Appendix F

Guide for Building and Classing
Offshore Racing Yachts

1994

American Bureau of Shipping
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and State of New York 1862

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<table>
<thead>
<tr>
<th>Year</th>
<th>Members</th>
</tr>
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</table>
| 1978–1979 | Olin J. Stephens II, Chairman  
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Foreword to the 1986 Guide

This Guide has been developed by the International Technical Committee (1978–1979 and 1979–1980) of the Offshore Racing Council and the American Bureau of Shipping. The strength standards given have been derived from the various existing standards established by satisfactory service experience.

Foreword to the 1994 Guide

This 1994 Guide includes the changes to the 1986 edition as developed jointly by the International Technical Committee of the Offshore Racing Council and the American Bureau of Shipping in 1991, 1992 and 1993. In accordance with 1.5.4, this guide will supersede the 1986 edition effective November 1, 1994; however, the Bureau may bring into force individual changes before that date if necessary or appropriate.  

30 April 1994

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SECTION 1
Scope and Conditions of Classification

1.1 Classification

1.1.1 Process
The Classification process consists of a) the development of Rules, Guides, standards and other criteria for the design and construction of marine vessels and structures, for materials, equipment and machinery, b) the review of design and survey during and after construction to verify compliance with such Rules, Guides, standards or other criteria and c) the assignment and registration of class when such compliance has been verified.

The Rules and standards are developed by Bureau staff and passed upon by committees made up of naval architects, marine engineers, shipbuilders, engine builders, steel makers and by other technical, operating and scientific personnel associated with the worldwide maritime industry. Theoretical research and development, established engineering disciplines, as well as satisfactory service experience are utilized in their development and promulgation. The Bureau and its committees can act only upon such theoretical and practical considerations in developing Rules and standards.

1.1.2 Certificates and Reports
Surveys during and after construction are conducted by the Bureau to verify to itself and its committees that, in this case for yachts, the structure and material are in compliance with this Guide and other Rules and standards as far as indicated to the satisfaction of the attending Surveyor. All reports and certificates are issued solely for the use of the Bureau, its committees, its clients and other authorized entities.

1.1.3 Representations as to Classification
Classification of an offshore racing yacht is a representation by the Bureau as to the fitness of the yacht with respect to those aspects covered by this Guide. The Rules, Guides, standards and other criteria of the American Bureau of Shipping are not meant as a substitute for the independent judgement of professional designers, naval architects, owners, operators, masters and crew nor as a substitute for the quality control procedures of yacht builders, steel or aluminum makers, suppliers, manufacturers and sellers of marine vessels, materials and equipment.

The Bureau represents solely to the yacht Owner or clients of the Bureau that when assigning and maintaining the class it will use due diligence in the development of Rules, Guides, standards and other criteria, and in using standards, procedures and techniques as called for by this Guide.

The Bureau further represents to the yacht Owner or other client of the Bureau that its certificates and reports evidence compliance only with one or more of the Rules, Guides, standards or other criteria of the Bureau in accordance with the terms of such certificates or reports.

Under no circumstances whatsoever are these representations to be deemed to relate to any third party.

1.1.4 Scope of Classification
Nothing contained in any certificate or report is to be deemed to relieve any designer, builder, Owner, manufacturer, seller, supplier, repairer, operator, other entity or person of any warranty express or implied. Any certificate or report evidences compliance only with one or more of the Rules, Guides, standards or other criteria of American Bureau of Shipping and is issued solely for the use of the Bureau, its committees, its clients or other authorized entities. Nothing contained in any certificate, report, plan or document review or approval is to be deemed to be in any way a representation or statement beyond those contained in 1.1.3. The validity, applicability and interpretation of any certificate, report, plan or document review or approval are governed by the Rules, Guides and standards of the American Bureau of Shipping who shall remain the sole judge thereof. The Bureau is not responsible for the consequences arising from the use by other parties of the Rules, Guides, standards or other criteria of the American Bureau of Shipping, without review, plan approval and survey by the Bureau.

The term “approved” shall be interpreted to mean that the plans, reports or documents have been reviewed for compliance with one or more of the Rules, Guides, standards, or other criteria of the Bureau.

1.1.5 Suspension of Representation as to Classification
In the event of any damage or casualty to hull or equipment which affects or may affect classification, or the structural integrity, quality or fitness for a particular use or service of a yacht structure or item of material, all representations as to classification are to be considered suspended unless notification of such damage or casualty is given at first opportunity and survey and repairs are thereafter undertaken as required in Section 11 of this Guide. Any use, operation or other application of any yacht structure or material for which it has not been approved and which affects or may affect classification or the structural integrity, quality or fitness for a particular use or service is to cause all representations as to classification to be suspended until such time as the condition shall be remedied.
1.6 Termination of Classification
The continuance of the classification of any yacht is conditional upon the Rule requirements for periodical, damage and other surveys being duly carried out. The Committee reserves the right to reconsider, withhold, suspend or cancel the class of any yacht for noncompliance with the Guide, for defects reported by the Surveyors which have not been rectified in accordance with their recommendations, or for nonpayment of fees which are due on account of classification and other surveys.

1.3 Classification Symbols

1.3.1 Offshore Racing Service
Offshore racing yachts which have been built to the satisfaction of the Surveyors to the Bureau to the full requirements of this Guide, or to their equivalent, where approved by the Committee for offshore racing service will be classed and distinguished in the Record by the symbols #A1 followed by the notation Offshore Racing Yacht.

1.3.2 Yachts Not Built under Survey
Yachts which have not been built under survey to this Bureau, but which are submitted for classification, will be subjected to a special classification survey. Where found satisfactory and thereafter approved by the Committee, they will be classed and distinguished in the Record by the symbols and notation as described in 1.3.1 above, but the mark # signifying the survey during construction will be omitted.

1.5 Rules for Classification

1.5.1 Application
This Guide is applicable to offshore racing yachts of up to 30.5 m (100 ft) in scantling length as defined in 2.1.
These requirements are applicable to those features that are permanent in nature and can be verified by plan review, calculation, physical survey or other appropriate means. Any statement in the Guide regarding other features is to be considered as a guidance to the designer, builder, owner, et al.

1.5.2 Alternatives
The Committee is at all times ready to consider alternative arrangements and scantlings which can be shown, through either satisfactory service experience or a systematic analysis based on sound engineering principles, to meet the overall safety and strength standards of the Guide.
The Committee will consider special arrangements or details which can be shown to comply with standards recognized in the country in which the yacht is registered or built, provided they are not less effective.

1.5.3 Novel Features
Yachts which contain novel features of design in respect of the hull to which the provisions of the Guide are not directly applicable may be classed, when approved by the Committee, on the basis that the Guide insofar as applicable has been complied with and that special consideration has been given to the novel features based on the best information available at the time.

1.5.4 Effective Date of Guide Changes

a Six Month Rule
Changes to the Guide are to become effective six months from the date of their publication. However, the Bureau may bring into force individual changes before that date if necessary or appropriate.

b Implementation of Guide Changes
In general, until the effective date, plan approval for designs will follow prior practice unless review under the latest Guide is specifically requested by the party signatory to the application for classification. If one or more yachts are to be constructed from plans previously approved, no retroactive application of the latest Guide changes will be required except as may be necessary or appropriate for all contemplated construction.

1.7 Other Regulations
While the Guide covers the requirements for the classification of new offshore racing yachts, the attention of Owners, designers, and builders is directed to the regulations of international, governmental and other authorities dealing with those requirements in addition to or over and above the classification requirements.

1.9 Submission of Plans
Plans showing the scantlings, arrangements, and details of the principal parts of the hull structure of each yacht to be built under survey and of each yacht to have Bureau plan approval, are to be submitted and approved. For yachts built under survey, plans are to be submitted before the work of construction is commenced. These plans are to indicate clearly the scantlings and fastenings, the minimum mechanical properties of the construction materials, and details of construction. For FRP construction, laminate lay-up information including ply specification, fiber material, ply orientation, ply weight, cured ply fiber content and thickness and minimum mechanical properties of the laminate, its constituent plies, the unreinforced resin and the cores is to be shown on the relevant plans. In general, these plans should include the following:

Framing sections
Bottom construction, floors, girders, etc.
Shell expansion
Deck and cockpit
Pillars
Watertight and tank bulkheads
Non-tight bulkheads, shelves, bunks which are glassed-in and used as structural supports
Stern frame, rudder and rudder bearings
Keel bolt and chain plate connections
Tiller
Cabin house-tops, sides and ends
Closing appliances for hull, decks and cabin houses

Plans should generally be submitted in triplicate, one copy to be returned to those making the submission, one copy for the use of the Surveyor where the yacht is being built, and one copy to be retained in the office performing the review for record.

1.11 Conditions for Surveys after Construction

1.11.1 Damage and repair
Damage, deterioration or repair which affects or may affect classification, is to be submitted by the Owners or their representatives for examination by the Surveyor at first opportunity. All repairs found necessary by the Surveyor are to be carried out to his satisfaction. Nothing contained in this section or in a rule or regulation of any government or other administration, or the issuance of any report or certificate pursuant to this section or such a rule or regulation, is to be deemed to enlarge upon the representations expressed in 1.1.1 through 1.1.5 hereof and the issuance and use of any such reports or certificates are to in all respects be governed by 1.1.1 through 1.1.5 hereof.

1.11.2 Notification and Availability for Survey
The Surveyors are to have access to classed yachts at all reasonable times. The Owners or their representatives are to notify the Surveyors on all occasions when a yacht can be examined in drydock or on a slipway.

The Surveyors are to undertake all surveys on classed yachts upon request, with adequate notification, of the Owners or their representatives and are to report thereon to the Committee. Should the Surveyors find occasion during any survey to recommend repairs or further examination, notification is to be given immediately to the Owners or the representatives in order that appropriate action may be taken. The Surveyors are to avail themselves of every convenient opportunity for carrying out periodical surveys in conjunction with surveys of damages and repairs in order to avoid duplication of work.

1.12 Hull Certification

Where the owner does not desire classification of the yacht, the Bureau is prepared, at owner’s request, to review the hull construction plans of the yacht, including building process description, for compliance with the appropriate hull requirements of this Guide, as well as with requirements for hull openings, such as seacocks, discharges, exhausts, etc., survey the construction of the hull of the yacht, and witness or otherwise verify the testing of the hull material and relevant fittings and issue a hull construction certificate indicating the extent of the review and survey.

