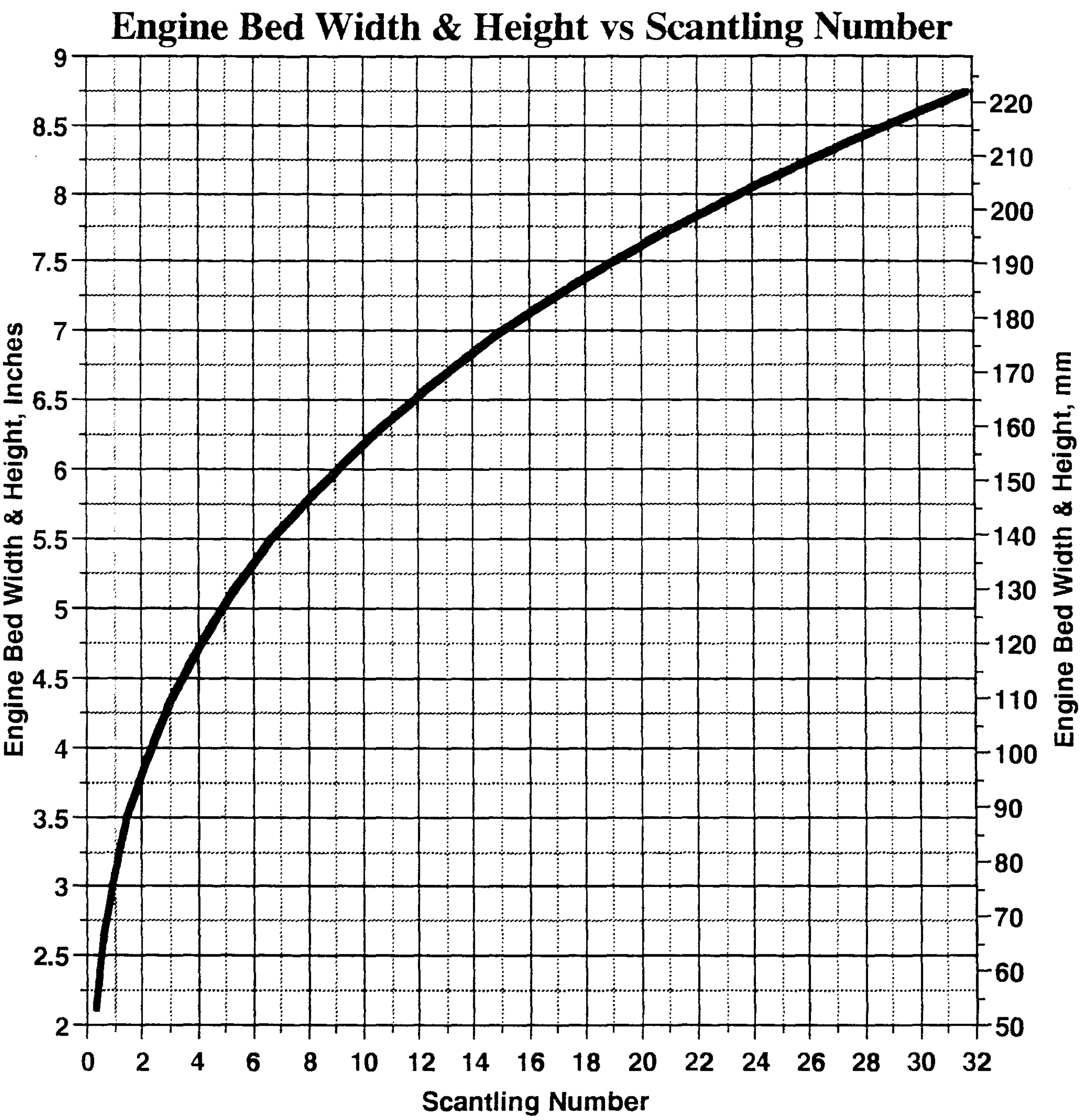
It is sometimes convenient for the builder to mix DuraKore strips, Baltek DecoLite panels, and ContourKore in building deck and cabin structures. The flat panels and ContourKore are more readily available in thicker sizes and can cover the flat shapes in many cabin and deck structures quickly.

With DecoLite panels (which have 1/16-in., or 1.58 mm veneers), the laminate can be identical to the DuraKore laminate. When using balsa core without hardwood veneer facings the total laminate (inside and out combined) should be increased in thickness by 0.10, or 2.5 mm (0.05 inches inside and 0.05 inches outside, or 1.25 mm inside and 1.25 mm outside).

INTERNAL STRUCTURE:

The hull shell is only part of the picture. The shell requires internal structure for adequate strength. The principal components of this internal structure are engine-bed/longitudinal stringers, bulkheads and/or ring frames, and floors.

It is *critical* to remember that all internal structures must be added on top of the finished interior laminate. The interior laminate must run smooth, unbroken, and uninterrupted throughout the entire vessel.



ENGINE-BED/STRINGERS:

Engine-bed stringers are the principal fore-n-aft (longitudinal) members in hulls. They should run continuous and unbroken over the bottom inside for nearly the full length of the vessel. Single-engine craft will usually have two engine beds and twin-engine craft four (two for each engine). On single-engine planing vessels it is recommended that four engine beds still be used. The outer beds will simply be a longitudinal stringer about midway between the outer engine bed and the chine or the turn of the bilge.

Engine beds are usually made of laminated solid wood or of laminated plywood. The wood is epoxied in place on top of the interior laminate and covered with a glass laminate that runs off onto the hull bottom on both sides of the stringer. This run-off is usually referred to as "tabbing." Engine-bed/stringer dimensions should be as follows:

Height and width of engine-bed/stringer solid laminated-wood core, not at the engines:

in inches = $3.1 \times Sn^{0.3}$ [English]

in mm = $78.7 \times Sn^{0.3}$ [Metric]

Height of wood cores at the engines = 1.5 x the width

Where:

Sn = Scantling Number

The laminate over the cores should be the same as the outside hull-bottom laminate and should be tabbed onto the hull bottom for a distance equal to the engine-bed/stringer width, on both sides of the stringer.

Engine-bed/stringers can also be made of balsa-core (stacked DuraKore build-up, or blocks of end-grain balsa) covered with a heavy laminate. The core thickness and height is the same as for solid laminated-wood cores but the laminate provides all the strength and must be considerably thicker.

Cored engine-bed/stringer laminate thickness, not at engines:
inches = 0.18 x $Sn^{0.4}$ [English]
mm = 4.6 x $Sn^{0.4}$ [Metric]
Laminate thickness at engines = 1.4 x laminate not at engines.

These fairly thick layups would be best made using a knitted stitch-mat style fabric. See section on solid-glass, no-core regions.

The entire length of engine-bed/stringer can be cored with balsa, but the region at the engine mount bolts must be cored with solid wood.

Example:
Our 40-foot (12.19-m) *Swift'n Swanky* with a scantling number of 2.97 would require solid laminated-wood cores of 4.3 inches thick and 4.3 inches high [109 x 109 mm], not at the engines; and 4.3 inches wide and 6.45 inches high at the engines [109 x 164 mm]. The cores should be covered with the same laminate as her hull bottom—42 oz./sq.yd., or 1423 g/m^2.

If the engine beds were balsa cored the core dimensions would be the same as above, but the laminate should be 0.28 inches (7.1 mm) thick, not at the engines, and 0.39 inches (9.9 mm) thick at the engines. Cloth weight (from the Thickness vs Fabric Weight chart or formula) is 170 oz./sq.yd., [5760 g/m^2] not at the engines. and 238 oz./sq.yd. [8050 g/m^2] at the engines.

In both cases the laminate should be tabbed onto the hull for 4.3 inches (109 mm) on either side of the engine-bed/stringers.

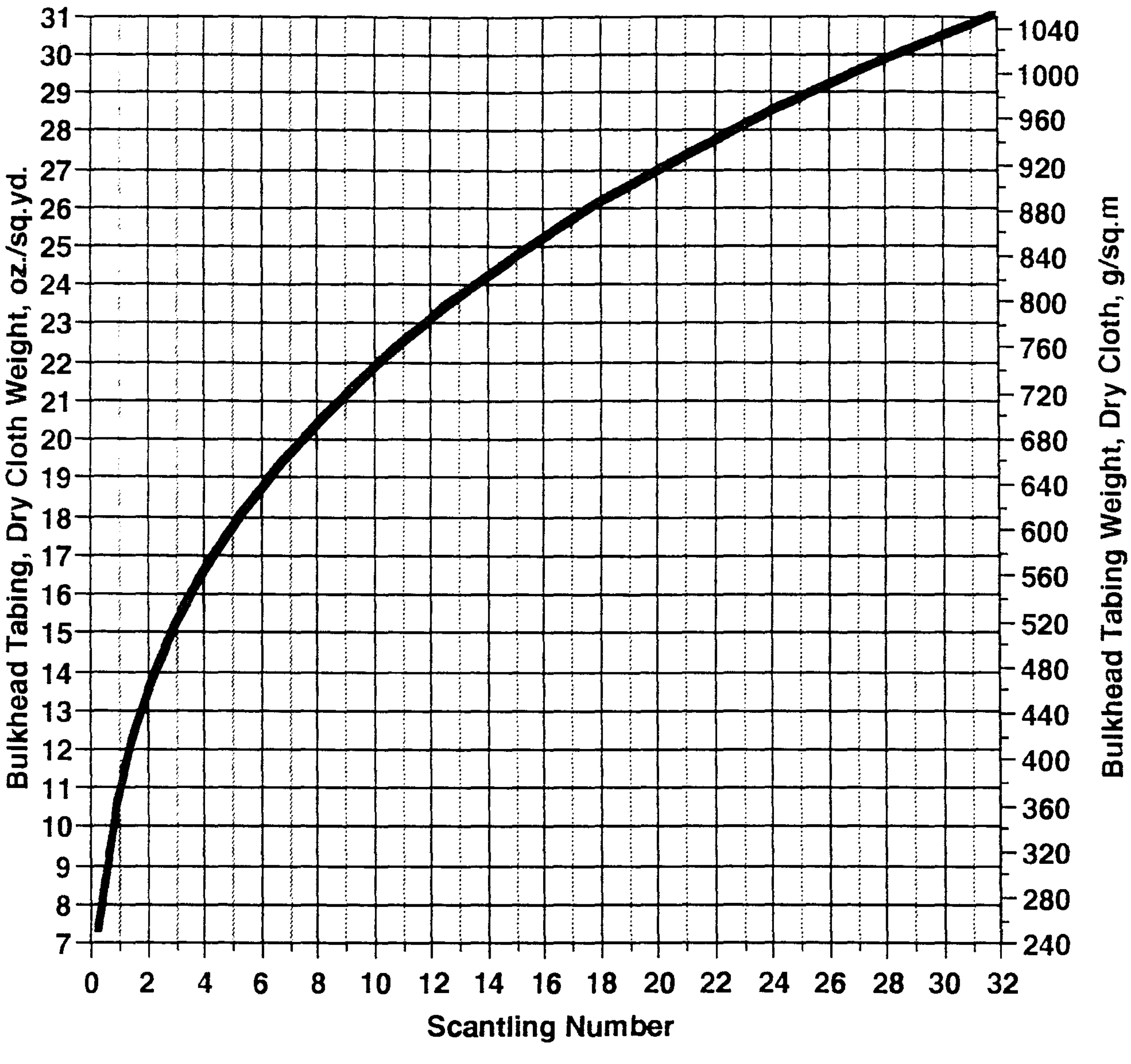
Note: Engine beds can be higher and/or thicker than called for above if necessary to mount engine properly. In all cases, there must be a balsa-core fillet strip or an epoxy-putty fillet in the corners of the stringer where it meets the hull. The laminate must run smoothly over this fillet onto the hull inside to ensure proper strength.

BULKHEADS:

Bulkheads and/or ring frames provide most of the transverse strength in a cored-FRP hull. Bulkheads must be tabbed into the hull along both front and back faces and around their entire perimeter. Bulkheads should be—very roughly—evenly spaced, and they should be closest together between stations 2 and 6, where slamming and rigging loads are maximum on both power and sailing boats.

Bulkhead Tabbing Cloth Weight vs Scantling Number

For Bulkheads With 2-inch (50-mm) Radius Low-Density Epoxy Grout Fillets Both Sides



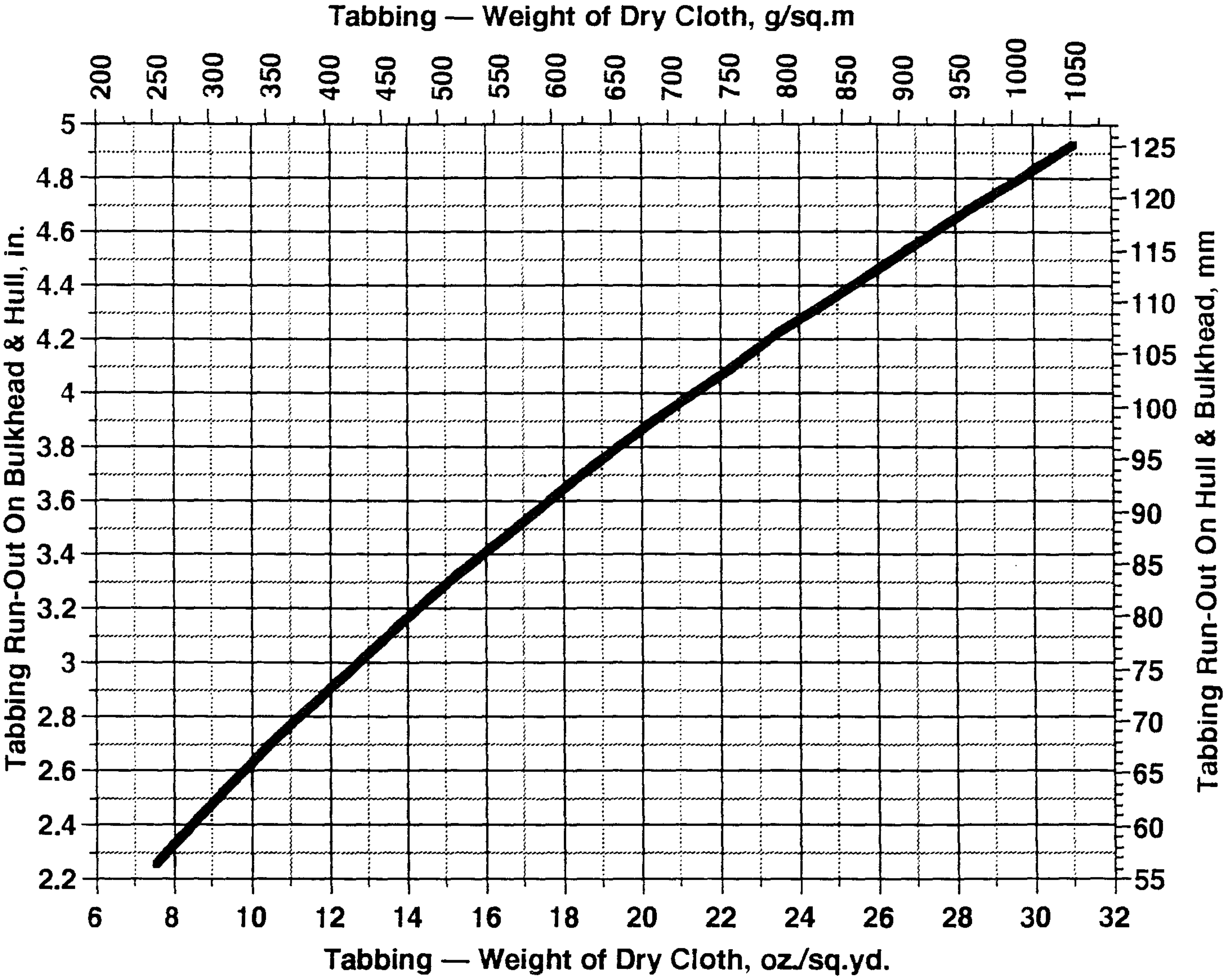
Note: Where bulkheads will intrude on the interior too much, ring frames can be substituted (see later, this section). Standard bulkheads are slightly stiffer than ring frames; however, and you should use as many true bulkheads as practical.

On sailboats, there should ideally be two bulkheads at the mast—one in front of the mast step and one aft. At least one bulkhead/ring frame at the mast is required.

There must also be at least one bulkhead/ring frame at or near the shroud chainplates.