1.13 Fees

Fees in accordance with normal ABS practice will be charged for all services rendered by the Bureau. Expenses incurred by the Bureau in connection with these services will be charged in addition to the fees. Fees and expenses will be billed to the party requesting that particular service.

1.15 Disagreement

1.15.1 Guide
Any disagreement regarding the proper interpretation of the Guide is to be referred to the Bureau for resolution.

1.15.2 Surveyors
In case of disagreement between the Owners or builders and the Surveyors regarding the material, workmanship, extent of repairs, or application of the Guide relating to any yacht classed or proposed to be classed by this Bureau, an appeal may be made in writing to the Committee, who will order a special survey to be held. Should the opinion of the Surveyor be confirmed, the expense of this special survey is to be paid by the party appealing.

1.17 Limitation of Liability

The combined liability of American Bureau of Shipping, its committees, officers, employees, agents or subcontractors for any loss, claim, or damage arising from its negligent performance or nonperformance of any of its services or from breach of any implied or express warranty of workmanlike performance in connection with those services, or from any other reason, to any person, corporation, partnership, business entity, sovereign, country or nation, will be limited to the greater of a) $100,000 or b) an amount equal to ten times the sum actually paid for the services alleged to be deficient.

The limitation of liability may be increased up to an amount twenty-five times that sum paid for services upon receipt of Client’s written request at or before the time of performance of services and upon payment by Client of an additional fee of $10.00 for every $1,000.00 increase in the limitation.
SECTION 2
Definitions

2.1 Length

$L$ is the scantling length, given by the following equation.

$$L = \frac{L_{OH} + L_{WL}}{2} \text{ meters or feet}$$

Where $L_{OH}$ is the overall length of the hull. See Figure 2.1. $L_{WL}$ is the length on the maximum estimated displacement waterline. See Figure 2.1.

2.3 Breadth

$B$ is the greatest breadth, excluding appendages, in meters or feet. See Figure 2.2.

2.5 Depth

$D$ is the maximum depth in meters or feet measured vertically from the bottom of the canoe hull at centerline to the top of the main weather deck at side. See Figure 2.2.

2.7 Draft for Scantlings

$d$ is the maximum distance in meters or feet measured vertically from the bottom of the canoe hull at its lowest point at centerline to the maximum estimated displacement waterline. See Figure 2.2.

2.9 Main Weather Deck

The main weather deck is the uppermost continuous deck having permanent means for closing all openings in its weather portions, and below which all openings in the yacht's side are equipped with permanent means for watertight closure.

2.11 Fiber-Reinforced Plastic (FRP)

FRP consists of two basic components: a glass-filament or other material fiber filament and a plastic, or resin, in which the reinforcing material is imbedded.

2.11.1 Reinforcement

Reinforcement is a strong, inert material bonded into the plastic to improve its strength, stiffness and impact resistance. Reinforcements are usually fibers of glass (a lime-alumina-silicate composition having a low alkali content) or other approved material in a woven or non-woven form, with a strong adhesive bond with the resin.

a. **Strand** A bundle of continuous filaments combined in a single, compact unit.

b. **Chopped-strand Mat** A blanket of randomly oriented chopped-glass strands held together with a binder.

c. **Roving** A band or ribbon or parallel strands grouped together.

d. **Woven Roving** A coarse fabric woven from rovings.

e. **Yarn** A twisted strand or strands suitable for weaving into a fabric.

f. **Cloth** A fabric woven from yarn.

g. **Warp** The roving or yarn running lengthwise in woven fabric.

h. **Fill** The roving or yarn running at right angles to the warp in a woven fabric. Also called woof.

i. **Binder** A substance applied in small quantities to fibers to hold them lightly together in mat form.

j. **Size** A substance applied to fibers at the time of their formation to allow resin to flow freely around and adhere to them, and to protect them from abrasion.

k. **Finish** A substance applied to fabrics to promote wetting of the fibers by the resin, to improve adhesion, and to reduce interfilament abrasion.

2.11.2 Resin

Resin is a highly reactive synthetic that in its initial stage is a liquid, but upon activation is transformed into a solid.

a. **Accelerator** A material that when mixed with resin speeds the cure time.

b. **Catalyst or Initiator** A material that is used to activate resin, causing it to harden.

c. **Crazing** Hairline cracks, either within or on the surface of resin, caused by mechanical or thermal stresses.

d. **Cure** To change resin from a liquid to a solid.

e. **Cure time** The time required for resin to change from a liquid to a solid after a catalyst has been added.

f. **Exothermic Heat** The heat given off as the result of the action of a catalyst on resin.

g. **Filler** A material added to resin to modify its working properties or other qualities, or to lower costs.

h. **Gel** A partially cured resin in a semifluid state similar to gelatin in consistency. Not to be confused with gel coat (2.11.3e).

i. **Gel Time** The time required to change a flowable, liquid resin into a nonflowing gel.
FIGURE 2.1
Profile at Centerline
FIGURE 2.2
Transverse Section at $D$

SECTION 2 | 3  Definitions
**Inhibitor** A material that retards activation or initiation of resin, thus extending shelf life or influencing exothermic heat or gel time.

**Polymerization** The reaction that takes place when resin is activated or initiated.

**Pot Life** The length of time that a catalyzed resin remains workable.

**Shelf Life** The length of time that an uncatalyzed resin maintains its working properties while stored in a tightly sealed, opaque container.

**Tack** The degree of stickiness of the resin.

**Thixotropy** The property or phenomenon, exhibited by some resins, of becoming jelly-like at rest but becoming fluid again when stirred or agitated. This facilitates the application of the resin to inclined or vertical surfaces.

### 2.11.3 Laminate

A laminate is a material composed of successive bonded layers of resin and fiber or other reinforcing substance.

**Bi-directional Laminate** A laminate with fibers oriented in various directions in the plane of the laminate where the mechanical properties in the two natural axes of the laminate plane are about equal. Bi-directional laminates may be constructed of bi-directional or uni-directional reinforcing layers, or a combination of each.

**Uni-directional Laminate** A laminate with substantially more of the fibers in the plane of the laminate oriented in one of the two natural axes of the laminate plane so that the mechanical properties along that axis, in general the warp, are appreciably higher than along the other natural axis.

**Barcol Hardness** A measurement of the hardness of a laminate and thereby the degree of completion of the cure.

**Delamination** The separation of the layers of material in a laminate.

**Gel Coat** The first resin applied to a mold when fabricating a laminate. It provides a smooth protective surface for the laminate. For decorative purposes, it usually has a coloring matter added. Not to be confused with gel (see 2.11.2h).

**Layup** The process of applying to a mold the layers of resin and reinforcing materials that make up a laminate. These materials are then compressed or densified with a roller or squeegee to eliminate entrapped air and to spread resin evenly. Also a description of the component materials and geometry of a laminate and laminate that has been assembled.

**Peel Ply** A partially impregnated, lightly bonded layer of glass, cloth or woven roving used to protect a laminate in anticipation of secondary bonding. This ply is readily peeled off just prior to secondary bonding, providing a clean, fresh bonding surface.

**Secondary Bonding** The practice of bonding fresh material to a cured or partially cured laminate.

**Encapsulation** The containment of a core material such as softwoods, including plywood, balsa, or plastic foam between two FRP single-skin laminates. The cores may be structurally effective or ineffective, see 5.3.2c.

**Verified Minimum Mechanical Property** The mechanical properties, listed in 4.5.4b, of laminates differing from the basic, verified by the appropriate test given in Table 5.1.

**Natural Axis** The two natural axes of a laminate are, for the application of this Guide, the axis that is parallel to the warp and the axis that is parallel to the fill.

### 2.13 Wood

#### 2.13.1 Cold-molded Wood Laminate

Cold-molded wood laminate is formed of thin layers of the same or similar property woods, laid on a hull mold formed by the framing, generally with alternate layers running parallel to each other and with adjacent layers perpendicular to each other. The layers are in general not to be thicker than \( \frac{1}{2} \) the overall laminate thickness, or 4.5 mm (\( \frac{3}{32} \) in.) if less, the grain of wood is to be parallel to the length of the layer. Each layer of wood is coated on the facing surfaces with resin or glue before being placed on the hull mold.

#### 2.13.2 Softwood

Softwoods are botanically named Gymnosperms, and fall into the category called conifers, having the seeds exposed, usually in cones.

#### 2.13.3 Hardwoods

Hardwoods are botanically named Angiosperms. They have true flowers and broad leaves and the seeds are enclosed in fruit.

### 2.15 Mechanical Properties

The following are definitions of the mechanical properties referred to in this Guide.

#### 2.15.1 Steel and Aluminum

**Yield Strength** For steel having a tensile strength of 400–490 N/mm² (41–50 kgf/mm², 58000–71000 psi) it is the first stress in a tensile test, less than the maximum obtainable stress at which an increase in strain occurs without an increase in stress. Alternatively it may be taken as the stress at which occurs a total strain extension of 0.5% of the test specimen gauge length.

For aluminum alloys and for steel having a tensile strength of 490 N/mm² (50 kgf/mm², 71000 psi) or greater it is the stress in a tensile test, at which there is a strain deviation, of 0.2% of the test specimen gauge length, from the line of proportionality of stress to strain. Alternatively for material whose stress-strain characteristics are well known from previous tests in which stress-strain curves are plotted it may be taken as the stress at which occurs a total strain extension of 0.5% of the test specimen gauge length.
2.15.2 Fiber-Reinforced Plastic

a Flexural Strength The measure of the capability of a plate to withstand a bending load without failing.

b Flexural Modulus The number used to calculate the distance a plate will deflect under a given bending load.

c Tensile Strength The measure of the capability of a plate or stiffening member to withstand a stretching load without failing.

d Tensile Modulus The number used to calculate the amount a plate or stiffening member will increase in length when a stretching load is applied to it.

e Compressive Strength The measure of the capability of a plate or stiffening member to withstand a compressing load without crushing.

f Compressive Modulus The number used to calculate the amount a plate or stiffening member decreases in length when a compressing load is applied to it.

g Shear Strength The measure of the capability of a body such as a plate or stiffening member to withstand a shearing load without one part of the body being forced to slide past the other.

h Shear Modulus The measure of the stiffness of a plate or stiffening member when a shearing load is applied to it. Also called the modulus of rigidity.

i Interlaminar Shear The shear strength of the bond between plies of reinforcing material. The measure of the capability of the bond to withstand a shear load without delamination.