Bulkhead Tabbing Run-Out vs Weight of Tabbing

For Bulkheads With 2-inch (50-mm) Radius Low-Density Epoxy Grout Fillets Both Sides



Minimum number of bulkheads and/or ring frames = 5 x $Sn^{0.25}$

Minimum bulkhead thickness (for solid plywood), inches = 0.45 x $Sn^{0.3}$ [English]

Minimum bulkhead thickness (for solid plywood), mm = 11.43 x $Sn^{0.3}$ [Metric]

Minimum cored bulkhead thickness = 1.1 x minimum solid plywood thickness

Weight of glass tabbing, oz./sq.yd. = 11 x $Sn^{0.3}$ [English]

Weight of glass tabbing, g/m^2 = 373 x $Sn^{0.3}$ [Metric]

Tabbing run out on hull and on bulkhead, in. = 0.72 x $(oz./sq.yd.)^{0.56}$ [English]

Tabbing run out on hull and on bulkhead, mm = 2.6 x $(g/m^2)^{0.56}$ [Metric]

Example:

Our trusty *Swift'n Swanky* would require:

6.56, use 7 bulkheads minimum

0.62 inch, use 5/8 inch solid ply bulkheads or

15.8 mm, use 15 mm solid ply bulkheads or

0.68 inch, use 5/8 inch or 3/4 inch DecoLite balsa-cored bulkheads

17.4 inch, use 18 mm DecoLite balsa-cored bulkheads

15.25 oz./sq.yd. tabbing, use Hexcell/Knytex DB170 (17 oz./sq.yd.)

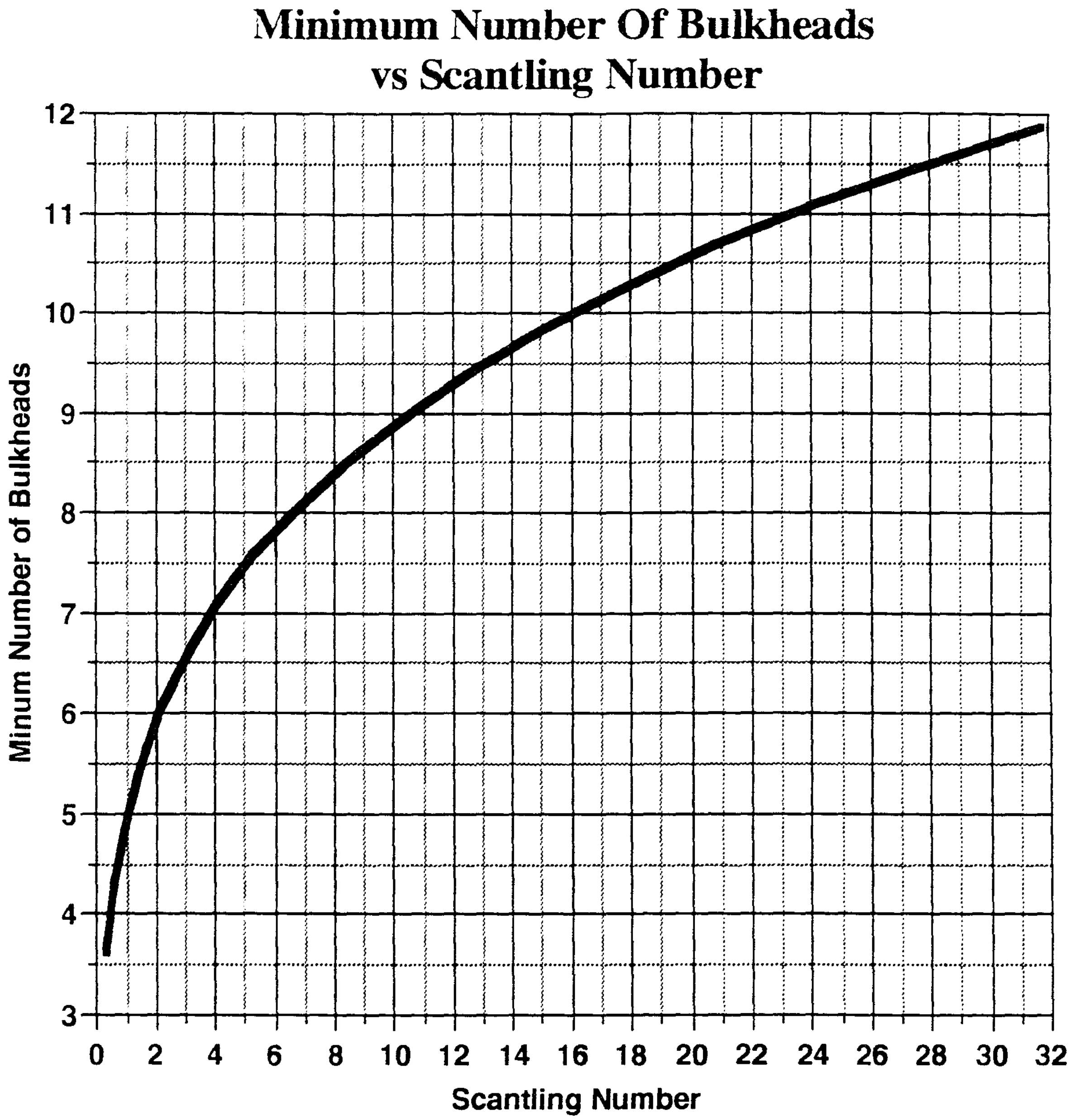
517 g/m^2 tabbing, use Hexcell/Knytex DB170 (17 oz./sq.yd.)

3.3 inch tabbing run out onto the hull and the bulkhead

85 mm tabbing run out onto the hull and the bulkhead

In all cases, there must be an epoxy-putty fillet in the corner of the bulkhead where it meets the hull. The fillet should be formed from low-density epoxy grout with a 2-inch (50 mm) radius. For bulkheads, the epoxy-grout fillet alone will provide much of the required fastening strength. The FRP tabbing must run smoothly over this fillet onto the hull inside to complete the joint and ensure proper strength.

NOTE: Bulkheads thinner than 5/8 inch (15 mm) are somewhat bendy and can be inconvenient to work with. Accordingly, many builders use 5/8-inch (15 mm) or thicker bulkheads even on smaller hulls. The alternative is to install either temporary or permanent cleats on thinner bulkheads to help hold them rigid until they are fully tabbed in place.



ELASTOMETRIC FOAM SPACERS AT BULKHEAD TO HULL JOINT:

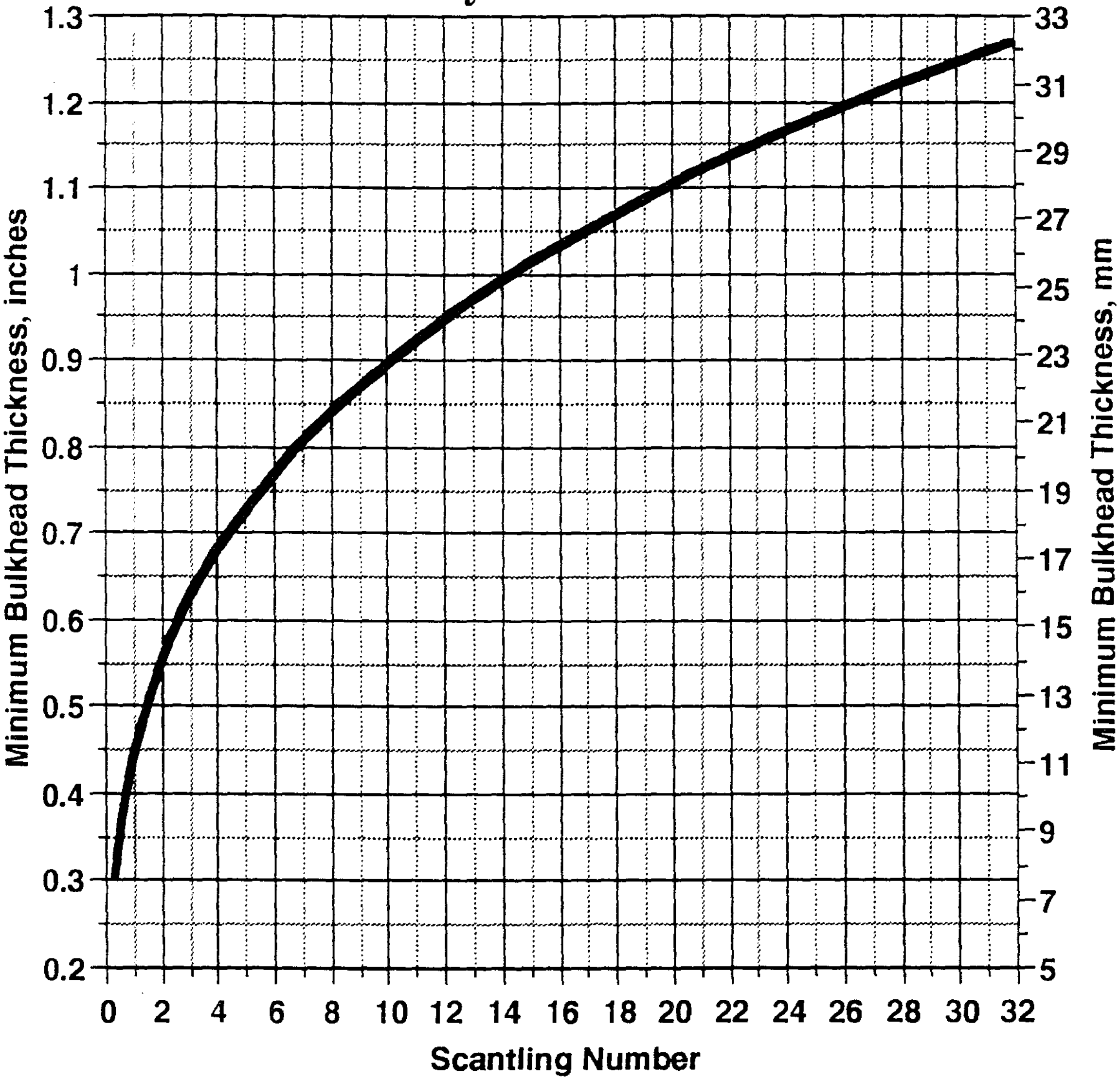
The Coast Guard and the Code of Federal Regulations (CFR) requires a trapezoidal foam spacer between the edge of the bulkhead and the inside of the hull shell on FRP vessels intended for passenger carrying as Subchapter-T boats. Batlek's RibKore (trapezoidal strips of end-grain balsa core held together with a scrim of glass) will also perform this function excellently. The purpose of the spacer is to avoid hard spots on the hull and to distribute the loads over the width of the tabbing. Though necessary for top-quality construction on single-skin and foam-cored-FRP hulls, the high compressive strength of end-grain balsa cores make the foam spacers superfluous on DuraKore craft. Nevertheless, if a T-boat is being built, you must install the spacers to comply with the CFR and obtain certification.

With the elastometric foam spacers (or RibKore), the tabbing carries *all* of the joint load. Accordingly, the tabbing weight or thickness should be increased 2.5 times from that specified above, and the tabbing run-off increased 10 percent.

RING FRAMES IN PLACE OF BULKHEADS:

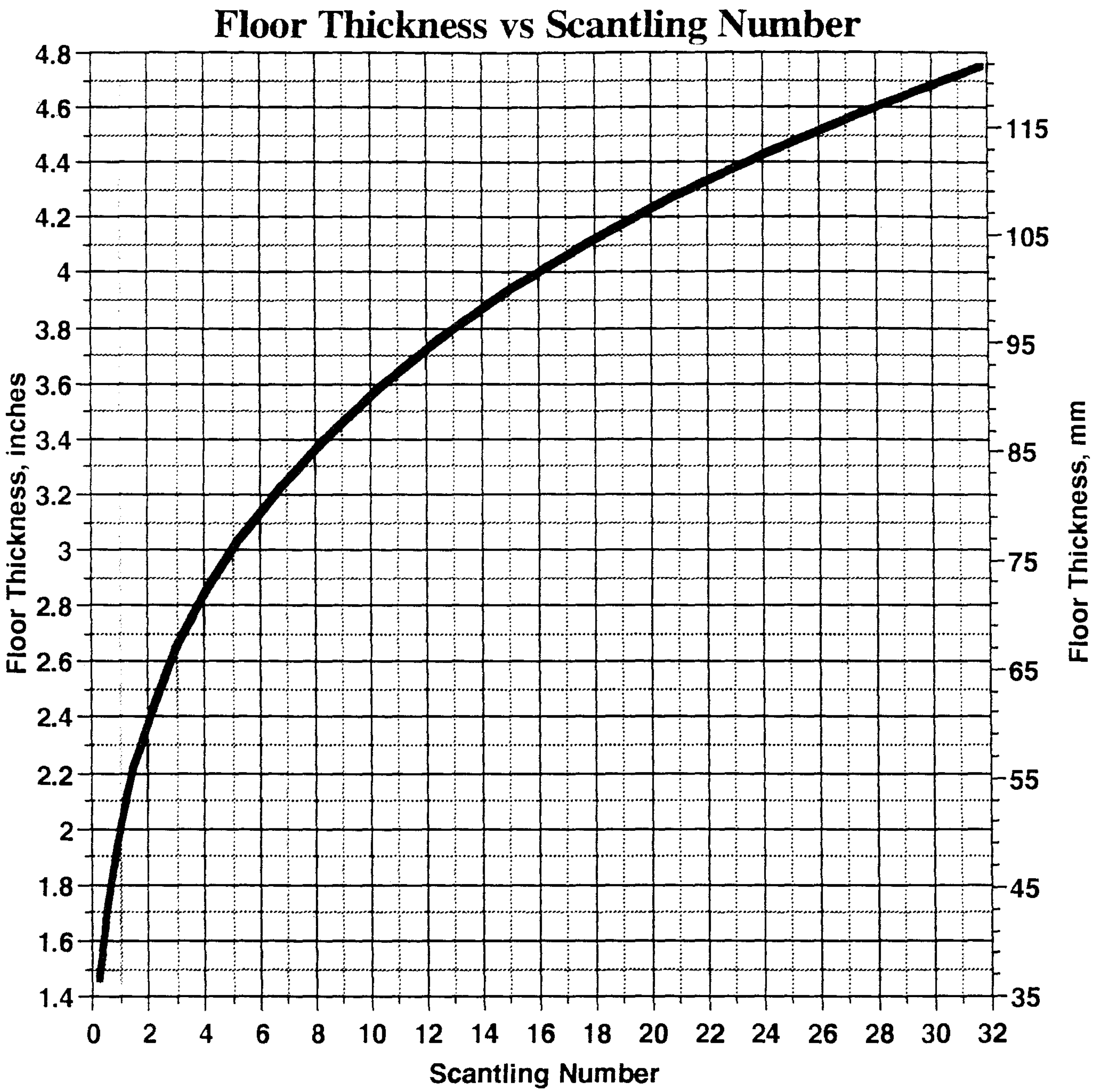
More bulkheads are better than fewer bulkheads. If possible, it is best to use one or two additional bulkheads over the minimum specified above. Frequently, this is difficult or inconvenient because the extra bulkheads would interfere with the machinery or accommodations. Where a bulkhead cannot be used, a ring frame can be substituted. The ring frame should be exactly the same dimensions and construction as the balsa-cored engine-bed/stringers, not at the engines, but—of course—running transversely. Blocks of end-grain balsa, stacks of DecoLite panels, ContourCore panels, or DuraKore strips can be cut and fabricated to form the ring-frame core.

Minimum Bulkhead Thickness vs Scantling Number
Solid Plywood Bulkheads



FLOORS:

Floors provide additional transverse strength at the hull bottom inside. They spread the loads of ballast-keel bolts and mast step. In cored-FRP construction, floors are principally used on sailboats; however, high-speed planing craft (over 30 knots) should have at least one floor midway between each bulkhead, between station 1 and station 6, where slamming loads are highest. Floors should be of solid laminated wood cores covered with FRP, similar to solid laminated-wood engine-bed stringers.



Minimum floor wood-core thickness, inches = 2 x $Sn^{0.25}$ [English]

Minimum floor wood-core thickness, mm = 50.8 x $Sn^{0.25}$ [Metric]

or 4 x keel-bolt diameter, whichever is greater

Minimum floor height = 3 x thickness

Laminate thickness, inches = 1.5 x outside hull-bottom laminate thickness or glass weight

Tabbing run-out on hull = 1.2 x floor's wood-core thickness

Maximum floor spacing at ballast keel, inches = 16 x $Sn^{0.2}$, on center [English]

Maximum floor spacing at ballast keel, mm = 406 x $Sn^{0.2}$, on center [Metric]

or centered on each keel bolt

Minimum number of floors at mast step = 3 x $Sn^{0.2}$

Where:

Sn = Scantling Number

Example:

Our *Swift'n Swanky*'s a 40-foot (12.19 m) sloop, with a Sn of 2.97, we'd find:

Minimum wood-core floor thickness = 2.62, use 2.75 inches

Minimum wood-core floor thickness = 66.7, use 70 mm

Minimum wood-core height = 7.86, use 8 inches

Minimum wood-core height = 200.1, use 200 mm

Laminate thickness = 0.09 inches thick, or cloth weight = 58 oz./sq.yd.

Laminate thickness = 2.43 mm thick, or cloth weight = 1970 g/m^2

Laminate tabbing run-out on hull = 3.6 inches

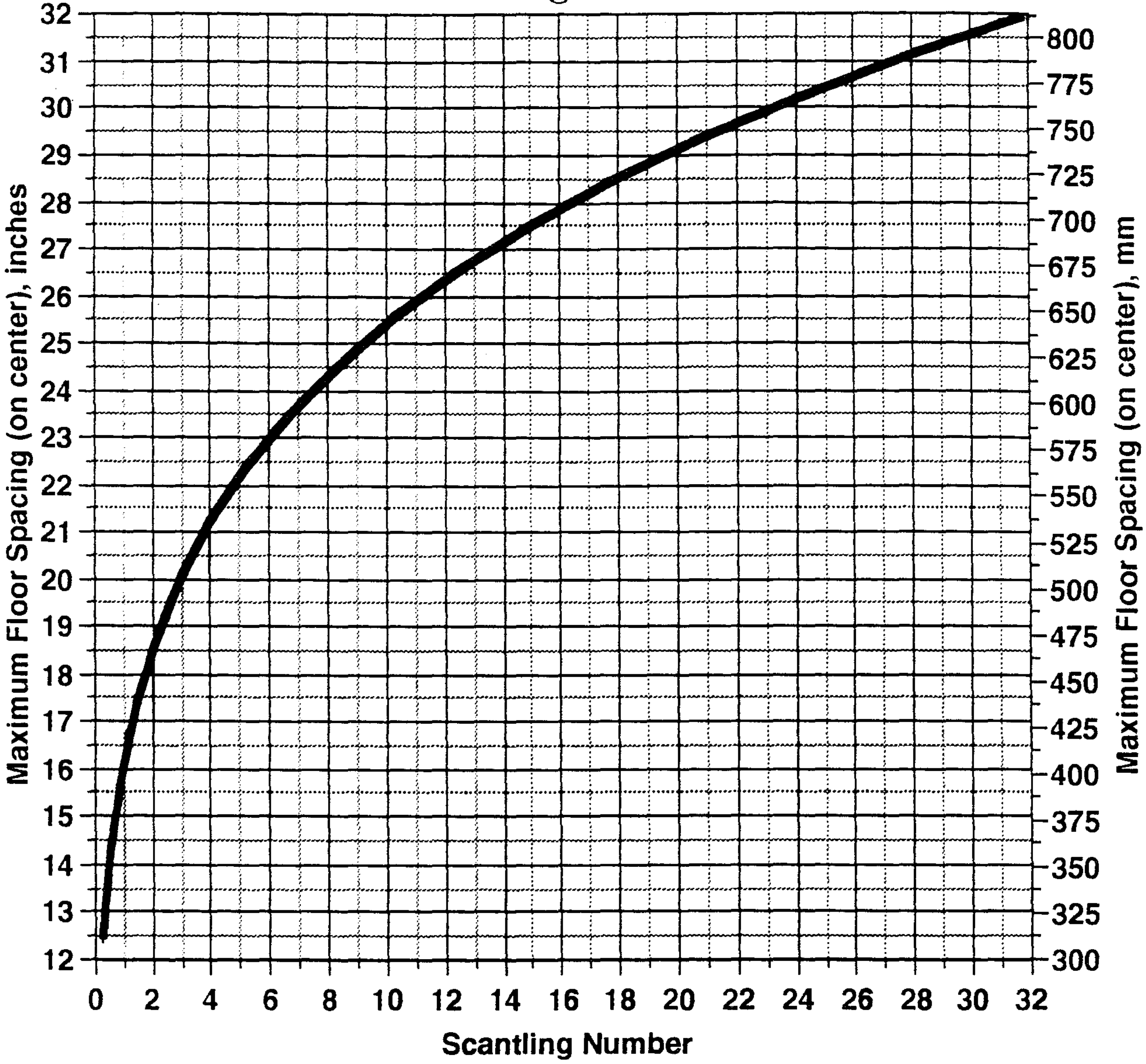
Laminate tabbing run-out on hull = 85 mm

Maximum floor spacing at ballast keel = 19.9, use 20 inches, on center

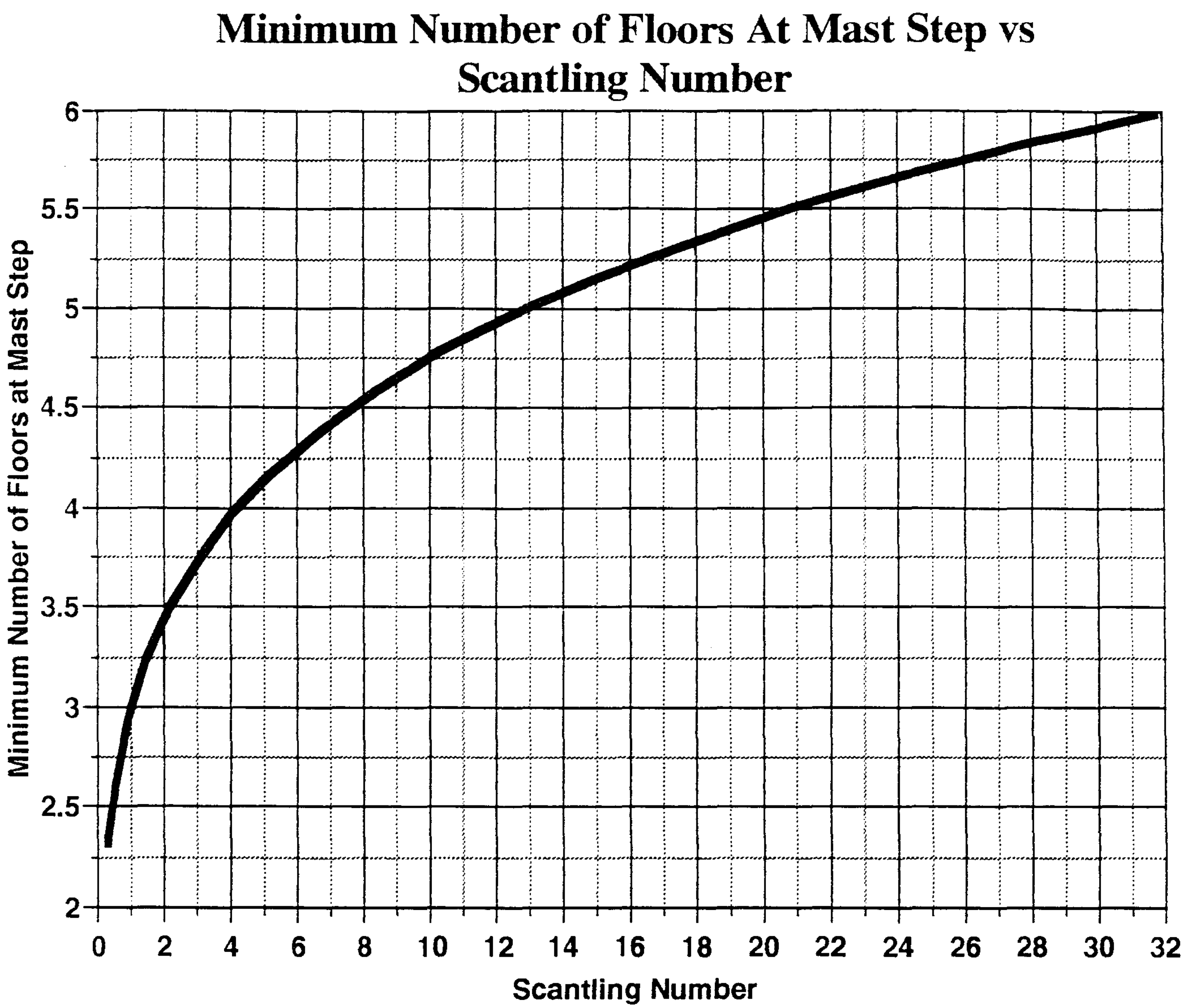
Maximum floor spacing at ballast keel = 532, use 530 mm, on center

Minimum number of floors at mast step = 3.73, use 4

Maximum Floor Spacing at Ballast Keel vs Scantling Number



Notes: The mast step should land on, be notched over, and be fastened to the floors. Where keel bolts pass through the solid-wood-core floors, care must be taken to seal the wood with epoxy, and—in addition—to seal and bed the keel and the keel bolts using a marine bedding compound formulated specifically for underwater use.



Floors must extend at least 30% of beam-overall athwartships (a span of 30% of beam or more), 40 to 45% span is better where possible. On the inside of hulls without hollow garboards the minimum heights given will usually automatically create floors of sufficient athwartships span. With hollow garboards or on very steep deadrise hulls, it may be necessary to increase floor height to get sufficient athwartships span.

If this intrudes too much on the interior arrangement or machinery, the floor height amidships can be limited to the minimum given above and the floor extended athwartships with a laminated "half-frame" top of solid laminated timber, the same width as the floor and the same height as the floor width (square in section). This laminated "half-frame" floor top is epoxied and fastened to the top of the floor and the hull inside, and is run athwartships up the hull bottom inside until the required span is reached. The laminated "half-frame" floor top should be tapered away at the ends, port and starboard, by reducing the number of laminations in steps. The entire floor and laminated "half-frame" floor top should be glassed in with the recommended floor layup.

Floors that are not being penetrated by fasteners, like keel bolts, can also be made of balsa core (end-grain balsa blocks, DecoLite, ContourCore, or DuraKore strips) cut and stacked as required. Where balsa-cored floors are employed, the laminate provides all the strength. Core dimensions should be the same as given above, but the laminate must be 2.8 times thicker.

Our *Swift'n Swanky,* with balsa-core floors,would require:
Laminate thickness = 0.25 inches thick
Laminate thickness = 6.8 mm thick

These fairly thick layups would be best made using a knitted stitch mat style fabric. See section on solid-glass, no-core regions.

SHEER CLAMP:

A sheer clamp is not required on most DuraKore/FRP hulls; however, the clamp facilitates attaching the deck to the hull. On heavy workboats, that will be docking or coming along side other vessels in rough weather frequently, the clamp is recommended for added side-impact strength.

Clamp thickness athwartships, inches = 0.75 + (Sn ÷ 10) [English]

Clamp thickness athwartships, mm = 19 + (Sn x 2.54) [Metric]

Clamp height, inches = 1.4 x thickness

Clamp laminate = same as inside of hull

BALLAST KEEL BOLTS:

To find the diameter of the keel ballast bolts:

Load per bolt, in pounds = S.F. 8 x Ballast Depth x Ballast Weight ÷ 2 bolt rows x Bolt Bearing Width x Number of Bolts on One Side.

Where:

Ballast Depth = distance from hull bottom, or keel bolt attachment level, to the underside of the ballast, inches or mm

S.F. 8 = a safety factor of 8

Ballast Weight = total weight of ballast, pounds or kilograms

Bolt Bearing Width = average distance from one row of ballast bolts to the opposite side of the top edge of the ballast keel. (Note: if the keel has a single row of bolts down the centerline—not recommended—the distance is to either edge and the bolt width is NOT multiplied by 2 as above.)

Note: Neglect all bolts on the centerline for keels fastened with most bolts running down two sides of the ballast.

Refer to the bolt tensile strength table to find bolt diameter.

Example:

Our old *Swift'n Swanky* is a 40-foot (12.19 m) cutter with 8,300 pounds (18290 kg) of ballast. The bottom of her ballast keel is 45.6 inches (1158 mm) below the keel bolts attachment point, and the average bolt bearing width is 10.5 inches (267 mm). She has 18 ballast bolts. Two bolts on the centerline are neglected leaving 16—8 each side. Then:

Load per bolt, lb. = S.F. 8 x 45.6 in. Ballast Depth x 8,300 lb. ÷ 2 x 10.5 in. Bolt Width x 8 Bolts = 18,020 lb. per bolt.

Load per bolt, lb. = S.F. 8 x 1158 mm Ballast Depth x 3765 kg ÷ 2 x 267 mm Bolt Width x 8 Bolts = 8165 kg per bolt.

Referring to the bolt breaking strength table we'd fit *Swift'n Swanky* with 3/4-inch diameter (20 mm dia.) silicon bronze bolts, with an ultimate tensile strength of 20,068 pounds or higher.

The floor's wood core must be at least 4 x bolt diameter or 3 inches (80 mm). Accordingly, we have to increase the 2.62-inch (66.7 mm) floor thickness found in the scantling rule above to 3 inches (80 mm).

KEEL BOLT BACKING PLATES:

Backing plates must be placed under each keel-bolt nut, on top of the floors, The backing plates should be equal to the floor's core width in diameter and 1/3 the thickness of the keel bolt diameter. Usually the backing plates are simply square the same width as the floor width. Even better is a continuous plate on top of the floor from port to starboard keel bolt. The plate thickness should 1/3 the bolt diameter and the same width as the floor's wood core.

Example:

For *Swift'n Swanky*'s 3/4-inch diameter keel bolts above, the backing plate should be 1/4-inch thick and 3-inches wide.

For *Swift'n Swanky*'s 20 mm diameter keel bolts above, the backing plate should be 6.6, use 8 mm thick and 80 mm wide.

SOLID GLASS (NO CORE) AT HIGHLY LOADED HULL PENETRATIONS:

Where there are holes in the hull carrying large loads or substantial running gear the DuraKore must be locally removed and replaced with a solid glass laminate that equals approximately 75% of the total hull-shell thickness (inside and outside laminate, plus core).

The principal items requiring core removal are:

- Ballast-bolt region in the hull bottom
- Penetrations for rudder ports
- Penetrations for shaft logs and stern tubes
- At the strut base and its mounting bolts
- At all chainplate bolts and attachments

- At towing eyes and hoisting rings
- At trim tabs
- Steering gear mountings and fastener penetrations
- Around installation cut-outs for surface-propeller drives and for jet drives

In these areas all the DuraKore should be routed out from the inside, and the core carefully beveled back at a 30° angle. The surface should be cleaned, and prepped and a layup run over the existing inside laminate, down into the routed-out region and back up the other side of the inside of the hull. This run-out length on top of the remaining inside laminate—around the removed-core area—should extend 100 times the thickness of the inside laminate or 16 inches (40 cm) whichever is less. The run-out itself should consist of only the top 20% of the new solid-glass layup; and, the run-out should taper away gradually, to just one or two layers of glass, at its outermost edge.

Example:

At *Swift'n Swanky*'s ballast keel attachment, all the DuraKore should be routed out, where the ballast meets the hull. The core ground and tapered back and a laminate built up to equal 65%—75% of the total hull-shell bottom thickness. For the planing version of *Swift'n Swanky,* we specified earlier:

Inside: 2 layers DB120 inside = 0.038 in.

Core: 1-in. DuraKore

Outside: 2 layers DB120 plus 1 layer CD180 = .068

Total thickness = 1.106 in.

or

Inside: 2 layers DB120 inside = 813 g/m2 = 0.97 mm

Core: 1-in. DuraKore = 25 mm

Outside: 2 layers DB120 plus 1 layer CD180 = 1423 g/m2 = 1.73 mm

Total thickness = 27.7 mm

1.1 in. total thickness x 0.75 = 0.82 in.

or

27.7 mm total thickness x 0.75 = 20.8 mm.

Since the outside laminate (which remains untouched) is 0.068 inches (1.73 mm) thick, the new interior solid-glass build up must be 0.75 inches, or 19 mm. [0.82 in. – 0.068 in = 0.75 in., or 20.8 mm – 1.73 mm = 19 mm]

This could be built up of bi-axial or tri-axial fabric, but the ideal material for these solid-glass build-ups is a knitted stitch-mat that is compatible with epoxy, like Hexcell/Knytex C-24 or BTI CM2415. Be very certain that the mat you use is *fully* compatible with epoxy, run a test panel before proceeding on the hull. C-24 or CM2415 is approximately 0.085 inches (2.1 mm) thick per layer, so 0.75 ÷ 0.085 = 8.8, use 9 layers [19 mm ÷ 2.1 mm = 9]. Heavier-weight fabrics with mat can be laid up successfully, unlike pure knitted bi-axials which shouldn't be applied in weights over 18 to 24 oz./sq.yd. [610 to 820 g/m^2]. If a 17-oz. (576 gram) bi-axial had been used (approximately 0.03 inches, or 0.74 mm thick), it would have required 25 layers, which is significant additional labor.