2.15.3 Wood

a Modulus of Rupture in Bending A reflection of the maximum load carrying capacity. It is obtained by the maximum bending moment that can be carried without rupture divided by the minimum section modulus of the plating or stiffening member. Values given are generally for the bending stress parallel to the grain.

b Modulus of Elasticity The number used to calculate the distance a plate or stiffening member will deflect under a given bending load. Values given are generally for the bending stress parallel to the grain.

c Tensile Strength Parallel to Grain The maximum stretching load, parallel to the grain, that a plate or stiffening member can withstand without rupture. As relatively few data are available for this property it may be conservatively estimated, for clear, straightgrained wood, by the modulus of rupture in bending.

d Tensile Strength Perpendicular to Grain The maximum stretching load, perpendicular to the grain, that a plate or stiffening member can withstand without rupture.

e Compressive Strength A reflection of the maximum compressive load a plate or stiffening member can withstand without crushing. It is obtained by the maximum load that can be carried without crushing divided by the cross-sectional area of the plate or stiffening member. Values given are generally for the compressive stress parallel to the grain.
SECTION 3

General

3.1 Structural Arrangement

The structural arrangements are to be in accordance with Section 8.

3.3 Openings

Major openings such as hatches and large vents are to be avoided in the hull in close proximity to the gunwale. Corners of openings in strength structures are to have generous radii. Compensation may be required for openings.

3.5 Effective Width of Plating

The section modulus and moment of inertia of stiffening member are provided by the member and a portion of the plating to which it is suitably attached.

3.5.1 FRP Laminates

Where the plating is an FRP single-skin laminate, the maximum effective width of plating is to equal either the stiffening member spacing in millimeters or inches or the width obtained from the following equation, whichever is less (Figure 3.1).

\[ w = 18t + b \text{ mm or in.} \]

where the stiffening member is the floor, frame, beam or bulkhead stiffeners

\[ w = \text{effective width of plating in mm or in.} \]
\[ t = \text{thickness of plating in mm or in.} \]
\[ b = \text{net width of stiffening member in mm or in., but not more than } 18t \]

Where the plating is an FRP sandwich laminate with a flexurally ineffective (balsa or plastic) core, \( t \) in the above equation is the thickness of a single-skin laminate having the same moment of inertia per unit width as the two skins of the sandwich.

For a stiffening member along an opening, the maximum effective width of plating is to equal either one-half the stiffening member spacing in millimeters or inches or the width obtained from the following equation, whichever is less.

\[ w = 9t + b \text{ mm or in.} \]

where \( w, t \) and \( b \) are as defined above

3.5.2 Plywood Plating

Where the plating is either plywood or an FRP sandwich laminate with a plywood core, the maximum effective width of plating is to equal either the stiffening member spacing in millimeters or inches or the width obtained from the following equation, whichever is less.

\[ w = 50t \text{ mm or in.} \]

where stiffening member, \( w \) and \( t \) are as defined in 3.5.1

For a stiffening member along an opening, the maximum effective width of plating is one-half of the effective widths given above.

3.5.3 Steel and Aluminum Plating

Where the plating is either steel or aluminum the maximum effective width of plating is equal to either the stiffening member spacing in millimeters or inches or the width obtained from the following equation, whichever is less.

\[ w = 100t \text{ mm or in.} \]

where stiffening member, \( w \) and \( t \) are as defined in 3.5.1

For a stiffening member along an opening, the maximum effective width of plating is one-half of the effective widths given above.

3.5.4 Wood

Where the plating is carvel construction the section modulus and moment of inertia of the stiffening member are those of the stiffening member only. Where cold-molded wood laminate is used and constructed in accordance with 5.52b1, the effective width of plating is equal to either the stiffening member spacing in millimeters or inches or the width obtained from the following equation, whichever is less.

\[ w = 25t \text{ mm or in.} \]

where stiffening member, \( w \) and \( t \) are as defined in 3.5.1

For a stiffening member along an opening, the maximum effective width of plating is one-half of the effective widths given above.
FIGURE 3.1
Effective Width of F.R.P. Plating and F.R.P. Stiffener Details
SECTION 4

Materials

4.1 Aluminum Alloys

The aluminum alloys used in yachts built to comply with this Guide are to be in accordance with the requirements in Section 30 and 35 of the "Rules for Building and Classing Aluminum Vessels". Consideration will be given to aluminum alloys of different properties provided they are suitable for marine applications and welding. Care is to be taken that aluminum alloys are insulated where necessary from other metals. Timber and paints containing copper, lead or mercury are not to be used with aluminum alloys.

For guidance, Table 4.1 gives the mechanical properties of some of the aluminum alloys in Sections 30 and 35 of the "Rules for Building and Classing Aluminum Vessels". The mechanical properties of other aluminum alloys suitable for marine applications, specified in recognized national or industrial standards, will also be considered.

4.3 Steel

The steel used in yachts built to comply with this Guide is to be in accordance with the requirements for Grade A ordinary-strength hull structural steel or Grade AH higher-strength structural steel in Section 2/1 of the "Rules for Building and Classing Steel Vessels", or other approved standards. Flat-rolled steel and flat bars less than 5 mm (0.20 in) in thickness and shapes of cross-section less than 645 mm² (1 in²) need not be subjected to tensile tests but chemistry consistent with the required tensile properties is to be complied with.

For guidance, Table 4.2 gives the mechanical properties of grades A and AH steels. The mechanical properties of other steels, specified in recognized national or industrial standards, will also be considered.

4.5 Fiber-Reinforced Plastic (FRP)

4.5.1 General

The basic laminate of the Guide is composed of alternate layers of glass fiber chopped-strand mat and woven roving, fabricated by the contact or hand-lay-up process. Laminates of other compositions and other types of lay-up will be considered on the submission of lay-up information and test data on the minimum mechanical laminate properties indicated in 1.9.

4.5.2 Resins

Resins, for the basic laminate of this Guide, other than those utilized for gel coats, are to be unsaturated, general-purpose or fire-retardant polyesters suitable for marine use, and are to be catalyzed in strict accordance with manufacturers' recommendations. Other resins, such as epoxy or vinylster, may be used. The properties of a resin are to be for the final form of the resin actually used in production with all additives and fillers included. The amount of silicon dioxide or other material added to provide thixotropy is to be the minimum necessary to resist flowing or draining. If mineral fillers are added, they are to be of a type recommended by the resin manufacturer.

4.5.3 Reinforcing Materials

Fiber reinforcing materials are to be as defined in 2.11.1. Binders, where used, are to be soluble polyester, epoxy, vinylster resin, as appropriate. Sizes and finishes are to be of the silane type, and are to be compatible with the laminating resins.

4.5.4 Laminates

a Basic FRP Laminate The basic laminate of this Guide consists of general-purpose polyester resin and alternate plies of fiberglass mat and fiberglass woven roving. The minimum glass content of this laminate is to approximate 35% by weight.

b Minimum Mechanical Properties of the Basic Laminate The basic FRP laminate is to have minimum mechanical properties as indicated in Table 4.3. Unless otherwise noted, the properties are in the warp direction.

c Exemptions from the Basic Laminate Gel coats and skin coats of either fiber mat weighing less than 30 grams per square meter (0.1 ounce per square foot) or fiber cloth weighing less than 30 grams per square meter (0.1 ounce per square foot) are considered to be nonstructural, and therefore are not to be included when calculating basic laminate scantlings.

d Laminate Thickness All FRP laminate thickness requirements in this Guide are based on cured resin-and-mat plies having average thicknesses equal to 0.25 millimeters per 100 grams of mat in each square meter (0.03 inches per ounce of mat in each square foot) of the laminate, and cured resin-and-woven roving plies having average thickness equal to 0.12 millimeters per 100 grams of woven roving in each square meter (0.0015 inches per ounce of woven roving in each square yard) of the laminate.

These are average thicknesses, and are given for design purposes only. Actual laminate thicknesses may vary as much as 15% over or under the average thicknesses without becoming excessively resin-rich or resin-dry. When measuring laminate thicknesses, the thicknesses of the exemptions from the basic laminate, described in 4.5.4c, are to
### TABLE 4.1
Properties of Aluminum Alloys

**Sheet and Plate**

<table>
<thead>
<tr>
<th>Alloy</th>
<th>Temper</th>
<th>Thickness</th>
<th>Minimum Ultimate Tensile Strength</th>
<th>Minimum Yield Strength</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Welded Condition</td>
<td>Unwelded Condition</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>N/mm²  kgf/mm²  psi</td>
<td>N/mm²  kgf/mm²  psi</td>
</tr>
<tr>
<td>5083</td>
<td>O</td>
<td>Up to 38 mm (1.5 in)</td>
<td>275  28.1  40000</td>
<td>125  12.6  16000</td>
</tr>
<tr>
<td></td>
<td>H116</td>
<td>Up to 38 mm (1.5 in)</td>
<td>275  28.1  40000</td>
<td>215  21.8  31000</td>
</tr>
<tr>
<td></td>
<td>H321</td>
<td>Up to 38 mm (1.5 in)</td>
<td>275  28.1  40000</td>
<td>215  21.8  31000</td>
</tr>
<tr>
<td>5086</td>
<td>H112</td>
<td>Up to 12.5 mm (0.5 in)</td>
<td>240  24.6  35000</td>
<td>125  12.6  16000</td>
</tr>
<tr>
<td></td>
<td>H116</td>
<td>Up to 25.5 mm (1.0 in)</td>
<td>240  24.6  35000</td>
<td>110  11.2  16000</td>
</tr>
<tr>
<td></td>
<td>H32</td>
<td>Up to 50.0 mm (2.0 in)</td>
<td>240  24.6  35000</td>
<td>195  19.7  28000</td>
</tr>
<tr>
<td></td>
<td>H34</td>
<td>Up to 50.0 mm (2.0 in)</td>
<td>240  24.6  35000</td>
<td>195  19.7  28000</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Up to 25.0 mm (1.0 in)</td>
<td>240  24.6  35000</td>
<td>235  24.0  34000</td>
</tr>
<tr>
<td>5454</td>
<td>H32</td>
<td>Up to 50.0 mm (2.0 in)</td>
<td>215  21.8  31000</td>
<td>180  18.3  26000</td>
</tr>
<tr>
<td></td>
<td>H34</td>
<td>Up to 25.0 mm (1.0 in)</td>
<td>215  21.8  31000</td>
<td>200  20.4  29000</td>
</tr>
<tr>
<td>5456</td>
<td>H116</td>
<td>Up to 30.0 mm (1.25 in)</td>
<td>290  29.5  42000</td>
<td>230  23.2  33000</td>
</tr>
<tr>
<td></td>
<td>H116</td>
<td>Up to 38 mm (1.5 in)</td>
<td>290  29.5  42000</td>
<td>215  21.8  31000</td>
</tr>
<tr>
<td></td>
<td>H32</td>
<td>Up to 12.5 mm (0.5 in)</td>
<td>290  29.5  42000</td>
<td>230  23.2  33000</td>
</tr>
<tr>
<td></td>
<td>H321</td>
<td>Up to 38 mm (1.5 in)</td>
<td>290  29.5  42000</td>
<td>215  21.8  31000</td>
</tr>
</tbody>
</table>