Thickness of all-mat layup can be estimated as follows:

Mat Thickness, in. = oz./sq.yd. ÷ 31.25 [English]

Mat Thickness, mm = g/m^2 ÷ 41.7 [Metric]

To estimate the laid-up thickness of a combined fabric style—mat stitched to a bi-axial—find the thickness of each and add to get total thickness. (In all cases, it's more accurate to make test panels to measure the actual thicknesses you're obtaining in your shop):

Example:

24 oz./sq.yd. bi-axial = (24 oz./sq.yd. - 0.3) ÷ 610 = 0.038 in.

1/5 oz./sq.yd. mat = 1.5 oz./sq.yd ÷ 31.25 = 0.048 in.

Total C-24 knitted stitch mat = 0.086 in.

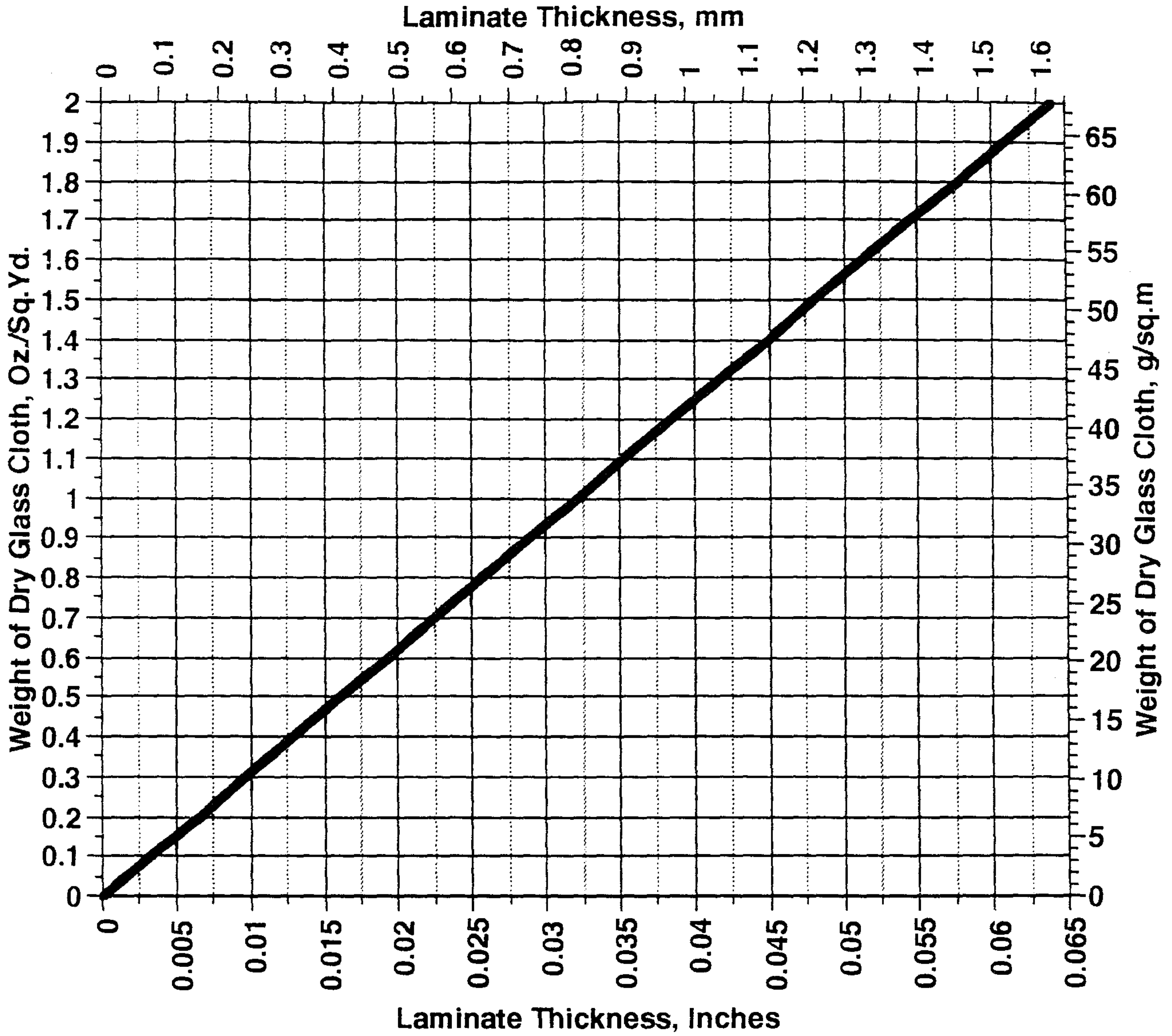
or

24 oz./sq.yd bi-axial = 814 g/m^2, thus: (814 g/m^2 - 9.7) ÷ 813 = 0.98 mm

1/5 oz./sq.yd mat = 50.85 g/m^2, thus: 50.85 g/m^2 ÷ 41.7 = 1.22 mm

Total C-24 knitted stitch mat = 2.20 mm

Dry Glass Cloth Weight vs Finished Laminate Thickness Chopped Strand Mat Only



TO CONVERT FROM OZ./SQ.YD. TO G/M^2, AND VISA VERSA

Multiply oz./sq.yd. by 33.9 to get g/m^2,

Divide g/m^2 by 33.9 to get oz./sq.yd.

Durakore Multihull Scantling Rule — Part II

Multihulls have radically different forms from monohulls, and multihulls experience dramatically different loads, stresses, and strains. The scantling number derived previously for monohulls is not applicable; however, the following multihull scantling rule refers extensively to the standard monohull rule above. You must be familiar with the monohull rule to use this multihull rule.

Multihulls Covered By This Rule:

The multihull scantling rule has been adjusted to work by entering a new "Multihull Scantling Number" (MSn) into the the preceding monohull formulas and charts (with appropriate adjustments) This rule should serve as a general guide for determining the scantlings of standard multihulls as follows:

- power and sailing catamarans and trimarans of normal form
- multihulls between 18 and 80 feet (5.4 and 24.4 m) LOA
- multihulls that do not exceed 50 knots top speed
- multihulls whose beam overall does not exceed 90% of LOA
- multihulls with displacement length-ratios between 40 and 180
- multihulls in which the length-to-beam ratio for any hull or float (vaka or ama) does not exceed 8:1.

Durakore is an excellent core material for multihulls of different form, type, or speed than listed above, but such vessels are *not* included in this rule.

The development of this multihull scantling rule was only made possible by the generous support of multihull designers: Dick Newick, Ian Farrier, Kurt Hughes, and Tillotson Composites, Inc. Each provided detailed information on many of their proven multihull craft. It would have been impossible to generate this rule without their invaluable sea-tested "raw" data.

Structural Components Not Covered By the Multihull Rule:

Because of the wide variety of types of multihulls and the vastly different crossbeams, crossarms (akas), and their attachment methods, this rule does *not* cover any crossarm, crossbeam, aka, their connections, or related components. These structures must be carefully engineered by a qualified naval architect or marine engineer.

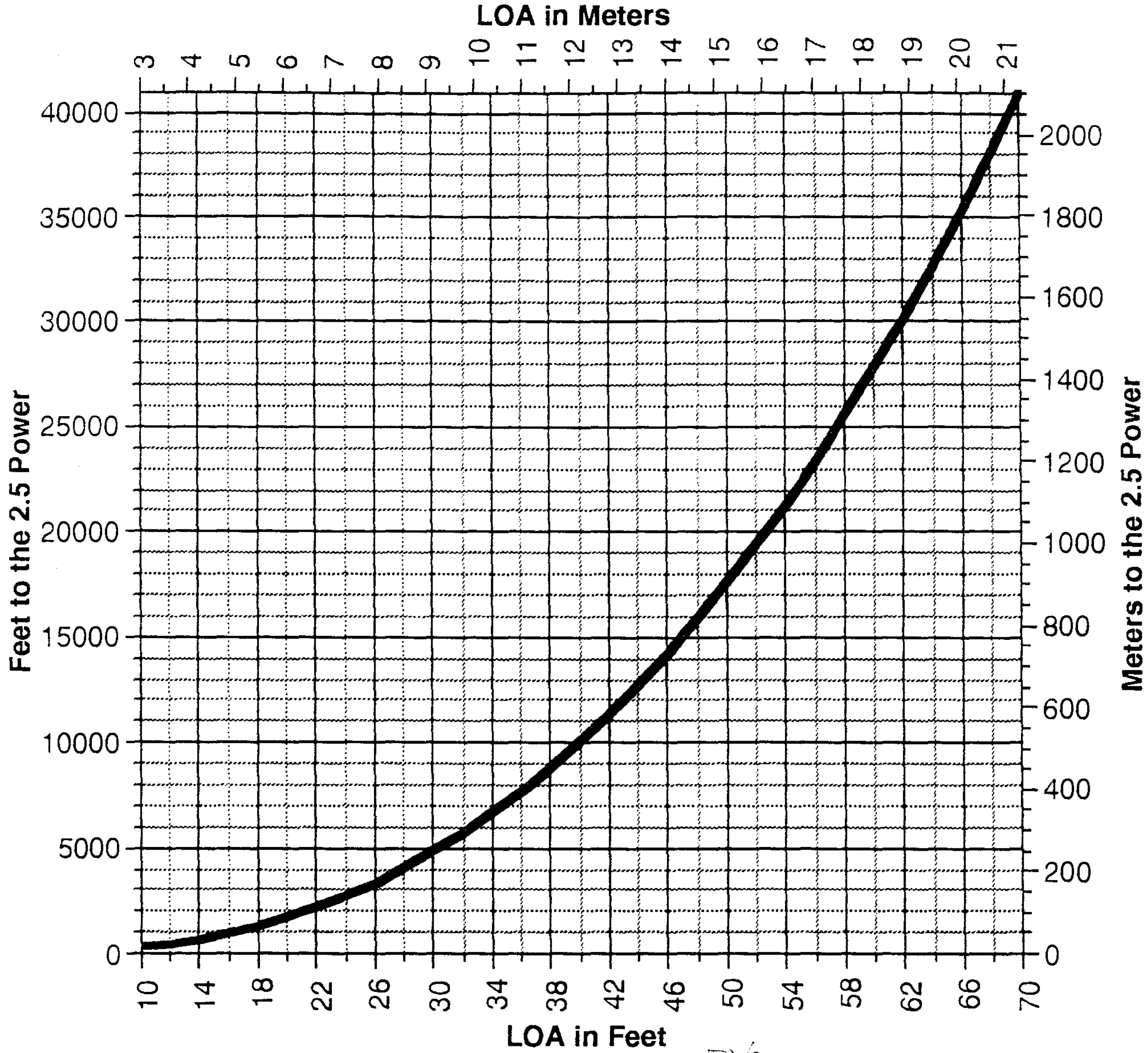
Materials Covered by the Multihull Rule:

All the comments on applicable materials for the standard monohull scantling rule apply to the multihull scantling rule, except as specifically noted.

The Multihull Scantling Number (MSn):

The standard, monohull scantling number (Sn) uses length times breadth times depth of hull as the basis for the scantling number. This works because these three dimensions correspond very closely to the real volume and therefore size and weight of the vessel. When analyzing the information from proven multihulls, it became apparent that depth of hull had little direct relationship with real multihull "size." After considerable investigation, the following scantling number (without depth of hull) proved reliable.

Length Overall to the 2.5 Power



The Multihull Scantling Number (MSn):

MSn = $(\text{LOA ft.})^{2.5}$ x Scantling Beam (ft.) ÷ 40,000 [English]

MSn = $(\text{LOA m})^{2.5}$ x Scantling Beam (m) ÷ 625.4 [Metric]

Where:

LOA = Length overall

$$\text{Scantling Beam} = \frac{(\text{BOA} \div 4) + \text{WL Beam, of Main Hull}}{2}$$

BOA = Beam overall across entire vessel (all hulls combined)

WL Beam, of Main Hull = Beam at the waterline of the main hull (or vaka) on a trimaran, or of just one (1) of the two hulls on a catamaran

Example:

If your new vessel, *Wavy Glider*, were a multihull:

LOA	35.92 ft.	10.94 m
Waterline	34.67 ft.	10.57 m
Beam Overall	28.00 ft.	8.53 m
WL Beam 1 Hull	3.25 ft.	0.99 m
Displacement	2.45 tons	2.49 mTons
D/L Ratio	58.8	58.8
Speed	22.0 kts	22.0 kts

She would have a Multihull Scantling Number (MSn) of 0.99.

$$\text{Scantling Beam} = \frac{(28.0 \text{ ft. BOA} \div 4) + 3.25 \text{ ft. WL Beam, of Main Hull}}{2} = 5.12 \text{ ft.}$$

$$\text{Scantling Beam} = \frac{(8.53 \text{ m BOA} \div 4) + 0.99 \text{ m WL Beam, of Main Hull}}{2} = 1.56 \text{ m}$$

Multihull Scantling Number (MSn):

$(35.92 \text{ ft. LOA})^{2.5} \times 5.12$ Scantling Beam $\div$ 40,000 = 0.989, use 0.99 MSn

(10.94 m LOA)$^{2.5}$ x 1.56 m Scantling Beam ÷ 625.4 = 0.987, use 0.99 MSn

For entry in the multihull scantling number formula, make the same adjustment to LOA, for long overhangs, as specified for monohulls. (Long overhangs are unusual on modern multihulls.)

Enter this Multihull Scantling Number (MSn) in the standard monohull charts or formulas to get basic topside laminate and core:

Example:

For *Wavy Glider,*

MSn of 0.99 gives a basic topsides DuraKore thickness of 0.60 in., or 15.3 mm

MSn of 0.99 gives a basic topsides laminate thickness of 0.052 in., or 1.34 mm

Do NOT use the monohull adjustment factors. Instead:

DISPLACEMENT-LENGTH RATIO ADJUSTMENT

Adjust core and laminate thickness for D/L Ratio as follows:

D/L Adjustment = (D/L Ratio ÷ 210) + 0.66

Multiply core and laminate thickness found by standard monohull charts or formulas by the D/L Adjustment.

See the monohull rule for D/L-ratio calculation.

(The multihull rule applies only to vessels with D/L ratios between 40 and 180.)

Example:

D/L Adjustment = (58.8 ÷ 210) + 0.66 = 0.94

0.60 in. DuraKore x 0.94 = 0.56 in. [English]

0.052 in. laminate x 0.94 = 0.048 in. [English]

15.3 mm DuraKore x 0.94 = 14.4 mm [Metric]

1.34 mm laminate x 0.94 = 1.26 mm [Metric]

SPEED ADJUSTMENT

Add 1% to the DuraKore and to the laminate thickness for every two (2) knots over 10 knots, of maximum potential boat speed.

Speed must be estimated by the builder. As a rough guide, most sailing multihulls will go well over 12 knots. Fourteen to 18 knots is a good average, for cruising sailboats between 25 and 35 feet (7.5 and 10.5 m). Larger multihulls over 35 to 40 feet (10.5 to 12.2 m), can make 20 knots, and racing multihulls will often reach 22 to 25 knots, or more. Power multihulls, will achieve speeds according to hull shape and the installed engine(s). Consult my *Propeller Handbook,* published by International Marine Publishing Co., for speed estimates.

Example:

Wavy Glider's top speed is estimated at 22 knots.

22 knots – 10 knots = 12 knots

12 knots ÷ 2 = 6

Add 6% or multiply laminate and core thickness by 1.06

0.56 in. DuraKore x 1.06 = 0.59 in. [English]

0.048 in. laminate x 1.06 = 0.051 in. [English]

14.4 mm DuraKore x 1.06 = 15.3 mm [Metric]

1.26 mm laminate x 1.06 = 1.33 mm [Metric]

COMMERCIAL SERVICE ADJUSTMENT:

For charter vessels and workboats multiply both core and laminate thickness by 1.1 (increase by 10%).

PERCENTAGE OF LAMINATE ON THE INSIDE AND THE OUTSIDE:

As with monohulls, when possible, it is best to place 60 percent of the laminate thickness on the outside of the hull, and 40 percent on the inside. Most multihull laminates are enough thinner than monohull laminates to make this difficult in practice except on multihulls over 50 feet (15 m). A 50%-outside and 50%-inside laminate is common practice.

WEIGHT OF DRY GLASS CLOTH FOR REQUIRED THICKNESS:

Enter the charts or formulas from the monohull rule to find the weight of dry glass required for the thickness.

Wavy Glider's 0.051-inch laminate would require 31 ounces of cloth laid in epoxy; or *Wavy Glider*'s 1.33-mm laminate would require 1070 grams of cloth laid in epoxy.

(0.051 in. laminate x 610) - 0.3 = 30.8, use 31 oz./sq.yd.

15.5 oz./sq.yd. inside and 15.5 oz./sq.yd. outside

(1.33 mm laminate x 813) - 9.7 = 1071, use 1070 g/m^2

535 g/m^2 inside and 535 g/m^2 outside

HULL BOTTOM LAMINATE:

For ordinary cruising multihulls:

Increase exterior bottom laminate thickness by 1.5 times from 6 inches (15 cm) above the waterline down.

Increase interior bottom laminate thickness by 1.3 times for a width of 1/2 the hull's waterline beam.

Example:

Bottom laminate for *Wavy Glider:*

INSIDE: 15.5 oz./sq.yd. x 1.3 = 20.1 oz./sq.yd.

OUTSIDE: 15.5 oz./sq.yd. x 1.5 = 23.2 oz./sq.yd.

or

INSIDE: 535 g/m^2 x 1.3 = 695 g/m^2

OUTSIDE: 535 g/m^2 x 1.5 = 802 g/m^2

SPECIFYING THE HULL SHELL FROM AVAILABLE MATERIALS:

The calculated laminate and core thickness or glass weights have to be adjusted to the materials readily available in the real world.

Example:

For *Wavy Glider:*

Core:

0.59 in. DuraKore, use 0.625 or 5/8-inch DuraKore [English]

15.3 mm DuraKore, use 15.9 mm DuraKore [Metric]

Topsides Laminate:

15.5 oz./sq.yd., inside and outside

535 g/m^2, inside and outside

Use 1 layer BTI X-15 bi-axial, 15 oz./sq.yd., (508 g/m^2) or equal, inside and outside

Bottom Laminate:

INSIDE:

20.1 oz./sq.yd., or 695 g/m^2

Use BTI X-24 bi-axial, 24 oz./sq.yd., (813 g/m^2), or equal, extending 1/2 hull waterline beam athwartships inside.

OUTSIDE:

23.2 oz./sq.yd., or 802 g/m^2

Use BTI X-24 bi-axial, 24 oz./sq.yd., (813 g/m^2), or equal, extending from 6 inches (15 cm) above the waterline down outside.

Note that the inside laminate is somewhat heavier than called for by the rule, to fit the available fabric styles. Similarly, the core thickness is slightly thicker than required by the rule, to fit standard DuraKore sizes.

DECK LAMINATE ON HULLS:

The deck laminate on the hulls should be the same as the topsides laminate (core and layup).

DECK LAMINATE BRIDGE DECKS & WIDE DECKS:

Where the width of the deck is greater than three times the waterline beam, the core thickness should be 1.4 times the thickness of the multihull topsides core. The laminate (inside and out) should be the same as the topsides.

CABIN SIDES:

The cabin sides should be the same laminate as the topsides.

BRIDGEDECK BOTTOM LAMINATE:

The bridgedeck bottom laminate should be the same as the topsides, except the core thickness should be 1.5 times greater than the topsides core.

Forward of station 4, the bridgedeck bottom layup should be increased in thickness by 40% on the outside (underside) and by 30% on the inside (top). This is because the forward bridgedeck can experience severe pounding in certain sea conditions.

FRP-TAPE "RUBSTRIP:"

On cruising vessels and commercial multihulls an FRP-tape "rubstrip" should be laminated along the topsides at the sheer. This increases longitudinal strength slightly and increases abrasion resistance considerably. The tape rubstrip should be: 33% the thickness of the outer topsides laminate, or 10 oz/sq.yd. (340 g/m^2), whichever is heavier. It should be 20% of the waterline beam wide. On smaller vessels, the tape rubstrip should be of bi-axial glass. Larger craft should use a tri-axial style, if available, with ±45° fibers and 0° degree fibers (running longitudinally). The rubstrip is optional on high-performance/racing multihulls.

FRP-TAPE KEEL "SHOE:"

Cruising multihulls should laminate in a FRP-tape keel shoe, on the outside bottom laminate, running along the keel and stem. The tape shoe should be 40% of the thickness of the outside bottom laminate, and should be 20% of the waterline beam wide. The keel shoe is optional on high-performance/racing multihulls.

BULKHEADS:

As with monohulls, bulkheads and ring frames are the principle source of transverse strength in multihull hulls. To find the minimum number of bulkheads:

Enter the Multihull Scantling Number (MSn) in the standard monohull bulkhead chart or formulas, then multiply the result by 1.3.

BULKHEAD THICKNESS:

Because light weight is especially critical to multihulls, only cored bulkheads (Baltek DecoLite panels) should be used. (Main structural cross-beam bulkheads, and/or cross-beam attachment bulkheads must be solid plywood, or equal, but are not covered in this rule.)

To find minimum cored, DecoLite bulkhead thickness enter the MSn in the standard monohull chart or formula, and multiply the result by 1.15.

BULKHEAD TABBING:

Enter the MSn in the standard monohull charts or formulas to get bulkhead tabbing, thickness, run out, and fillet size. No adjustment is required.

IMPORTANT NOTE:

Main structural cross-beam bulkheads, and/or cross-beam attachment bulkheads require heavier tabbing. A rough guide is that the tabbing weight should be 30% greater than standard tabbing, and the run-out should be 15% greater. The loads on all cross beams and attachments must be carefully checked.

RING FRAMES:

When using ring frames in place of bulkheads, enter the MSn in the standard monohull formulas and charts. No adjustment is necessary.

ENGINE BED/STRINGERS:

For powered multihulls, enter the MSn in the standard monohull formulas. No adjustment is necessary.

IMPORTANCE OF LIGHT-WEIGHT STRUCTURE:

Weight is critical to all multihull design and construction. Excess weight drastically reduces performance and also increases strain on the hull and gear. In some respects, multihulls are closer to airplanes than to standard monohulls. You MUST think light! Use great care to avoid excess weight. Do not arbitrarily increase scantlings to be much heavier or thicker than given above unless you have a very clear and specific reason to do so.

Several steps can be taken to reduce weight further and/or to avoid excess weight during construction:

1) Vacuum bag the laminate and cores. The vacuum bagging process produces a higher glass-to-resin ratio in the laminate, making it stronger. Vacuum bagging also greatly reduces excess resin. Using the same glass cloth and resin, the difference in weight between a mediocre hand-layup and a good vacuum bag layup can be 15%, or higher. This weight saving is multiplied over the whole structure.

300–400# difference with Williwaw II @ 2500# dry

Apply the weights of glass cloth specified using the rules above, but then vacuum bag. You will obtain slightly thinner (thus lighter) layups that are just as strong.

2) Use S-glass (aircraft-grade fiberglass cloth), in the same uni-directional, bi-axial and tri-axial styles. S-glass laminates have higher mechanical properties than E-glass. To use S-glass calculate thickness and glass weights using the multihull rule above, then reduce glass weight by 10%. Vacuum bag to achieve best results.

3) Use Kevlar on the inside skins only. Kevlar is highly abrasion resistant, so there's a tendency to place it outside. Unfortunately, Kevlar has high tensile

strength but relatively low compressive strength. The exterior skins are in compression, so Kevlar should not be used there, unless it is *in addition* to the standard laminate thickness, and for abrasion resistance only.

To use Kevlar on the inside skin, you should calculate the laminate using the multihull rule above and reduce glass weight by 18%. Again, vacuum bagging will give the best results.

4) The highest strength to lightest weight will be achieved by using S-glass exterior and Kevlar interior laminates vacuum bagged. S-glass and Kevlar fabric styles are considerably more expensive than E-glass fabrics. Most ordinary cruising and cruiser/racer multihulls will find standard uni-directionals (bi- and tri-axial) E-glass laminates to be quite light, strong, and serviceable, especially if vacuum bagged.

GRAPHITE AND CARBON FIBER:

This rule does not cover graphite or carbon fiber reinforcements (really the same material—carbon—but graphite is, by convention, purer and somewhat stronger). Though carbon-fiber laminates have very high stiffness properties, they also have very low elongation. (They don't stretch much before they break). This makes carbon fiber laminates brittle and subject to sudden, violent failure. Carbon/graphite laminates and reinforcement can offer advantages at the cutting edge of design and construction. These laminates should be carefully engineered, however, and are NOT covered in this rule.

SOLID GLASS OR SOLID-WOOD CORE AT HIGHLY LOADED HULL PENETRATIONS:

All the comments, in the standard monohull rule, on solid glass at highly loaded hull penetrations apply to multihulls. Again, however, weight is very critical on multihulls. A common and advisable weight-saving measure is—instead of the solid glass described (which is acceptable)—replace the DuraKore at these areas with solid-wood strip planking (fir, cedar, spruce, etc.) Take GREAT care to seal all the exposed wood at penetrations with resins *AND* to bed and seal with marine bedding compound as well.

Solid-wood cores with the standard multihull skin laminates in these regions weigh approximately one half that of the solid-glass layup, which is 75% of total cored shell in thickness, as specified in the monohull rule.

About the Author:

The DuraKore scantling rule was devised by noted naval architect and author Dave Gerr. In addition to specialized engineering, surveying, and consulting projects, Gerr designs both yachts and commercial vessels out of his New York City office. He is author of *Propeller Handbook* and *The Nature of Boats,* both published by International Marine Publishing Co., of Camden, Maine. A contributing editor to *Yachting, Offshore,* and *Boatbuilder* magazines, Gerr's new book, *Boat Strength*—a handbook on boat structures—will be available soon from International Marine.

PLEASE NOTE:

All scantling rules are design short-cuts. Though every effort has been made to present a rule that will produce strong, safe, and long lasting hulls, the builder uses this rule at his or her own risk. Baltek Corporation makes no presentations as to the suitability of this rule for determining the scantlings of any vessel. If a builder needs any further information as to the use of a scantling rule, he or she is urged to consult a qualified naval architect or marine engineer.

BOLT BREAKING STRENGTH IN LBS. — IN TENSION

DIAMETER				STAINLESS		BRZ. & A36 STEEL	
NO. or	DECIMAL	Threads/Inch		85,000	PSI	60,000	PSI
INCHES	INCHES	UNC	UNF	UNC	UNF	UNC	UNF
No. 4	0.112	40	48	513	561	362	396
No. 6	0.138	32	40	772	862	545	609
No. 8	0.164	32	36	1,191	1,252	841	884
No. 10	0.190	24	32	1,490	1,699	1,052	1,200
No. 12	0.216	24	28	2,054	2,192	1,450	1,547
1/4	0.250	20	28	2,705	3,092	1,909	2,182
5/16	0.313	18	24	4,457	4,936	3,146	3,484
3/8	0.375	16	24	6,587	7,465	4,649	5,270
7/16	0.438	14	20	9,036	10,091	6,379	7,123
1/2	0.500	13	20	12,061	13,596	8,514	9,597
9/16	0.563	12	18	15,465	17,253	10,917	12,179
5/8	0.625	11	18	19,210	21,756	13,560	15,357
3/4	0.750	10	16	28,429	31,702	20,068	22,378
7/8	0.875	9	14	39,247	43,305	27,704	30,568
1	1.000	8	12	51,488	56,359	36,345	39,782
1 1/8	1.125	7	12	64,878	72,736	45,797	51,343
1 1/4	1.250	7	12	82,374	91,200	58,147	64,377
1 3/8	1.375	6	12	98,165	111,751	69,293	78,883
1 1/2	1.500	6	12	119,446	134,387	84,315	94,861
1 3/4	1.750	5		161,454		113,968	
2	2.000	4 1/2		212,349		149,894	
2 1/4	2.250	4 1/2		276,054		194,861	
2 1/2	2.500	4		339,900		239,930	
2 3/4	2.750	4		419,391		296,041	
3	3.000	4		507,227		358,042	
3 1/4	3.250	4		603,407		425,935	
3 1/2	3.500	4		707,933		499,717	
3 3/4	3.750	4		820,803		579,390	
4	4.000	4		942,018		664,954	

FORMULA:

P = S x At

S = Ultimate fiber tensile strength, At = Net effective tensile area

P= Ultimate breaking load in pounds

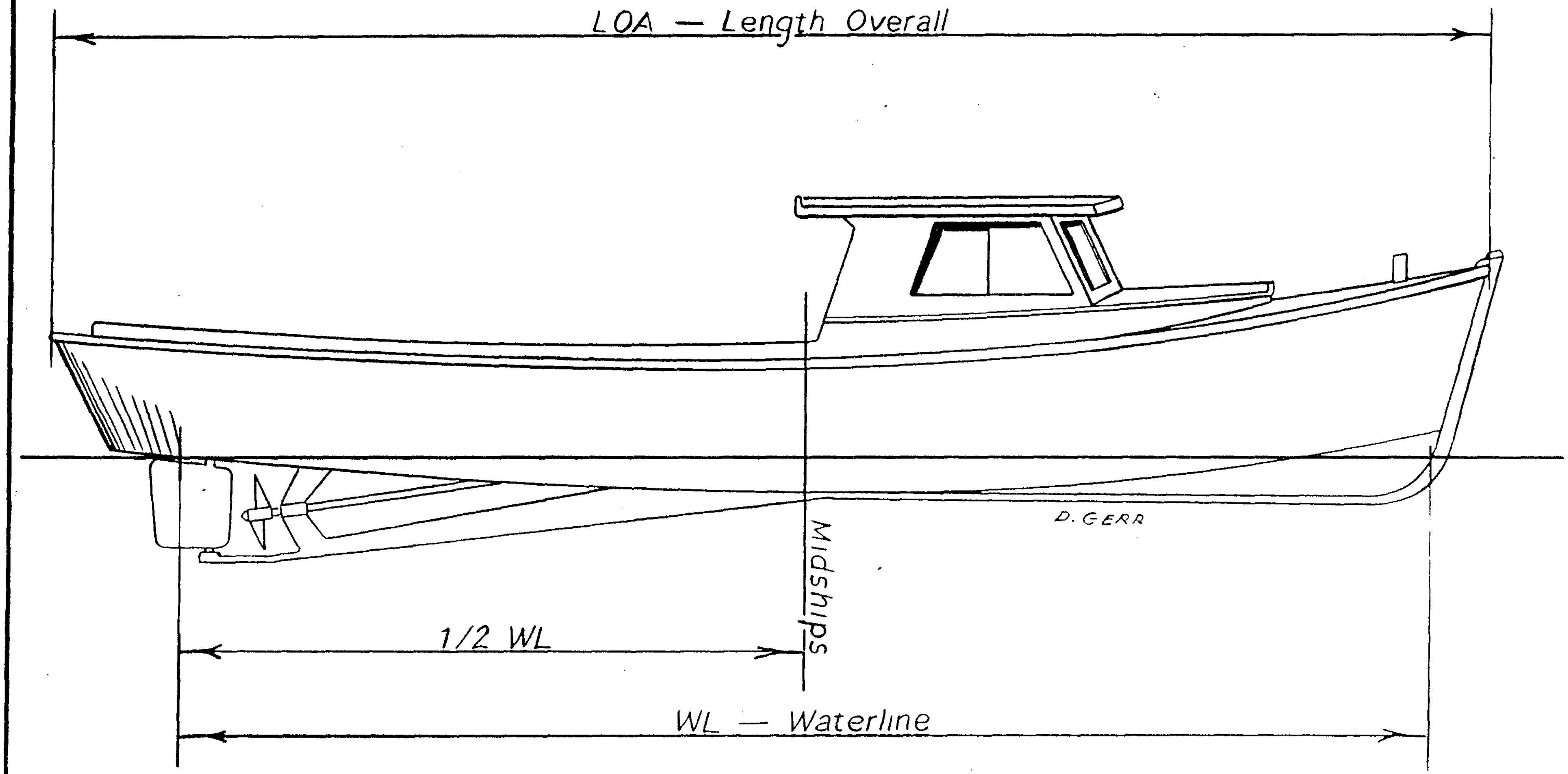
At = 0.7854(D - (0.9743/n))^2

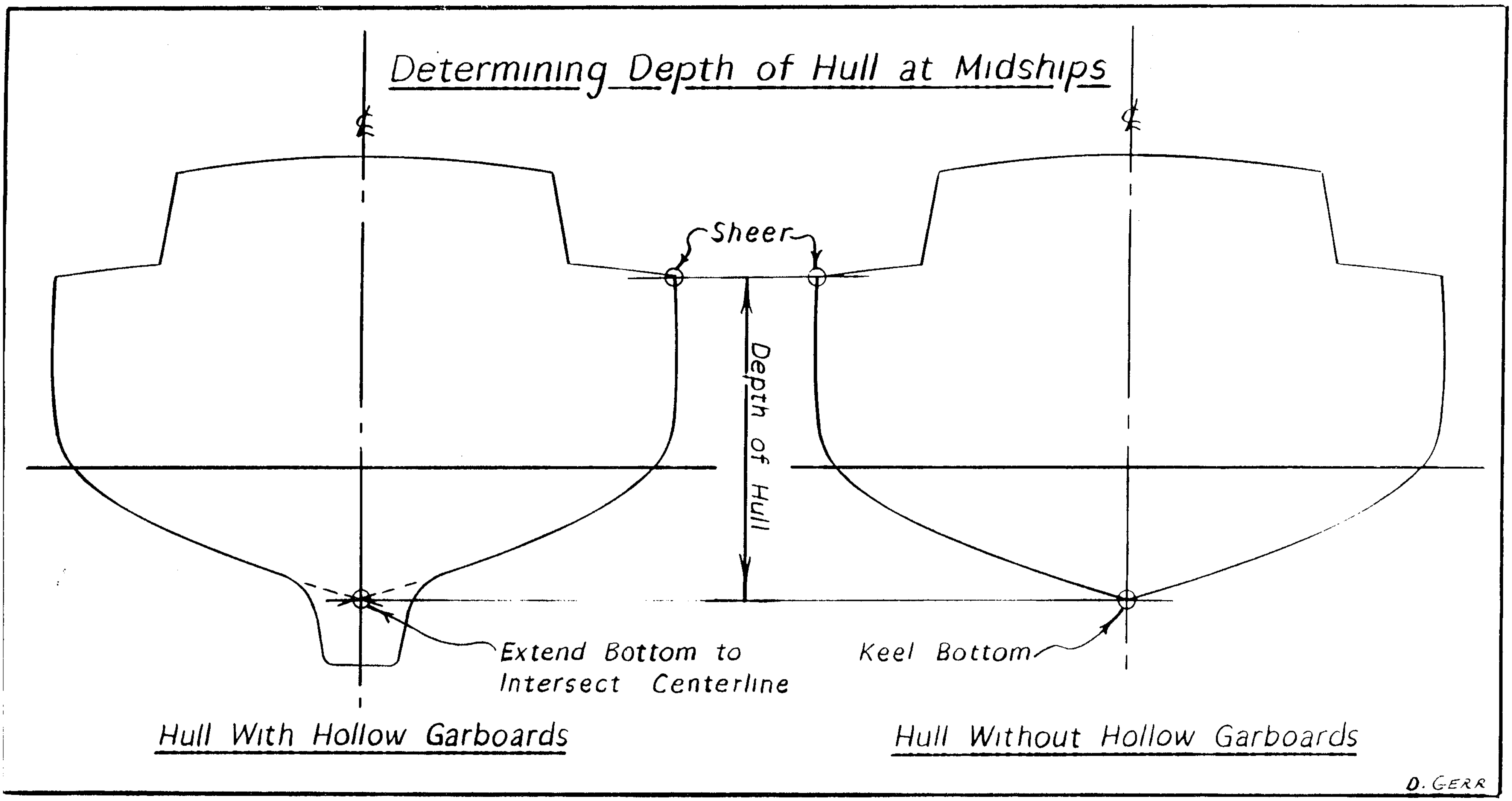
D = Nominal screw diameter in inches, n = Number of threads per inch

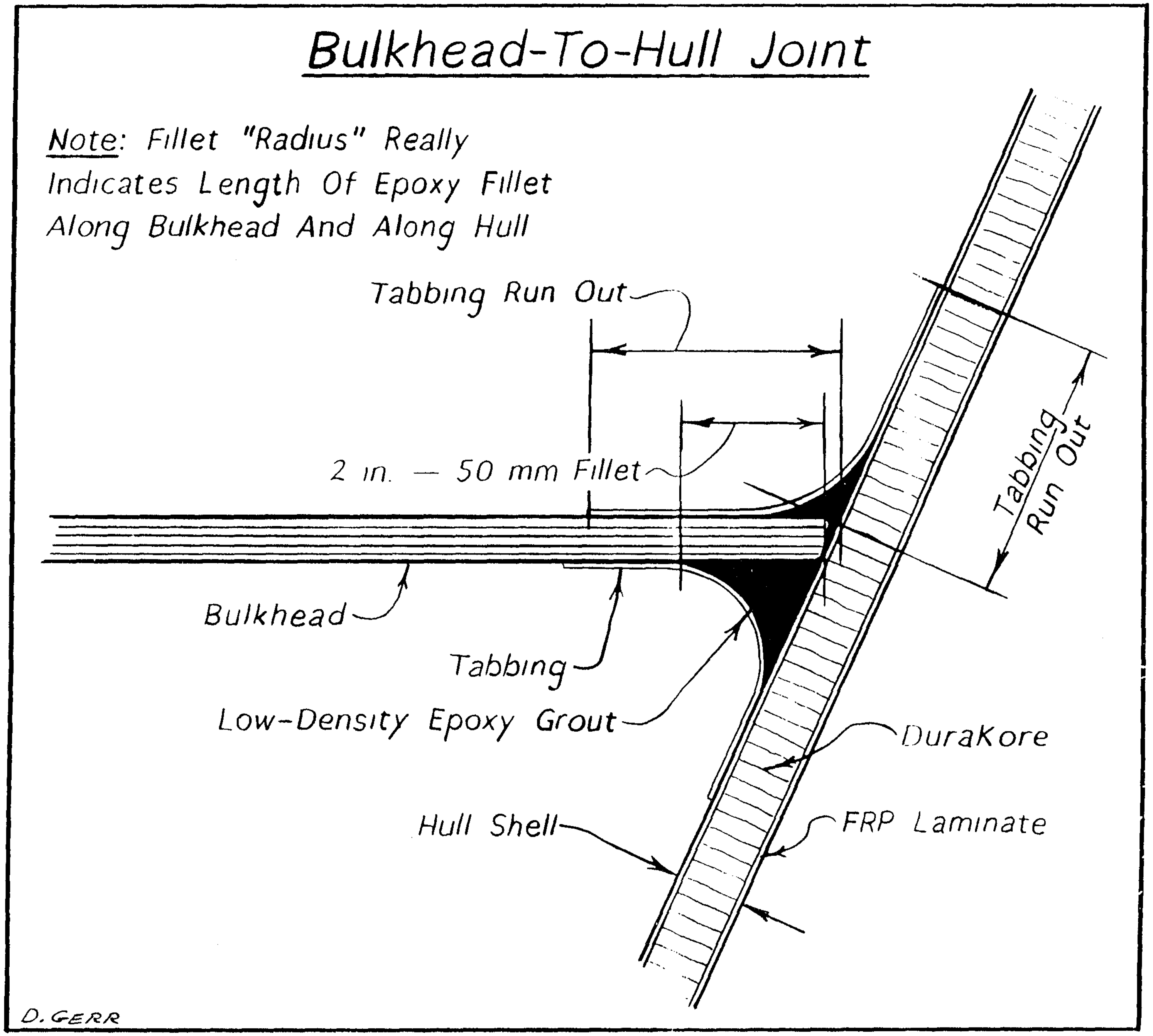
Prepared by Dave Gerr

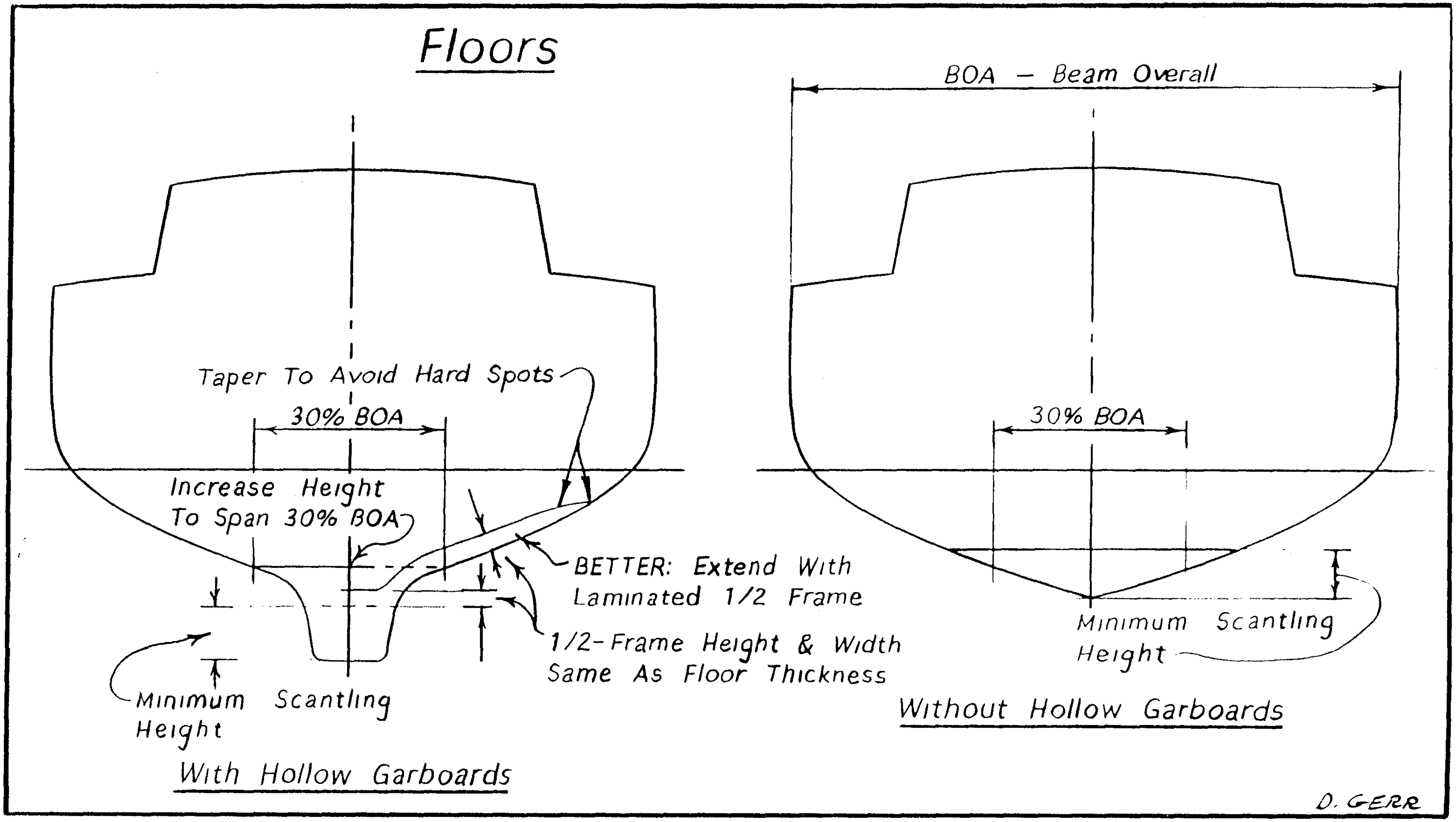
BTI — Brunswick Technologies, Inc.					
	FIBER	FIBER WEIGHT		MAT WEIGHT	
DESIGNATION	ORIENTATION	OZ./SQ.YD.	G/SQ.M.	OZ./SQ.FT.	G/SQ.M.
C-18	0°–90°	18	610	NONE	NONE
C-24	0°–90°	24	810	NONE	NONE
CM-1603	0°–90°	16	540	0.25	75
CM-1808	0°–90°	18	610	0.75	225
CM-1810	0°–90°	18	610	1.00	300
CM-1815	0°–90°	18	610	1.50	450
CM-2408	0°–90°	24	810	0.75	225
CM-2410	0°–90°	24	810	1.00	300
CM-2415	0°–90°	24	810	1.50	450
TH-22	90°+45°-45°	22	745	NONE	NONE
THM-2210	90°+45°-45°	22	745	1.00	300
THM-27	90°+45°-45°	27	915	NONE	NONE
THM-2710	90°+45°-45°	27	915	1.00	300
U-0901	0°	9	300	0.03	9
U-1201	0°	12	405	0.03	9
U-2401	0°	24	810	0.03	9
UM-1810	0°	18	610	1.00	300
UM-1210	0°	24	810	1.00	300
X-13	+45°-45°	13	440	NONE	NONE
X-1305	+45°-45°	13	440	0.50	150
X-15	+45°-45°	15	510	NONE	NONE
X-1505	+45°-45°	15	510	0.50	150
X-18	+45°-45°	18	610	NONE	NONE
X-24	+45°-45°	24	810	NONE	NONE
XM-1808	+45°-45°	18	610	0.75	225
XM-1810	+45°-45°	18	610	1.00	300
XM-1815	+45°-45°	18	610	1.50	450
XM-2408	+45°-45°	24	810	0.75	225
XM-2410	+45°-45°	24	810	1.00	300
XM-2415	+45°-45°	24	810	1.50	450
Hexcell / Knytex					
DB090	+45°-45°	9	305	NONE	NONE
DB120	+45°-45°	12	405	NONE	NONE
DB170	+45°-45°	17	575	NONE	NONE
DB240	+45°-45°	24	810	NONE	NONE
DBM1208	+45°-45°	12	405	0.75	225
DBM1708	+45°-45°	17	575	0.75	225
DBM1715	+45°-45°	17	575	1.50	450
DBM2408	+45°-45°	24	810	0.75	225
DBM2415	+45°-45°	24	810	1.50	450
CD180	0°–90°	18	610	NONE	NONE
CD230	0°–90°	23	780	NONE	NONE
A130	0°	13	440	NONE	NONE
A260	0°	26	880	NONE	NONE

Location of "Midships"

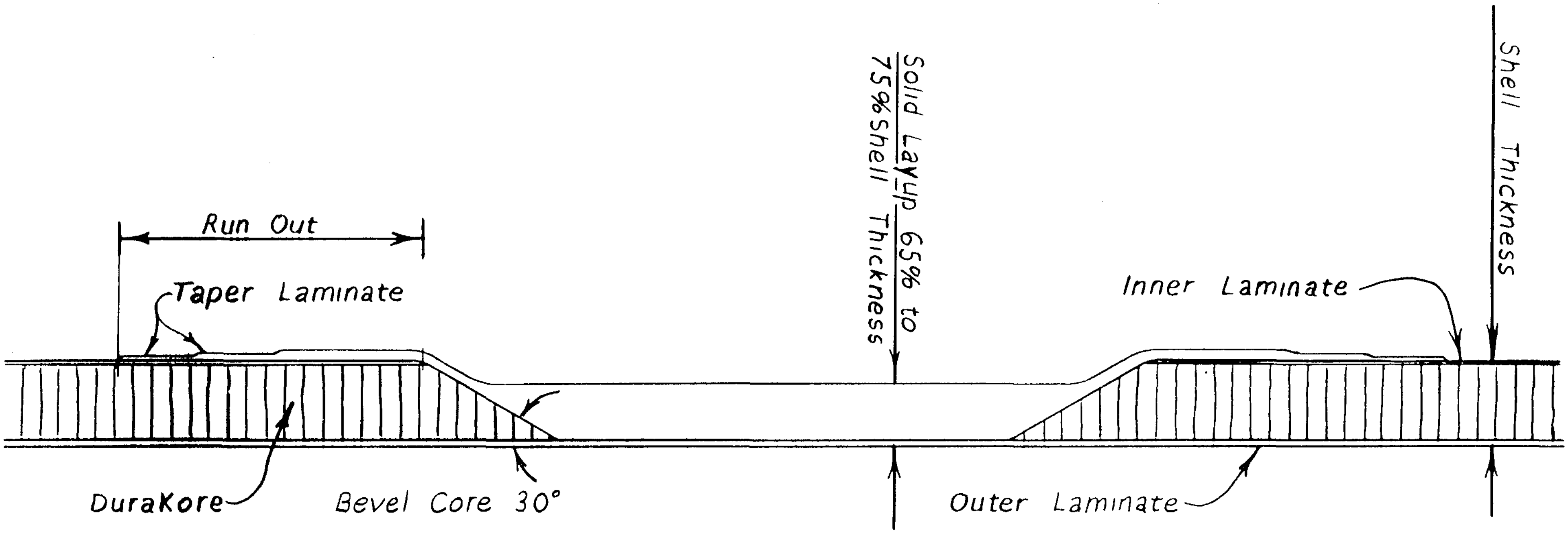



Determining Depth of Hull at Midships
℄
℄
Sheer
Depth of Hull
Extend Bottom to
Intersect Centerline
Keel Bottom
Hull With Hollow Garboards
Hull Without Hollow Garboards
D. GERR