**Extrusions**

<table>
<thead>
<tr>
<th>Alloy</th>
<th>Temper</th>
<th>Minimum Ultimate Tensile Strength</th>
<th>Minimum Yield Strength</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Welded Condition</td>
<td>Unwelded Condition</td>
</tr>
<tr>
<td></td>
<td></td>
<td>N/mm²  kgf/mm²  psi</td>
<td>N/mm²  kgf/mm²  psi</td>
</tr>
<tr>
<td>5083</td>
<td>O</td>
<td>275  28.1  40000</td>
<td>110  11.2  16000</td>
</tr>
<tr>
<td></td>
<td>H112</td>
<td>275  28.1  40000</td>
<td>110  11.2  16000</td>
</tr>
<tr>
<td>5086</td>
<td>O</td>
<td>240  24.6  35000</td>
<td>95   9.8   14000</td>
</tr>
<tr>
<td></td>
<td>H112</td>
<td>240  24.6  35000</td>
<td>95   9.8   14000</td>
</tr>
<tr>
<td>5456</td>
<td>O</td>
<td>290  29.5  42000</td>
<td>130  13.4  19000</td>
</tr>
<tr>
<td></td>
<td>H111</td>
<td>290  29.5  42000</td>
<td>180  18.3  26000</td>
</tr>
</tbody>
</table>

### TABLE 4.2
Properties of Steels

<table>
<thead>
<tr>
<th>Grade</th>
<th>Minimum Ultimate Tensile Strength</th>
<th>Minimum Yield Strength</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N/mm²  kgf/mm²  psi</td>
<td>N/mm²  kgf/mm²  psi</td>
</tr>
<tr>
<td>A</td>
<td>400  41  58,000</td>
<td>235  24  34,000</td>
</tr>
<tr>
<td>AH32</td>
<td>470  48  68,000</td>
<td>315  32  46,000</td>
</tr>
<tr>
<td>AH36</td>
<td>490  50  71,000</td>
<td>355  36  51,000</td>
</tr>
</tbody>
</table>

 SECTION 4 | 2 Materials
be deducted from the actual thicknesses to determine the effective thicknesses.

**Composites Differing from Basic Laminate** Where bi-directional reinforced-plastic laminates other than the basic are to be used, the appropriate verified minimum mechanical properties are to be used in the scantling equations. These properties of the laminate and lay-up details as indicated in 1.9 are to be indicated on the drawings.

**Laminates Utilizing Uni-directional Reinforcing Materials** Where uni-directional reinforcing materials are employed, a sufficient balance of properties in the warp and fill directions is to be maintained to prevent laminate failure in any direction. For uni-directional laminates the ratio of the verified minimum laminate strengths in the fill direction to the verified minimum strength properties in the warp direction are to be not less than the following.

<table>
<thead>
<tr>
<th>Member</th>
<th>Fill Strength/Warp Strength</th>
</tr>
</thead>
<tbody>
<tr>
<td>Panel, aspect ratio = 1.0</td>
<td>0.80</td>
</tr>
<tr>
<td>Panel, aspect ratio ≥ 2.0</td>
<td>0.61</td>
</tr>
<tr>
<td>Stiffening member</td>
<td>0.25</td>
</tr>
</tbody>
</table>

For panels with aspect ratios between 1.0 and 2.0, the factors are to be obtained by interpolation.

The required scantlings of members fabricated with unidirectional materials are to be determined by using the appropriate verified minimum mechanical properties in the scantling equations. The values of \( E_s/F \), \( E_s/T \) and \( E_s/C \) in the fill direction are not to exceed the same ratios in the warp direction.

Where the properties of the finished laminates forming the crown, webs or shell or deck flanges of an internal differ, in the direction of bending stresses, the internal is to meet the requirements of Section 8 at all locations.

Where the arrangement of the layers of uni-directional reinforcement of the laminate and the physical properties of the laminate are such that the laminate meets the definition of a bi-directional laminate it may be considered as such.

The verified minimum mechanical properties of the laminate and lay-up details as indicated in 1.9 are to be indicated on the drawings.

### 4.7 Wood

#### 4.7.1 General

All wood used is to be of the best quality, properly seasoned, clear, free of defects adversely effecting its strength and with the grain suitable for the purpose intended. It is suggested that all wood members, except cold-molded wood laminates coated with resin, be treated with a preservative.

The strength properties for some such woods are given in Table 4.4. Where other woods are to be used, the strength properties are to be based on the recognized national standards.

#### Wood Preservatives

Wood preservatives are to be of an approved type. Consideration should also be given that they do not have a harmful effect on coatings or, where used, on synthetic resins.

Wood encapsulated in FRP or used on cold-molded wood laminate is not to be treated with a preservative of a type that will prevent adhesion of polyester, or other resin, where used.

#### Wood Glues

Wood glues, where used, are to be of a waterproof type having the necessary durability and strength, and are to be mixed and applied in accordance with the manufacturer’s instructions. Attention is to be given to the application which is to be appropriate to the particular species of wood.

#### Encapsulation

Softwoods encapsulated in FRP are considered effective structural materials where used above the waterline; it is recommended they not be used below the waterline, but where used in this location they are to be considered ineffective, nonstructural, core materials.

With the exception of balsa, hardwoods are not to be used as core materials. Encapsulated balsa or plastic foam are to be considered ineffective in resisting bending or deflection.

#### Plywood

Plywood is to be of marine quality and manufactured in accordance with a recognized national standard.

### 4.11 Core Material

The required core thickness may be based on the following minimum shear strengths, provided they are verified by submitted test data.
### Density

<table>
<thead>
<tr>
<th>Material</th>
<th>kg/m³</th>
<th>lb/ft³</th>
</tr>
</thead>
<tbody>
<tr>
<td>Balsa, end-grain</td>
<td>128</td>
<td>8</td>
</tr>
<tr>
<td>Balsa, end-grain</td>
<td>144</td>
<td>9</td>
</tr>
<tr>
<td>Polyvinyl chloride, cross-linked</td>
<td>80</td>
<td>5</td>
</tr>
<tr>
<td>Polyvinyl chloride, cross-linked</td>
<td>100</td>
<td>6.25</td>
</tr>
<tr>
<td>Polyvinyl chloride, linear</td>
<td>80–90</td>
<td>5–6</td>
</tr>
</tbody>
</table>

### Minimum Ultimate Shear Strength

<table>
<thead>
<tr>
<th></th>
<th>N/mm²</th>
<th>kgf/mm²</th>
<th>psi</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1.9¹</td>
<td>0.19¹</td>
<td>270¹</td>
</tr>
<tr>
<td></td>
<td>2.1¹</td>
<td>0.21¹</td>
<td>300¹</td>
</tr>
<tr>
<td></td>
<td>1.0 to 1.2</td>
<td>0.10 to 0.12</td>
<td>145 to 171</td>
</tr>
<tr>
<td></td>
<td>1.4 to 1.5</td>
<td>0.14 to 0.15</td>
<td>200 to 217</td>
</tr>
<tr>
<td></td>
<td>1.2</td>
<td>0.12</td>
<td>169</td>
</tr>
</tbody>
</table>

**Note:**

1. These values are for Ecuadorian balsa.

Where test data is not available for cross-linked polyvinyl chloride, the lower shear strength value of the range is to be used.

Where the core materials given above have different minimum shear strengths than indicated, the different minimum shear strengths may be used to determine the required thickness, provided the minimum shear strengths are verified by submitted test data.

Core materials other than indicated above will be subject to special consideration.