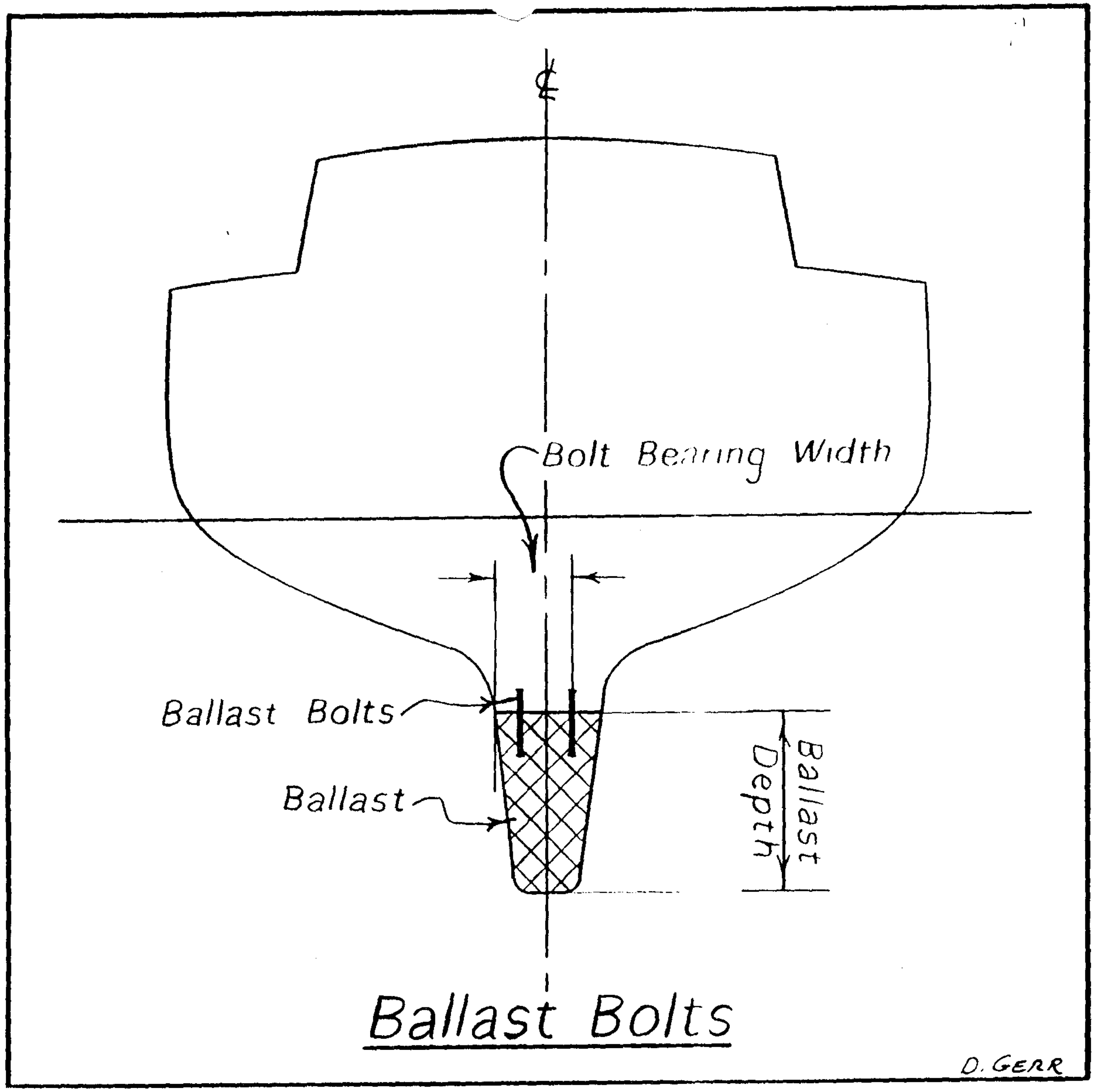

Bulkhead-To-Hull Joint
Note: Fillet "Radius" Really
Indicates Length Of Epoxy Fillet
Along Bulkhead And Along Hull
Tabbing Run Out
2 in. — 50 mm Fillet
Tabbing Run Out
Bulkhead
Tabbing
Low-Density Epoxy Grout
DuraKore
Hull Shell
FRP Laminate
D. GERR



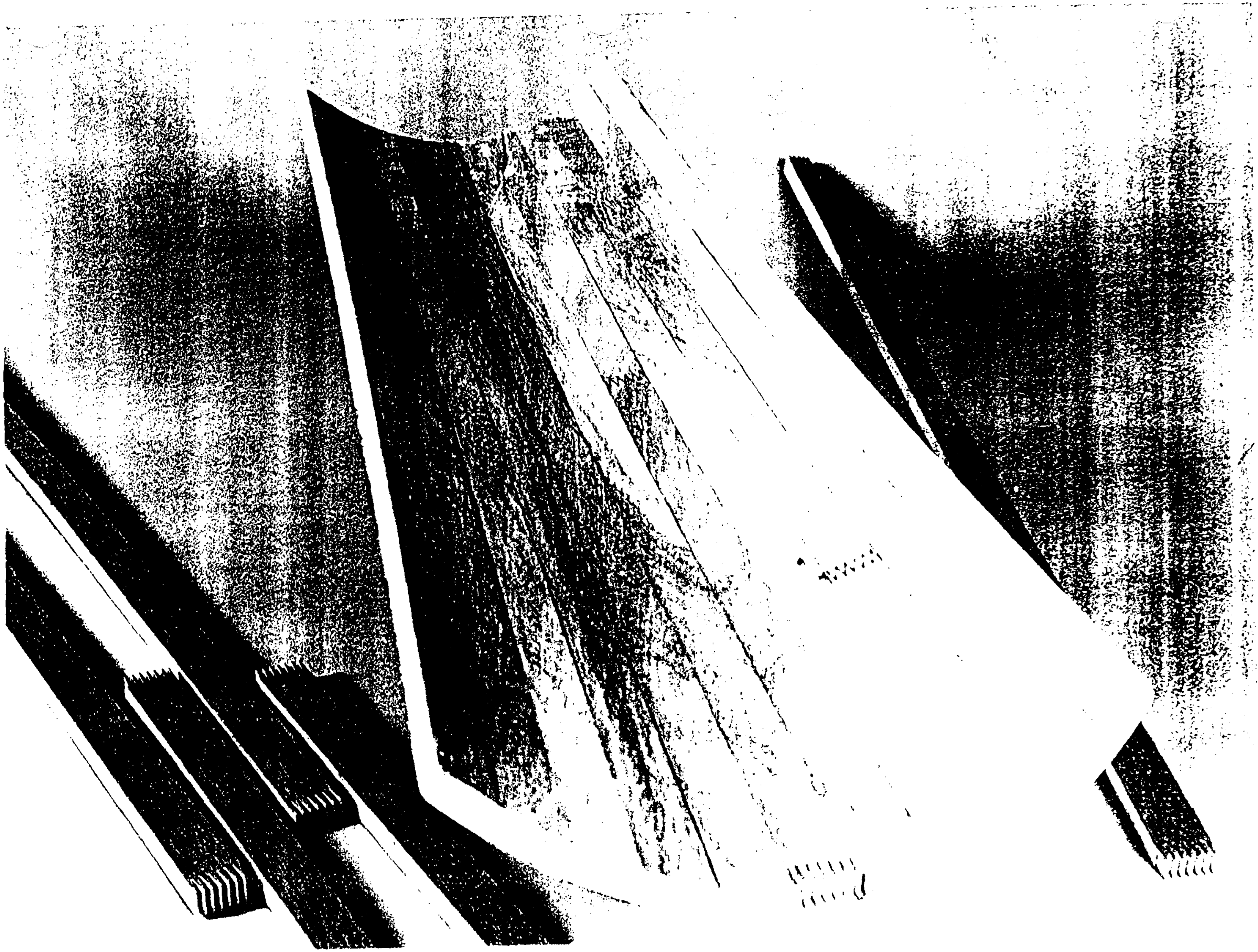
Floors
BOA – Beam Overall
Taper To Avoid Hard Spots
30% BOA
Increase Height
To Span 30% BOA
BETTER: Extend With
Laminated 1/2 Frame
1/2-Frame Height & Width
Same As Floor Thickness
Minimum Scantling
Height
With Hollow Garboards
30% BOA
Minimum Scantling
Height
Without Hollow Garboards
D. GERR



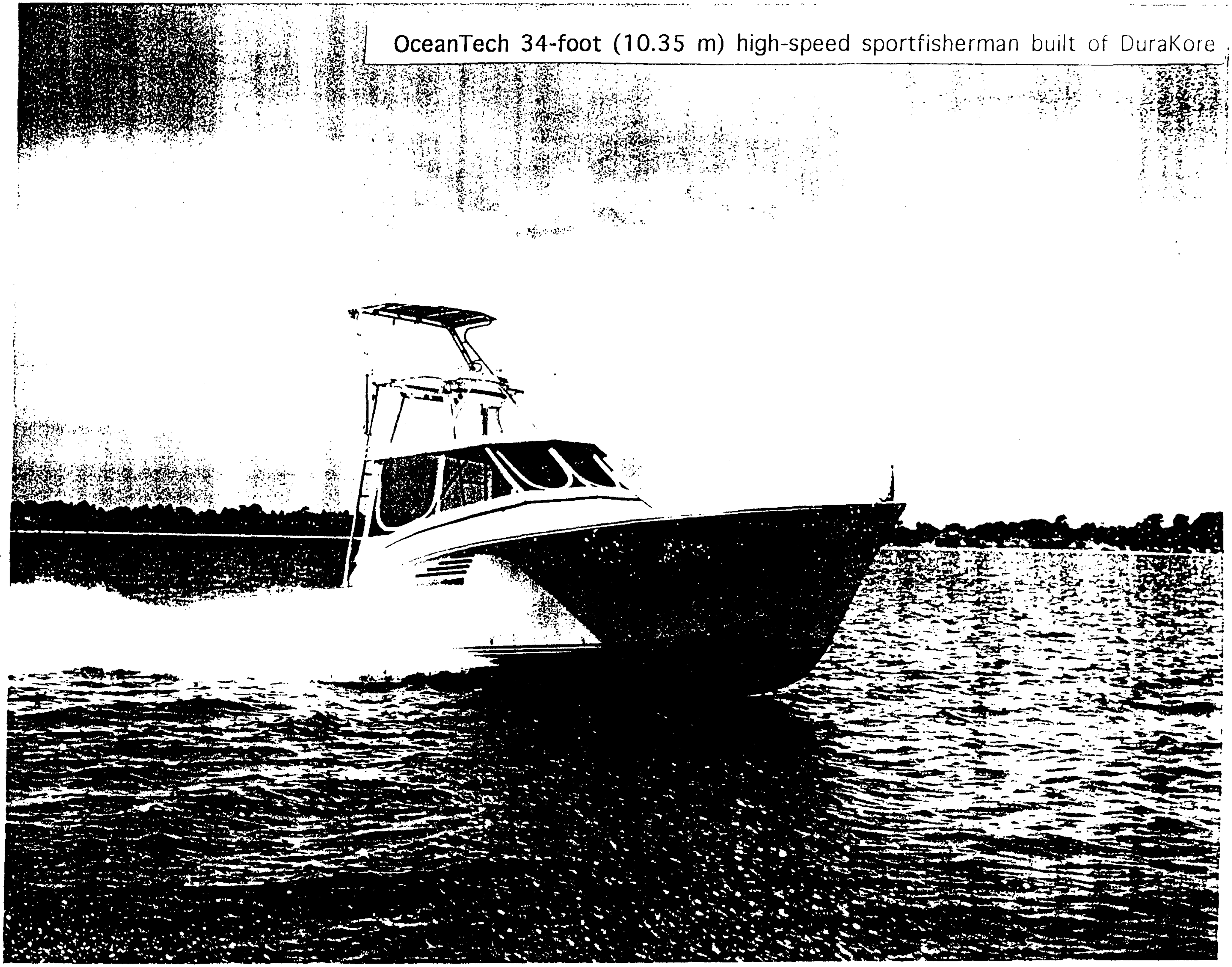
Solid Glass At Hull Penetrations



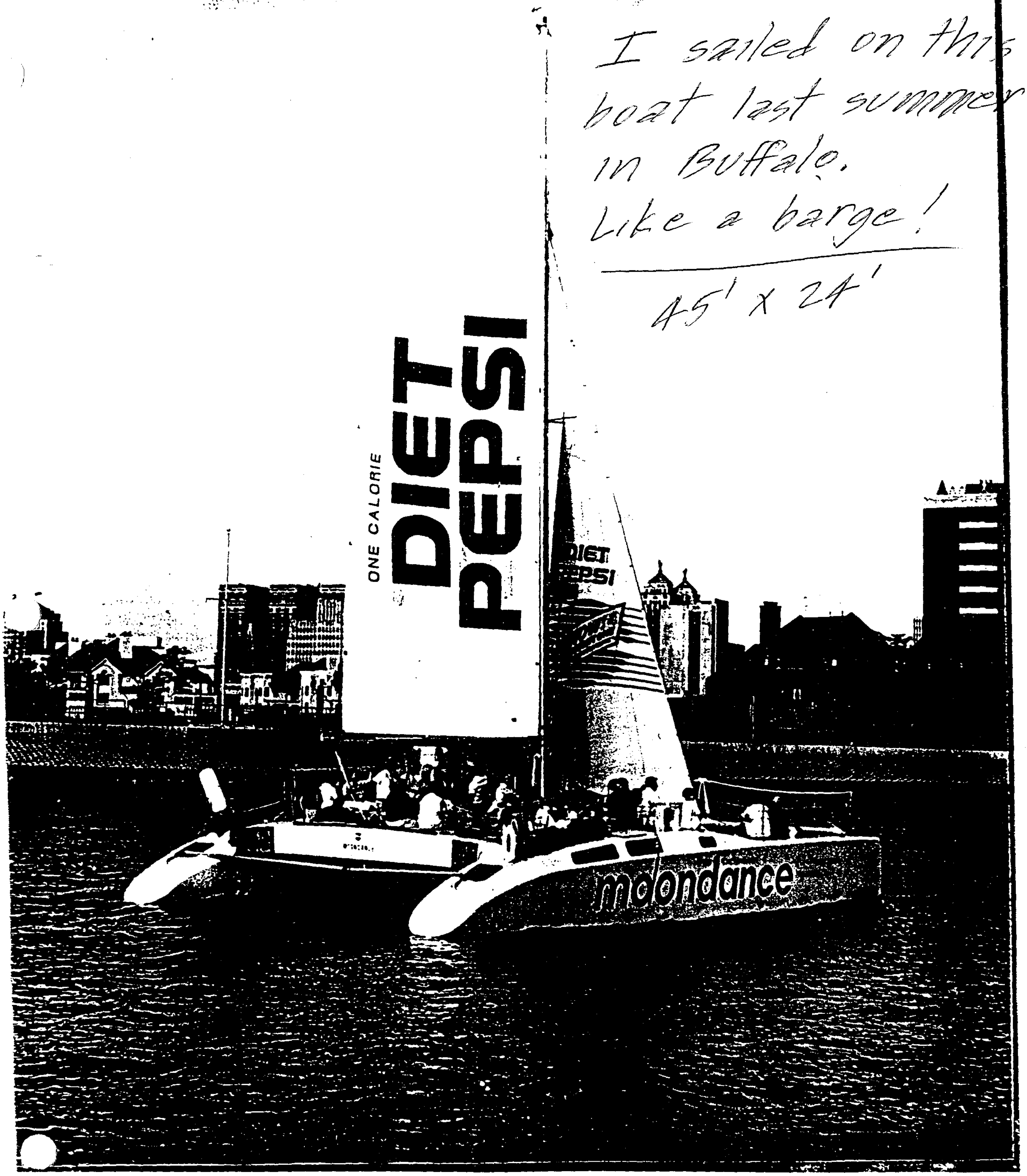
Ballast Bolts



Durakore strip planks go together easily to produce complex shapes with low labor hours and light weight