**4.13 Fastenings**

Mechanical fastenings are to be of materials suitable for the service intended and are to be either galvanically compatible with the materials being fastened or provided with the necessary insulation. Brass fastenings are not to be used. Noncorrosive-resistant ferrous fastenings are to be galvanized. Fastenings used with aluminum alloys are to be austenitic corrosion-resistant (stainless) steel or of a suitable aluminum alloy.
TABLE 4.4
Properties of Various Woods

<table>
<thead>
<tr>
<th>Common Name of Species</th>
<th>Specific Gravity</th>
<th>Modulus of Rupture N/mm²</th>
<th>kgf/mm²</th>
<th>psi</th>
<th>Modulus of Elasticity N/mm²</th>
<th>kgf/mm²</th>
<th>psi</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ash, White</td>
<td>0.60</td>
<td>106</td>
<td>10.87</td>
<td>15400</td>
<td>12.0 × 10⁶</td>
<td>1228</td>
<td>1.74 × 10⁶</td>
</tr>
<tr>
<td>Cedar, Alaska</td>
<td>0.44</td>
<td>76</td>
<td>7.84</td>
<td>11100</td>
<td>9.79 × 10⁶</td>
<td>1002</td>
<td>1.42 × 10⁶</td>
</tr>
<tr>
<td>Cedar, Western Red</td>
<td>0.32</td>
<td>52</td>
<td>5.30</td>
<td>7500</td>
<td>7.65 × 10⁶</td>
<td>733</td>
<td>1.11 × 10⁶</td>
</tr>
<tr>
<td>Elm, American</td>
<td>0.50</td>
<td>81</td>
<td>8.33</td>
<td>11800</td>
<td>9.24 × 10⁶</td>
<td>964</td>
<td>1.34 × 10⁶</td>
</tr>
<tr>
<td>Elm, British</td>
<td>0.56</td>
<td>41</td>
<td>4.24</td>
<td>6000</td>
<td>7.65 × 10⁶</td>
<td>783</td>
<td>1.11 × 10⁶</td>
</tr>
<tr>
<td>Elm, Rock</td>
<td>0.63</td>
<td>102</td>
<td>10.45</td>
<td>14800</td>
<td>10.6 × 10⁶</td>
<td>1087</td>
<td>1.54 × 10⁶</td>
</tr>
<tr>
<td>Fir, Douglas</td>
<td>0.48</td>
<td>86</td>
<td>8.75</td>
<td>12400</td>
<td>13.5 × 10⁶</td>
<td>1376</td>
<td>1.95 × 10⁶</td>
</tr>
<tr>
<td>Mahogany, Central and South America</td>
<td>—</td>
<td>80</td>
<td>8.19</td>
<td>11600</td>
<td>10.4 × 10⁶</td>
<td>1066</td>
<td>1.51 × 10⁶</td>
</tr>
<tr>
<td>Oak, English</td>
<td>0.70</td>
<td>66</td>
<td>6.78</td>
<td>9600</td>
<td>10.0 × 10⁶</td>
<td>1023</td>
<td>1.45 × 10⁶</td>
</tr>
<tr>
<td>Oak, White</td>
<td>0.68</td>
<td>105</td>
<td>10.73</td>
<td>13200</td>
<td>12.3 × 10⁶</td>
<td>1256</td>
<td>1.78 × 10⁶</td>
</tr>
<tr>
<td>Pine, Longleaf Yellow</td>
<td>0.59</td>
<td>100</td>
<td>10.24</td>
<td>14500</td>
<td>13.7 × 10⁶</td>
<td>1398</td>
<td>1.98 × 10⁶</td>
</tr>
<tr>
<td>Pine, Oregon</td>
<td>0.48</td>
<td>86</td>
<td>8.75</td>
<td>12400</td>
<td>13.5 × 10⁶</td>
<td>1376</td>
<td>1.95 × 10⁶</td>
</tr>
<tr>
<td>Pine, Western</td>
<td>0.38</td>
<td>67</td>
<td>6.85</td>
<td>9700</td>
<td>10.1 × 10⁶</td>
<td>1031</td>
<td>1.46 × 10⁶</td>
</tr>
<tr>
<td>Pine, White</td>
<td>0.35</td>
<td>59</td>
<td>6.07</td>
<td>8600</td>
<td>8.55 × 10⁶</td>
<td>875</td>
<td>1.24 × 10⁶</td>
</tr>
<tr>
<td>Spruce, Sitka</td>
<td>0.40</td>
<td>70</td>
<td>7.20</td>
<td>10200</td>
<td>10.8 × 10⁶</td>
<td>1108</td>
<td>1.57 × 10⁶</td>
</tr>
<tr>
<td>Teak</td>
<td>0.63</td>
<td>88</td>
<td>9.04</td>
<td>12800</td>
<td>12.4 × 10⁶</td>
<td>1271</td>
<td>1.80 × 10⁶</td>
</tr>
<tr>
<td>Tensile Strength</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Perpendicular to Grain</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Compressing Strength</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Parallel to Grain</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Values given are adjusted for 12% moisture content.
SECTION 5
Fabrication and Quality Control

5.1 Steel and Aluminum

The requirements of this Guide apply to all-welded yachts; workmanship is to be of good quality. In general, the welding for steel yachts is to comply with Section 23 of the "Rules for Building and Classing Steel Vessels Under 61 Meters (200 ft) in Length" and for aluminum yachts with Section 30 of the "Rules for Building and Classing Aluminum Vessels."

5.3 Reinforced Plastic

5.3.1 General
The use of fabricating procedures differing from those in this Guide will be specially considered.

5.3.2 Fabrication Procedures

a General The laminate is to be fabricated by the contact or hand-layup process for either single-skin or sandwich construction. Other methods of fabrication will be subject to consideration. The resin gel time used in production is to be within the limits recommended by the resin manufacturer.

b Laminate Layup A layer or ply of reinforcing material may consist of a number of pieces. The pieces are to be lapped along their edges and ends. The width of each lap is to be not less than 50 mm (2 in.). Unless otherwise specifically approved, no laps in the various plies of a laminate are to be closer than 100 mm (4 in.) to each other.

Transitions in laminate thickness are to be tapered over a length not less than three times the thickness of the thicker plate. A gradual transition in fiber reinforcement is to be provided between bi-directional and uni-directional laminates.

c Sandwich Panel Layup Sandwich panels may be laminated with cores that are either effective in resisting bending and deflection (e.g., plywood) or are essentially ineffective in resisting bending and deflection (e.g., balsa wood and plastic foam).

Cores are to be effectively bonded to the skins. Joints in core materials are to be scarfed and bonded, or connected by similar effective means.

In way of mechanically connected structures, gear, and equipment, sandwich panels with ineffective cores are to be fitted with inserts of an effective material or a single skin laminate is to be used. The inserts are to be bonded to the skins or faces of the sandwich and to the adjacent ineffective sandwich.

The ply of skin laminate in contact with each face of a core material is to be chopped-strand mat. The mat is to be thoroughly impregnated with resin and the core is to be coated with resin before layup. The use of plies other than chopped strand mat adjacent to the core will be approved with due consideration being given to the adhesive used to bond the ply to the core.

d Secondary Bonds The final ply of laminate along the bond line of the cured laminate preferably is to be chopped-strand mat. The bonding surfaces are to be fresh and free from wax, grease, dirt and dust. The first ply of the secondary layup is to be chopped-strand mat.

5.3.3 Facility Requirements

a Storage Area The area used for storage of resins and reinforcements is to be cool, dry, and clean. The materials are to be sealed and maintained within the temperature and humidity limits recommended by the material manufacturers until shortly before the materials are to be used. The shelf lives specified by the material manufacturers are not to be exceeded.

b Laminating Area The laminating area is to be fully enclosed, shaded from the sun, dry, clean, and adequately ventilated and lighted. The temperature in the area is to be maintained between 16C and 32C (60F and 90F). If the temperature is consistently above 32C (90F), the material manufacturers are to be consulted for special recommendations.

5.3.4 Quality Control

a General A quality-control system is to be set up in accordance with a process description. The objective of the system is to measure and record compliance with approved plans and the process description. Quality-control records are to be carefully kept, and are to be available at all times for review and routine verification by the Surveyor to the Bureau. Prior to conducting the tests described in 5.3.6, the dates of the tests are to be given to the Surveyors by the builder.

b Receiving As all materials are received by the builder, they are to be inspected by the builder to assure conformance with the builder's purchase orders, which in turn are to reflect the material specifications in the approved plans and the process description.

c Gel Time The builder is to establish and implement a resin gel-time control system for the gel-time desired in production. This gel time is to be within the gel-time upper and lower limits recommended by the resin manufacturer. Resin mixes are to be monitored to assure proper gel times.
During layup the temperature in the laminating area is to be recorded at regular intervals, and the catalyst and gel time are to be adjusted to suit changing conditions.

d **Laminate Proportions** The quantities of resin and reinforcement going into a laminate are to be monitored and recorded.

5.3.5 **Visual Inspection**
A constant visual inspection of the laminating process is to be maintained by the builder. If improper curing or blistering of the laminate is observed, immediate remedial action is to be taken.

Defects are to be assessed using a recognized national standard. Defects deemed by the Surveyor to be repairable without affecting the serviceability of the laminate may be rectified; methods used to make the repairs are to be acceptable to the Surveyor.

5.3.6 **Tests**

a **Barcol Hardness** Prior to removal from the mold each laminate is to be checked with a Barcol hardness tester to determine the degree of cure. The Barcol hardness number of the cured laminate, measured on the surface without the gel coat, is to be not less than 40.

b **Burnout and Thickness** The builder is to conduct and record the results of a predetermined, significant number of burnout tests and thickness checks on cutouts or plugs that have been removed from laminates to make way for through-hull and through-deck fittings. Each burnout test is to be made on a sample that is at least 25 mm (1 in.) in diameter.

Additionally, when deemed necessary by the Surveyor, a visual inspection of the residue may be required to determine the types and the number of layers of reinforcement used in the laminate.

c **Laminate Properties** Laminate properties derived from qualification testing of sample panels, which are to be witnessed as necessary by the Surveyor are to be included in the process description. In series production, maintenance of laminate quality in yachts subsequent to the prototype yacht is to be demonstrated by an approved method of assembling and testing panels, in accordance with the following frequency schedule or as required by the Surveyor.

<table>
<thead>
<tr>
<th>Frequency of Testing</th>
<th>L &lt; 9.15m</th>
<th>9.15m ≤ L &lt; 12.2m</th>
<th>12.2m ≤ L &lt; 15.2m</th>
<th>15.2m ≤ L &lt; 18.3m</th>
<th>18.3m ≤ L &lt; 21.3m</th>
<th>21.3m ≤ L &lt; 24.4m</th>
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<td>30ft ≤ L &lt; 40ft</td>
<td>40ft ≤ L &lt; 50ft</td>
<td>50ft ≤ L &lt; 60ft</td>
<td>60ft ≤ L &lt; 70ft</td>
<td>70ft ≤ L &lt; 80ft</td>
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<td></td>
<td>Every 12th yacht</td>
<td>Every 10th yacht</td>
<td>Every 8th yacht</td>
<td>Every 6th yacht</td>
<td>Every 4th yacht</td>
<td>Every other yacht</td>
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<td>L ≥ 80ft</td>
<td>L ≥ 80ft</td>
<td>L ≥ 80ft</td>
<td>L ≥ 80ft</td>
<td>L ≥ 80ft</td>
<td>L ≥ 80ft</td>
</tr>
</tbody>
</table>

5.5 **Wood**

5.5.1 **Facility Requirements**
The construction area is to provide the hull, during construction, suitable protection from weather and climate that may have an adverse effect on the strength of the hull. For cold-molded wood laminate the hull frame mold is to be clean and free of grease, dirt or other substances harmful to the strength or quality of the hull.

5.5.2 **Fabrication Procedures**
The wood is to be clean and dry and areas to be connected free of dust and grease. The moisture content of the wood at the time of gluing or application of resin is to be neither less than 7% nor more than 16% and the variation in moisture content of the laminates is not to exceed 5%. Sufficient pressure is to be applied to obtain thin, uniform effective joints. Workmanship is to be of a good quality.

a **Carvel Construction** In single planking carvel construction the planks, with the grain running parallel to the length of the plank, are to be parallel to the longitudinal axis in association with transverse floors, frames and beams. The floors, frames and beams are to be effectively attached to the planking.

b **Cold-molded Wood Laminate Construction** In cold-molded wood laminate construction there are, in general, to be at least three layers of wood, of thickness generally not greater than ½ the laminate thickness or 4.5 mm (⅛ in.) whichever is the lesser, with the wood grain running parallel to the length of the layer. Each layer is to be coated on the facing surfaces with resin or glue. The floors, frames and beams are to be effectively attached to the cold-molded wood laminate plating.

1. The wood layers are to be placed on the mold at about 45 degrees to the longitudinal axis of the hull with alternate layers parallel to each other and adjacent layers perpendicular to each other. Using this method of construction, the framing is in general to be longitudinal see also 8.3.1.

2. Alternatively where the inner wood layers are fabricated in accordance with 5.5.2b1, each of the two outer wood layers, provided they are parallel to the longitudinal axis of the hull, may be placed at 45 degrees to the adjacent inner layer. This form of construction in general is to be in association with transverse floors, frames and beams and in such cases special consideration may be given to a reduction in the laminate thickness required by this Guide. However special consideration will have to be given to the effective width of laminate to be used in calculating the geometric properties of stiffening member which with this construction will be less than 3.54.

SECTION 5 | 2 Fabrication and Quality Control
## TABLE 5.1
Tests for Mechanical Properties of F.R.P. Laminates

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<thead>
<tr>
<th>Item</th>
<th>Property</th>
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<tr>
<td>Single Skin</td>
<td>Flexural Strength</td>
<td>ANSI/ASTM D 790</td>
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<td></td>
<td>Flexural Modulus</td>
<td>ANSI/ASTM D 790</td>
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<tr>
<td></td>
<td>Tensile Strength</td>
<td>ANSI/ASTM D 638 or ASTM D 3039</td>
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<tr>
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<td>Tensile Modulus</td>
<td>ANSI/ASTM D 638 or ASTM D 3039</td>
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<td></td>
<td>Compressive Strength</td>
<td>ANSI/ASTM D 695 or ASTM D 3410</td>
</tr>
<tr>
<td></td>
<td>Compressive Modulus</td>
<td>FTMS 406 1041</td>
</tr>
<tr>
<td></td>
<td>Shear Strength, Perpendicular to Warp</td>
<td>FTMS 406 1041</td>
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<tr>
<td></td>
<td>Shear Strength, Parallel to Warp</td>
<td>ASTM D 3846</td>
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<td>Interlaminar Shear Strength</td>
<td>ASTMC 273</td>
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<tr>
<td>Core</td>
<td>Shear Strength</td>
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<td></td>
<td>Shear Modulus</td>
<td>ASTMC 393</td>
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<tr>
<td></td>
<td>Tensile Strength, Facings</td>
<td>ASTMC 393</td>
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<tr>
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<td>Compressive Strength, Facings</td>
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<td>Structural Test</td>
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<td></td>
<td>Shear Strength, Composite</td>
<td>ASTMC 393</td>
</tr>
<tr>
<td></td>
<td>Bond Strength, Core to Facings</td>
<td>ASTMC 393</td>
</tr>
</tbody>
</table>
SECTION 6
Details and Fastenings

6.1 Details

6.1.1 General
Where frames, beams and stiffeners are intercostal at an intersecting member the connections are to provide continuity of strength; where frames, beams and stiffeners stop at an intersecting member the end connection is to develop the strength of the member and provide end fixity.

Care is to be taken to ensure structural continuity and to avoid sharp corners and abrupt changes in section and shape; the toes of brackets are not to terminate on unstiffened plate panels.

Compensation may be required in way of openings.

6.1.2 Aluminum and Steel
Openings are to be arranged clear of concentrated loads or high shearing forces; beam slots in girders and transverses in such locations are to be fitted with collars. The edges of thick insert plates are to be tapered at their butt-welded connection to thin plating.

In aluminum construction, where bimetallic connections are unavoidable, suitable insulation is to be provided. It is recommended that where in direct contact with aluminum, wood is to be coated with a suitable paint.

6.1.3 Fiber-Reinforced Plastic (FRP)
All exposed edges of FRP laminates are to be sealed with resin. Edges of sandwich panels and edges of holes in sandwich panels are to be sealed with resin impregnated mat. Ferrules installed in sandwich panels or in stiffeners for drains or wire penetrations are to be set in bedding compound.

Piping and wiring passing through foam-filled spaces is to be installed in plastic tubing to facilitate removal and replacement.

Frames, girders, beams and stiffeners may be entirely of FRP, FRP laid over nonstructural cores or forms, or composites of FRP and other approved structural materials such as plywood or wood. Where forms are neither structural nor as indicated in 4.11, the proportions of these members are to comply with the following requirements. $F$ is to be not less than $0.2h$ or 50 mm (2 in.) whichever is greater, but need not be greater than $6t$, where this value is greater than 50 mm (2 in.); for half-round stiffeners, the inside radius or 50 mm (2 in.) whichever is greater.

$W_c$ is not to exceed $18Kn_t$.

$h$ is not to exceed $30Kn_t$.

where

\[ K = \sqrt[3]{\frac{E_c}{1.0 \times 10^6}} \sqrt[4]{17000/C \text{ US units}} \]

$E_c = \text{minimum compressive modulus of the laminate in kip/mm}^2$ (psi)

$C = \text{minimum compressive strength of the laminate in kip/mm}^2$ (psi)

$F, W_c, h, t_n, \text{ and } t_9$ are as indicated in Figure 3.1.

The webs and crowns of frames, beams or stiffeners encapsulating effective wood or plywood cores or having other effective cores as indicated in 4.11 may have a minimum thickness of 3 mm (0.125 in.), however the thickness of the flanges is to be no less than 0.033 times the height of stiffener web.

Where frames, beams or stiffeners are constructed by laying FRP over pre-molded FRP forms, the forms may be considered structurally effective if their mechanical properties are no less than the overlay laminates. Pre-molded stiffeners are to be bonded to the plating laminate with FRP boundary angles. The joints in premolded stiffeners are to be scarped and spliced or otherwise reinforced to maintain the full strength of the stiffener. Encapsulated wood or plywood is to comply with 4.7 and 4.9.

Where bulkheads, bunks, shelves, or other structurally effective components are glassed-in to provide structural support for the shell or deck plating, they are in general to be glassed-in on both sides and the thickness, strength and overlap of the tapes or angles are to provide strength and stiffness equivalent to the shell or deck laminates to which they are being attached. Where it is impractical to glass-in from both sides, special consideration will be given to glassing-in from one side only, provided the strength and stiffness of the connection are adequate.

6.1.4 Wood
All edges of plywood, including in way $r^c$ cut-outs, are to be effectively sealed by glues, resin, paint or other suitable composition. The faying surfaces of frames, beams, stiffeners etc. are to be treated with wood preservative.

6.3 Fastenings

6.3.1 Keel Bolts
Keel bolts are to be of an approved corrosion resistant material; the nuts, washers and other fittings are to be either of the same material as the bolts or of materials that are compatible with the bolt material. Doublers and brackets may be required in way of the bolt connections.
to transmit the loads to the floors or girders or both. The keel bolts are to be spaced longitudinally so that the weight of the keel is uniformly distributed onto the bolts. In aluminum hulls the bolts, nuts, washers, etc. are to be suitably insulated. The bolts are to be effectively secured into the keel, by nuts bearing on substantial backing plates or by the use of J bolts, or by other effective means.

The diameter, \( d_k \), at the bottom of the thread of each keel bolt is to be not less than obtained by the following equation.

\[
d_k = \sqrt{\frac{2.55 \cdot W_i \cdot Y_i}{\sigma_y \cdot \sum \ell_i}} \text{ mm or in.}
\]

where

\( W_i \) = total weight of the ballast keel in N(kgf, lbf)
\( Y_i \) = vertical distance in mm or in. from the center of gravity of the keel to the bearing surfaces at the bolt connection
\( \sigma_y \) = minimum yield strength of the keel bolt material in N/mm² (kgf/mm², psi) but is not to be taken greater than 50% of the minimum specified tensile strength of the keel bolt material.
\( \sum \ell_i \) = summation of transverse distances at each bolt from the center of the bolt on one side of the keel to the edge of the keel on the other side, in mm or ins.

Where there are fewer bolts on one side of the keel, the summation of distances is to be measured from the centerlines of the bolts on that side. In the case of centerline bolts only, the summation is to be of the distances measured on one side from the centerline of the bolts to the edge of the keel.

Where the keel is raked aft so that the keel LCG is significantly aft of the center of the keel bolt connection system, consideration is to be given to the additional torsional moment on the keel bolts.

The bearing surfaces between the bottom of the canoe hull and the top of the keel are to be of a hard material that will not deform under the bearing loads.

Shear and primary stresses in the keel bolts under the following grounding loads acting separately are not to exceed the grounding design stresses given below.

**Grounding Loads:**

1. Load as indicated below acting along the centerline of the yacht at the bottom leading edge of the keel.

For \( L_{WL} \geq 20m \) (66 ft); \( 3F_a \)

For \( L_{WL} \leq 10m \) (33 ft); \( 1.5F_a \)

Linear interpolation is to be used to determine grounding loads for vessels with intermediate values of \( L_{WL} \).