OceanTech 34-foot (10.35 m) high-speed sportfisherman built of DuraKore

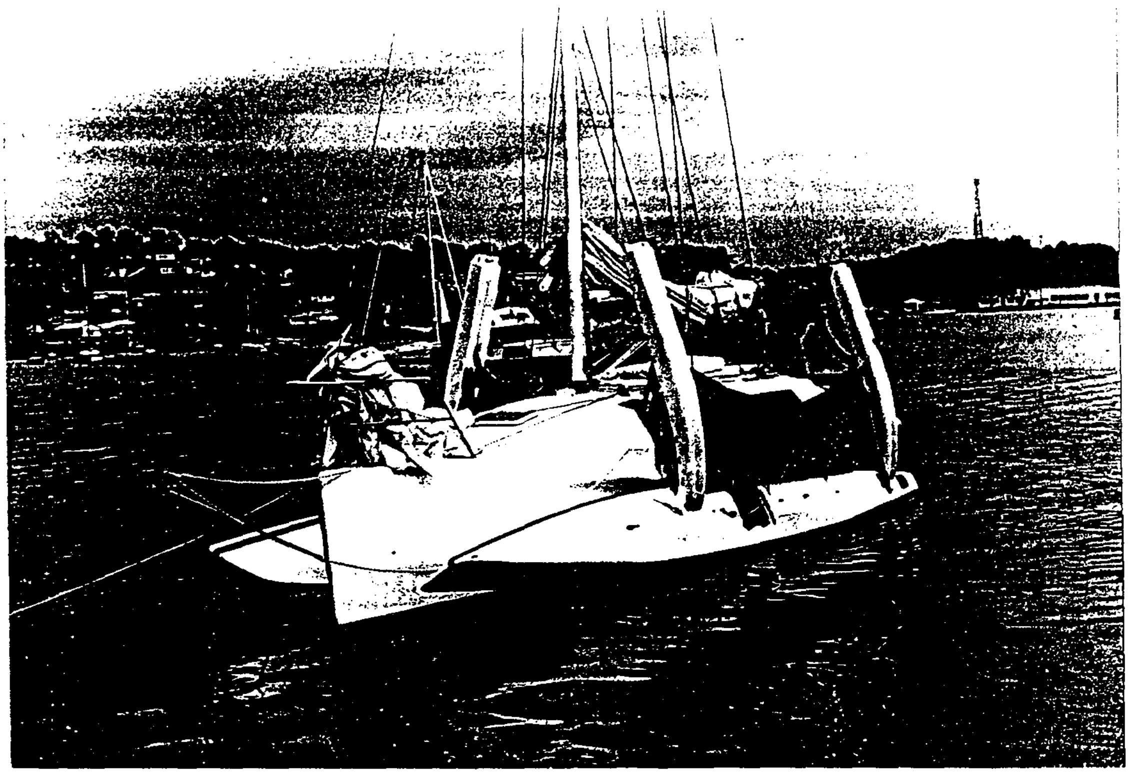


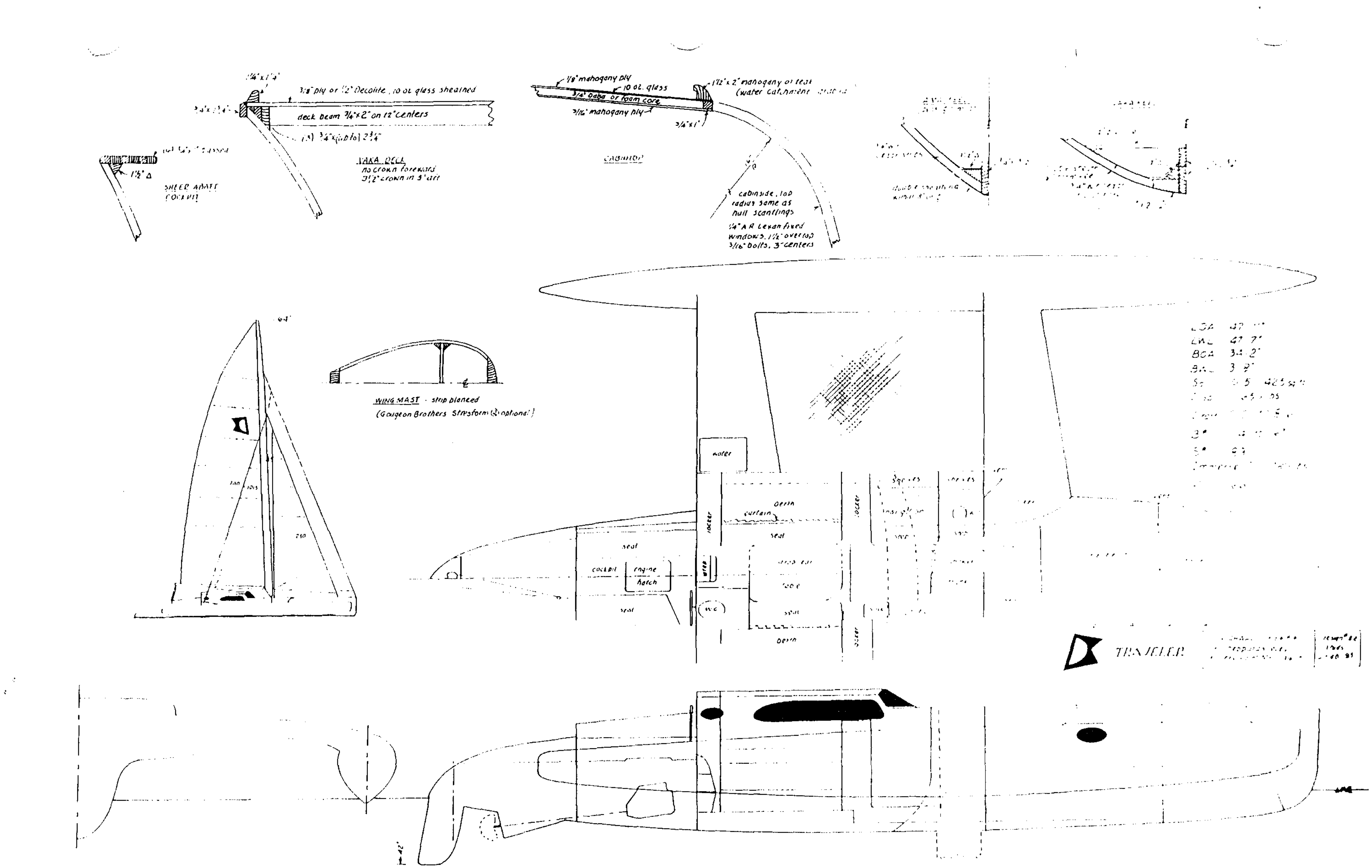
I sailed on this boat last summer in Buffalo.
Like a barge!
45' x 24'

The Kurt Hughes designed DuraKore charter catamaran, *Moondance*.

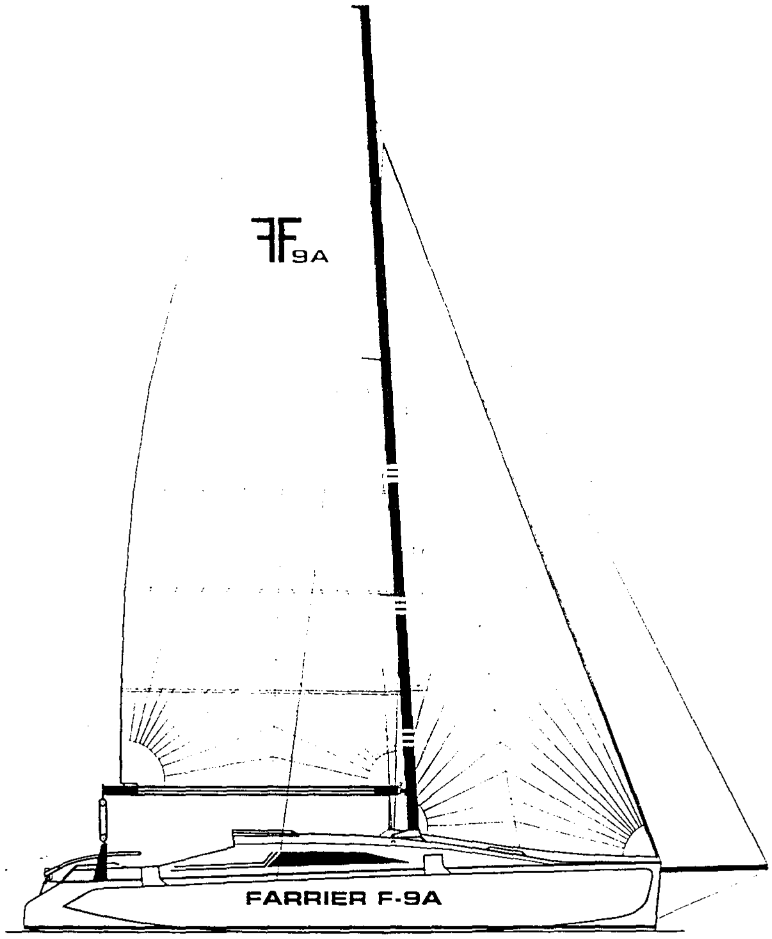
36-foot "White Wings" trimaran designed by Dick Newick and built completely of DuraKore by David Nutt in Maine.

Ian Farrier-designed TrailerTri, folded. Extreme light weight in DuraKore.

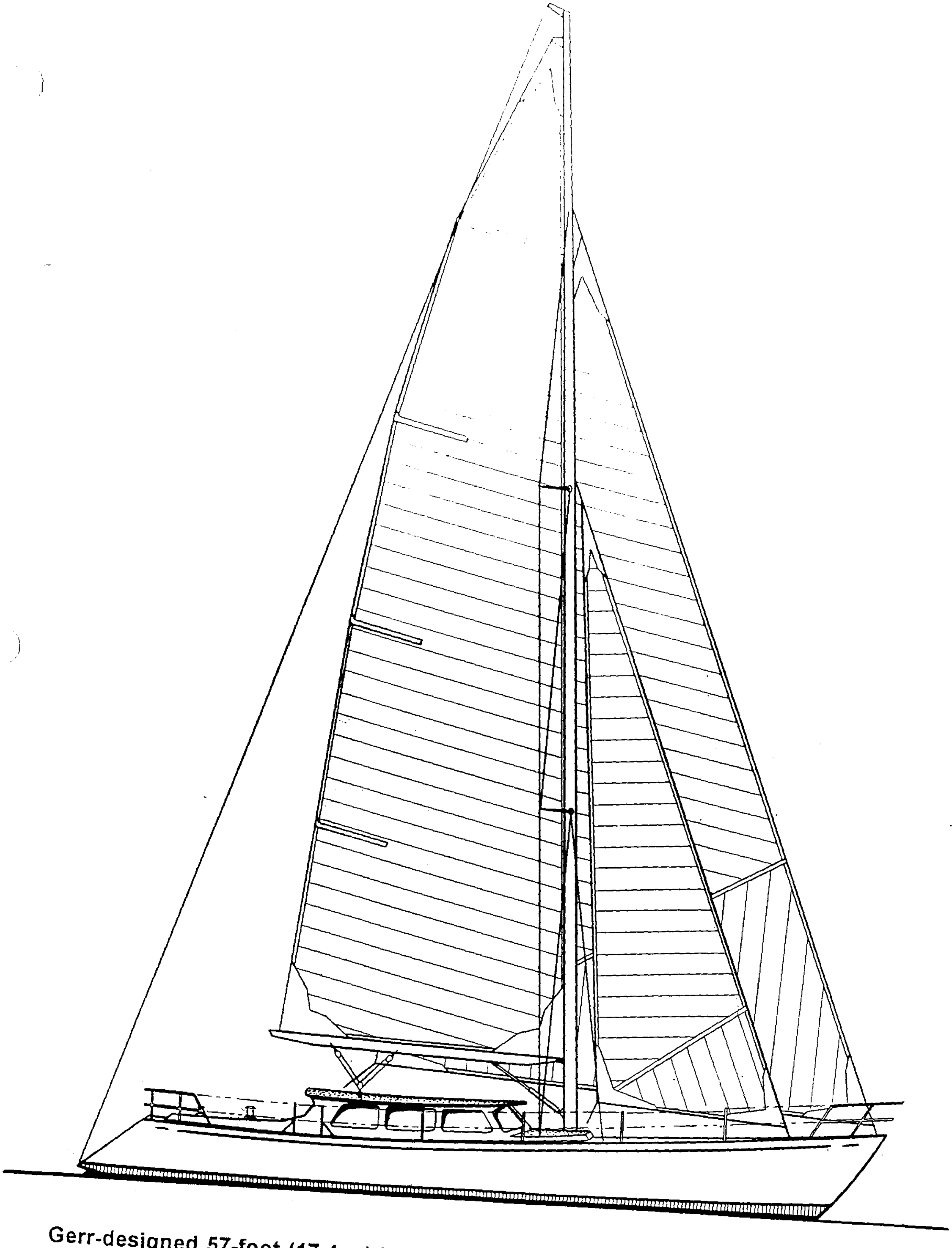




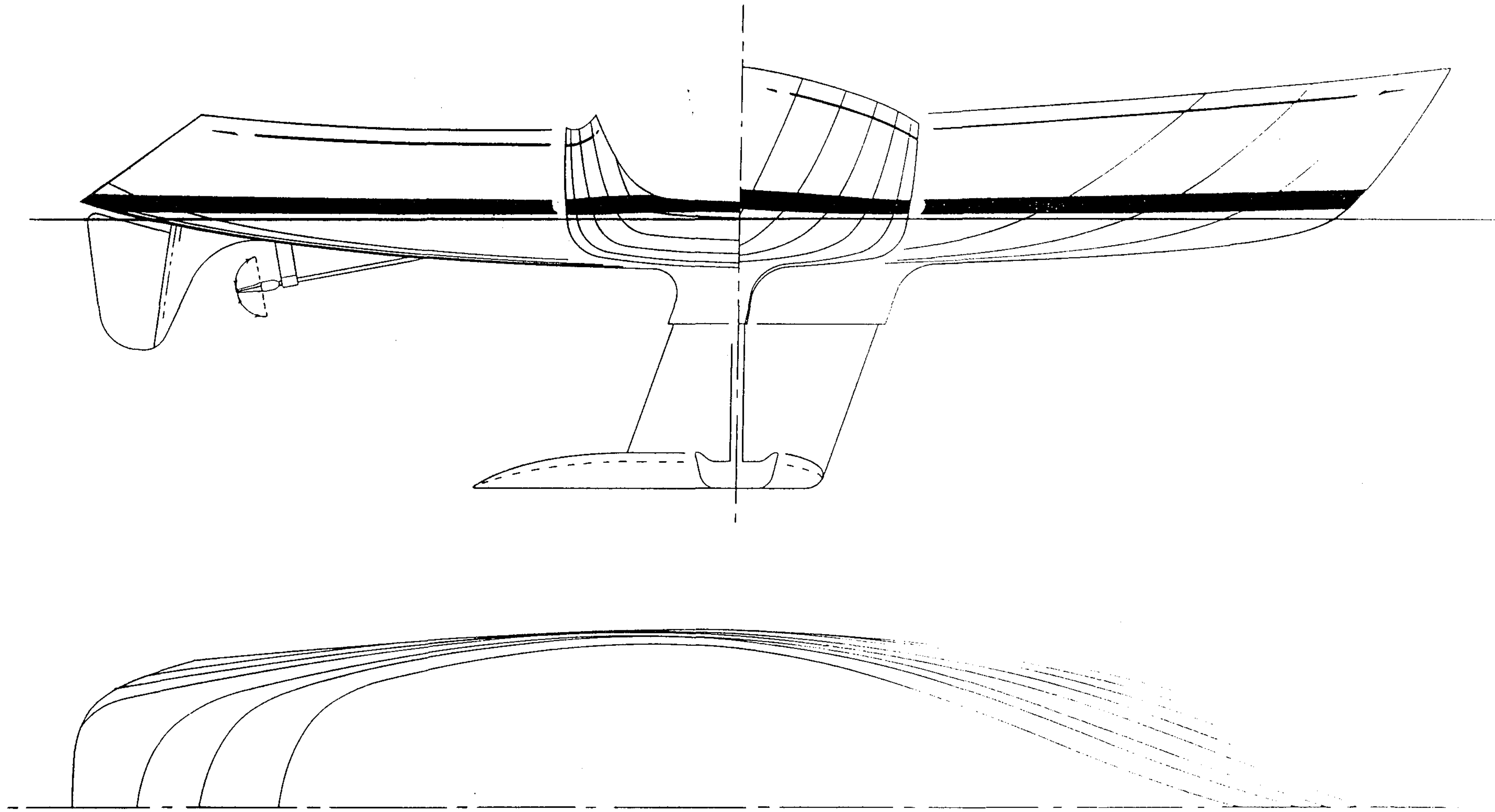
Richard Newick's 48-foot (14.6 m) DuraKore cruising trimaran, *Traveler*



Ian Farrier's F-9A 30-foot (9.1 m) ultra-light DuraKore cruising trimaran



Gerr-designed 57-foot (17.4 m) high-performance motorsailer, designed for Baltek DuraKore construction.



Gerr-designed 57-foot (17.4 m) high-performance motorsailer, designed for **Baltek DuraKore construction.**