2. Load of \( 1.5F_a \) acting upward on the bottom of the keel.

**Grounding Design Stresses:**

Shear stress - \( 0.75\tau_y \)
Primary stress - \( 0.75\sigma_y \)

where

\( L_{WL} \) = length on the maximum estimated displacement waterline. See Figure 2.1.
\( F_a \) = force corresponding to the maximum displacement of the yacht
\( \tau_y \) = as defined above
\( \sigma_y \) = minimum shear yield strength of the material

6.3.2 Chain Plates
Chain plates are to be of mild steel, stainless steel, monel or aluminum, or other approved material. Bolts are to be of a compatible, approved, corrosion resistant material. Where aluminum chain plates are used, stainless steel sleeves are to be fitted in the bolt holes.

The chain plates are in general to be slotted through the deck, and effectively attached to bulkheads, webs or brackets.

Substantial reinforcement of the deck structure is to be provided in way of the chain plates in the form of bulkheads or web frames.

6.3.3 Other Fastenings
Components may be mechanically fastened by corrosion resistance metal fastening spaced and arranged to ensure an effective joint. The size, type, arrangement and material of the fastenings are to comply with good practice and are to be submitted for review. Washers or backing plates are to be fitted under all fastening heads and nuts. The bolts, washers, backing plates and fittings are to be of compatible material. Where chemically incompatible, suitable insulation is to be provided. Where watertight joints are required, suitable sealants or bedding compounds are to be used.

With FRP sandwich construction, low density core materials are to be replaced with structurally effective inserts in way of bolted connections and fittings. The insert is to be effectively bonded to the laminate skins and to the adjacent low density core. Alternatively a single skin laminate of the same thickness as the sandwich laminate may be used in way of fastenings.

In wood construction, where screws are used, they are to be secured into the frame, beam, etc. for a distance not less than the thickness of the plating.
7.1 Aluminum, Steel, and Cold-molded Wood Laminate
In general, the structural arrangement for aluminum and steel hulls is to be as given in 8.1.1 and for cold-molded wood as given in 8.3.1. The thickness of the shell, deck and bulkhead plating is to be not less than given by the following equation,

\[ t = sc \sqrt{\frac{pk}{\sigma_s}} \text{ mm (in)} \]

where
- \( s \) = the spacing, in mm or in., of the shell longitudinal, deck longitudinal, transverse frame, deck beam or bulkhead stiffener or other supporting member; where the plating is curved it is the chord length distance between the two supporting members.
- \( p = 0.01 \text{ Fh (0.001 Fh, 0.44 Fh)} \)
- \( h = \) the design head, in m or ft., given in Table 7.1
- \( F = \) the design head reduction factor given in Table 7.4 for shell plating and in Table 7.5 for deck plating, \( F_h \) is in general not to be taken as less than \( D \) (see 2.5) for the bottom shell, nor less than 0.80 for the side shell plating
- \( k = \) the coefficient varying with plate panel aspect ratio given in Table 7.3 but, unless specially approved otherwise, not to be taken as less than 0.5 for cold-molded wood laminate
- \( \sigma_s = \) the design stress, in N/mm² (kgf/mm², psi) as given in Table 7.2.
- \( c = (1-A/s), \) the correction factor for curved plating but is not to be taken less than 0.70.
- \( A = \) the distance in mm or in., measured perpendicular from the chord length \( s \) to the highest point of the curved plating arc between the two supporting members.

Changes in plating thickness are to be gradual and the need for continuity of overall strength is to be considered. Where closely spaced stiffening members are fitted for local reinforcement, such as floors in the glass area of the hull, or stringers in the slamming area, the plating thickness is in general not to be reduced locally for the lesser spacing.

Where the frame spacing is such that the cold-molded wood laminate thickness can be relatively light for local strength, consideration is to be given to the hull-girder strength of the yacht.

The bottom shell thickness is to be increased in way of the keel for the extent shown, and using the heads given in Figures 7.1 and 7.2.

After all other requirements are met the thickness for steel is, in general, to be not less than \( s/115 \), or 2.5 mm (0.1 in.) whichever is greater and for aluminum in general, the thickness is to be not less than \( s/100 \) or 2.5 mm (0.1 in.) whichever is greater. Special consideration will be given to minimum thicknesses for transversely framed hulls.

7.3 Fiber-Reinforced Plastic

7.3.1 Single-skin Laminate
In general, the structural arrangement is to be as given in 8.1.2a. The thickness of the shell, deck and bulkhead plating is to be not less than given by the following equations.

\[ a \quad t = sc \sqrt{\frac{pk}{\sigma_s}} \text{ mm (in.)} \]

\[ b \quad t = 0.75 sc \sqrt{\frac{pk_1}{0.02 E}} \text{ mm (in.)} \]

where \( h, \sigma_s, \) and \( c \) are as defined in 7.1.

- \( s = \) the spacing, as defined in 7.1 or the unsupported width, in mm or in., of the laminate panel between supporting structure such as structurally effective, glassed-in bulkheads, bunks, shelves, etc.
- \( P = 0.01F_h (0.001F_h, 0.44F_h) \)
- \( F = \) the design head reduction factor given in Table 7.4 for shell plating, and in Table 7.5 for deck plating.

In equation \( a, \) \( F_h \) is not in general to be taken less than \( D \) (see 2.5) for the bottom shell nor less than 0.50 for the side shell plating.

In equation \( b, \) \( F \) is not in general to be taken less than 0.5 for the bottom and side shell plating.

- \( k = \) the coefficient varying with the plate panel aspect ratio as shown in Table 7.3, not to be taken less than 0.5 for uni-directional laminates
- \( k_1 = \) the coefficient varying with the plate panel aspect ratio as shown in Table 7.3, not to be taken less than 0.028 for uni-directional laminates

\( E = \) the minimum flexural modulus of the laminate in N/mm² (kgf/mm², psi)

Where uni-directional laminates are used for the deck or shell, the warp, or axis containing the greater reinforcement, is in general to run in a forward and aft direction. In addition the warp, or axis containing the greater reinforcement, is in general, to be perpendicular to the longest edge of the laminate panel, that is, parallel to the distance, \( s \).

Special consideration will be given to other arrangements.
The bottom shell thickness is to be increased for the extent shown, and using the design heads given on Figures 7.1 and 7.2. In addition, the thickness of the bottom shell extending over the length of the keel attachment to points 50 mm (2 in) forward and aft of the forward and aft keel bolts, respectively, and 50 mm (2 in) outboard of the bolts is not to be less than the diameter of the keel bolts. Bi-directional laminates are in general to be used. Bi-directional laminates are to be used also in way of local reinforcements for chain plate and other load-carrying fittings. Care is to be taken to provide a gradual transition in fiber reinforcement between bi-directional and uni-directional laminates to avoid abrupt changes in strength and stiffness.

7.3.2 Sandwich Construction

In general the structural arrangement is to be as given in 8.1.2.b. The section modulus and the moment of inertia of the skins about the neutral axis of a strip of sandwich panel 1 cm (1 in) wide are to be not less than given by the following equations.

\[ SM_x = \frac{t_s F}{600T} \text{ cm}^3 \]
\[ SM_y = \frac{t_s F}{600C} \text{ cm}^3 \]
\[ I = \frac{t_s E}{5060E_r} \text{ cm}^4 \]

where

- \( SM_x \) = required section modulus to outer skin for 1 cm (1 in.) width of sandwich laminate
- \( SM_y \) = required section modulus to inner skin for 1 cm (1 in.) width of sandwich laminate
- \( t_s \) = required thickness of single-skin laminate given by equation 7.3.1a, in mm or ins.
- \( F \) = minimum flexural strength used in Table 7.2 to obtain \( \sigma_s \) for use in equation 7.3.1a, to determine \( t_s \) in N/mm² (kgf/mm², psi)
- \( T \) = minimum tensile strength of outer skin, in N/mm² (kgf/mm², psi)
- \( C \) = minimum compressive strength of the inner skin, in N/mm² (kgf/mm², psi)
- \( I \) = required moment of inertia of the skins about the neutral axis of the sandwich, for 1 cm (1 in.) width of sandwich laminate.
- \( t_s \) = required thickness of single skin laminate given by equation 7.3.1b, in mm or ins.
- \( E_r = 0.5 \) (\( E_r + E_v \)).
- \( E \) = minimum flexural modulus used in equation 7.3.1b to determine \( t_s \).
- \( E_s \) = minimum tensile modulus of the inner skin, in N/mm² (kgf/mm², psi)
- \( E_c \) = minimum compressive modulus of the outer skin, in N/mm² (kgf/mm², psi)

In general, the minimum tensile strengths of the outer skin and the inner skin are to be approximately the same. However, special consideration will be given to the use of external and internal skins having different strengths. Where both the inner and outer skins are unusually thin, consideration is to be given to the hull-girder strength of the yacht. In calculating the section modulus and inertia of the sandwich, consideration is to be given where the skins have different tensile moduli or different compressive moduli.

The skins are in general to be bi-directional laminates constructed of either uni-directional or bi-directional layers or a combination of both.

In general, single skin laminate is to be used for the bottom shell in way of the keel; the thickness is in general not to be less than the overall thickness of the adjacent sandwich shell, nor, less than obtained using the design heads given in Figures 7.1 and 7.2 for the extent shown thereon. In addition, the thickness of the bottom shell extending over the length of the keel attachment to points 50 mm (2 in) forward and aft of the forward and aft keel bolts, respectively, and 50 mm (2 in) outboard of the bolts is not to be less than the diameter of the keel bolts. However, special consideration will be given to sandwich construction in way of the keel, provided the inner and outer skins are suitably increased in thickness, a high density core material is used and the keel bolt loads are directly transmitted to, supported by, and effectively distributed into the hull by the floors and side girders.

It is recommended that the required shell reinforcement in way of the keel be extended forward to the mast step structure.

A single skin laminate is to be used for the deck locally in way of the mast; for reinforcement in way of fastenings see 6.3.3.

The thickness of the core and skins are to be not less than given by the following equation.

\[ \frac{d_c + d_s}{2} = n \cdot \frac{F_{hs}}{\tau} \text{ mm (in)} \]

where \( h \) is as defined in 7.1 and \( s \) is as defined in 7.3.1
- \( d_c \) = overall thickness of sandwich, in mm or ins.
- \( d_s \) = thickness of core, in mm or ins.
- \( v \) = the coefficient varying with plate panel aspect ratio given in Table 7.6, inner and outer skins are to be bi-directional laminates.
- \( F_s \) = the design head reduction factor for shell plating given in Table 7.7; for decks given in Table 7.5.
- \( \tau \) = the design stress, in N/mm² (kgf/mm², psi), 0.5 times minimum ultimate shear strength of the core material (see 4.11).
- \( n = 0.01 \) SI units (0.001 metric units, 0.44 ft-in units)

Where honeycomb type core materials are used, the specified cell size and thickness are to be submitted together with the associated specified minimum shear strength in the direction of the two principal axes of the core. Also, structural plans are to indicate the direction of each principal axis with respect to the yacht structure. Required honeycomb core thickness will be given special consideration.
The skin buckling stress, $\sigma_t$, given by the following equation, is not to be less than $1.0C$ in either skin.

$$e \quad \sigma_t = 0.60 \sqrt{E_{CS} E_{CC}} \frac{G_C}{C}$$

where

- $E_{CS} = \text{in plane compressive modulus of the skin in N/mm}^2$ (kgf/cm$^2$, psi)
- $E_{CC} = \text{compressive modulus of the core, in N/mm}^2$ (kgf/cm$^2$, psi), perpendicular to the skins
- $G_C = \text{shear modulus of the core, the lesser value, perpendicular or parallel to the skins in N/mm}^2$ (kgf/cm$^2$, psi)
- $C = \text{minimum compressive strength of the skin in N/mm}^2$ (kgf/cm$^2$, psi)

The weight of reinforcement in the outer skin of shell plating sandwich laminates is not to be less than given in Table 7.8. Special consideration will be given to skin reinforcement weights for panels having cores with densities greater than 80 kg/m$^3$ (5 lbs/ft$^3$), for panels having hybrid outer skins consisting of a combination of any of the fiber reinforcements indicated in Table 7.8 and for panels containing approved reinforcing fibers other than indicated in Table 7.8. For all types of reinforcement, the number of plies of at least 175 g/m$^2$ (5.16 oz/yd$^2$) in the outer skin of shell plating sandwich laminate is to be no less than indicated below. Quadraxial plies of 600 g/m$^2$ (17.7 oz/yd$^2$) or greater will be considered as two plies for the purpose of this requirement.

- 2 plies  $L < 9.15 \text{ m (30 ft)}$
- 3 plies  $9.15 \text{ m (30 ft)} \leq L < 15.2 \text{ m (50 ft)}$
- 4 plies  $15.2 \text{ m (50 ft)} \leq L < 21.4 \text{ m (70 ft)}$
- 5 plies  $21.4 \text{ m (70 ft)} \leq L \leq 24.4 \text{ m (80 ft)}$

where $L$ is as defined in 2.1.

7.5 Wood

7.5.1 Single-skin Carvel Construction

The thickness of the shell and deck plating is to be not less than given by the following equation.

$$t = 1.09|4.2 - 1.13 \sqrt[6]{L}| s \frac{0.001h}{\sigma_t} \text{ mm}$$

$$t = 1.09|4.2 - 0.84 \sqrt[6]{L}| s \frac{0.44h}{\sigma_t} \text{ in.}$$

where $L$ is as defined in 2.1 and $s$, $h$ and $\sigma_t$ are as defined in 7.1.

7.5.2 Multi-skin Carvel Construction

Special consideration will be given to the required thickness where the shell and deck are constructed of two or more skins of planking having glued seams and butts.
### TABLE 7.1
Design Heads for Plating,

**Basic Head:**

\[
h = 3.0d + 0.14L + 1.62m = 3.0d + 0.14L + 5.30\text{ ft}
\]

#### Plating Location

<table>
<thead>
<tr>
<th>Shell below (d + 0.15m, (d + 0.5\text{ ft}))</th>
<th>(0.80h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>at forward end of (L_{03})</td>
<td>(1.20h)</td>
</tr>
<tr>
<td>at (0.05L_{03}) aft of fore end of (L_{03})</td>
<td>(1.20h)</td>
</tr>
<tr>
<td>at (0.35L_{03}) aft of fore end of (L_{03})</td>
<td>(0.70h)</td>
</tr>
</tbody>
</table>

- **Shell above \(d + 0.15m, (d + 0.5\text{ ft})\)**
  - is measured vertically from the underside of canoe hull at its lowest point.
  - \(0.70 \ (h\cdot d\cdot ft)\)
  - \(0.04L + 1.83m\)
  - \(1.98m \text{ but not less than } 1.98L/24 \text{ m}\)
  - \(6.5 \text{ ft but not less than } 6.5L/60 \text{ ft}\)
  - distance from lower edge of bulkhead to main weather deck at centerline, not less than \(1.52m\) (5.0 \text{ ft.})
  - distance to top of tank overflow, not less than \(1.52m\) (5.0 \text{ ft.})

#### Deck

- Main weather deck, cockpit and cabin house front
- Cabin house top, sides and end
- \(0.63 \ (h\cdot d\cdot ft)\)
- \(0.04L + 6.0\text{ ft}\)
- \(1.98m \text{ but not less than } 1.98L/24 \text{ m}\)
- \(6.5 \text{ ft but not less than } 6.5L/60 \text{ ft}\)
- distance from lower edge of bulkhead to main weather deck at centerline, not less than \(1.52m\) (5.0 \text{ ft.})
- distance to top of tank overflow, not less than \(1.52m\) (5.0 \text{ ft.})

#### Bulkheads

- Watertight or structural
- \(0.04L + 0.091m (0.048L + 0.30 \text{ ft.})\)
- \(0.04L + 1.83m\)
- \(1.98m \text{ but not less than } 1.98L/24 \text{ m}\)
- \(6.5 \text{ ft but not less than } 6.5L/60 \text{ ft}\)
- distance from lower edge of bulkhead to main weather deck at centerline, not less than \(1.52m\) (5.0 \text{ ft.})
- distance to top of tank overflow, not less than \(1.52m\) (5.0 \text{ ft.})

#### Tank boundary

**Notes:**

1. Shell design heads between locations given above are to be obtained by interpolation.
2. \(fe\) = local freeboard at location being considered; it is the distance, above the maximum estimated displacement waterline, to the center of the panel or internal being considered.
3. \(d\) = draft as defined in 2.7 except that in calculation of basic head for yachts having \(L > 24m(80 \text{ ft})\), \(d\) is not to be taken as less than \(0.048L + 0.091m (0.048L + 0.30 \text{ ft.})\).

### TABLE 7.2
Design Stress \(\sigma_d\) for Plating

<table>
<thead>
<tr>
<th>Plating</th>
<th>Steel and Aluminum</th>
<th>Reinforced Plastic Single-skin</th>
<th>Cold-molded Wood Laminate</th>
<th>Wood Carvel Construction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shell and Deck</td>
<td>0.60 minimum ultimate tensile strength(^1)</td>
<td>0.5 minimum flexural strength</td>
<td>0.5 modulus of rupture(^3)</td>
<td>0.4 modulus of rupture</td>
</tr>
<tr>
<td>Watertight Bhd</td>
<td>0.75 minimum yield strength(^2)</td>
<td>0.5 minimum flexural strength</td>
<td>0.5 modulus of rupture(^3)</td>
<td>0.4 modulus of rupture</td>
</tr>
<tr>
<td>Tank Bhd</td>
<td>0.75 minimum yield strength(^2)</td>
<td>0.5 minimum flexural strength</td>
<td>0.5 modulus of rupture(^3)</td>
<td>0.4 modulus of rupture</td>
</tr>
</tbody>
</table>

**Notes:**

1. For aluminum, the minimum ultimate tensile strength is for the welded condition.
2. For aluminum, the minimum yield strength is for the unwelded condition at 0.2% offset.
3. For cold-molded wood laminate the modulus of rupture is to be 22% of the values given in Table 4.1. Special consideration will be given to the design stress where the modulus of rupture for cold-molded wood laminate is determined by sample testing. In such cases the modulus of elasticity is also to be determined and the required thickness is also to comply with 7.3.1, equation b.

---

**SECTION 7 | 4 Plating**
### TABLE 7.3
Co-efficients, $K_i$ and $K_i$, for Sub-section 7.1 and Paragraph 7.3.1

<table>
<thead>
<tr>
<th>Panel Aspect Ratio $\ell/s$</th>
<th>$k$</th>
<th>$k_1$</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;2.0</td>
<td>0.500</td>
<td>0.028</td>
</tr>
<tr>
<td>2.0</td>
<td>0.495</td>
<td>0.028</td>
</tr>
<tr>
<td>1.9</td>
<td>0.493</td>
<td>0.027</td>
</tr>
<tr>
<td>1.8</td>
<td>0.491</td>
<td>0.027</td>
</tr>
<tr>
<td>1.7</td>
<td>0.487</td>
<td>0.026</td>
</tr>
<tr>
<td>1.6</td>
<td>0.482</td>
<td>0.025</td>
</tr>
<tr>
<td>1.5</td>
<td>0.474</td>
<td>0.024</td>
</tr>
<tr>
<td>1.4</td>
<td>0.462</td>
<td>0.023</td>
</tr>
<tr>
<td>1.3</td>
<td>0.443</td>
<td>0.021</td>
</tr>
<tr>
<td>1.2</td>
<td>0.414</td>
<td>0.019</td>
</tr>
<tr>
<td>1.1</td>
<td>0.370</td>
<td>0.017</td>
</tr>
<tr>
<td>1.0</td>
<td>0.308</td>
<td>0.014</td>
</tr>
</tbody>
</table>

$k$ may be given by the equation, $k = \frac{0.5}{(1 + 0.623 (z/F)^2)}$

$k_1$ may be given by the equation, $k_1 = \frac{0.028}{(1 + 1.056 (z/F))^2}$

$s$ = the short edge of the plate panel in mm or in., as defined in 7.1 or 7.3.1.

$\ell$ = the long edge of the plate panel in mm or in., as defined in 8.1.3.

Values of $k$ less than 0.5 and $k_1$ less than 0.028 are not applicable to wood construction and are applicable for fiber reinforced plastic only where bi-directional laminates are used.

### TABLE 7.4
Co-efficient $F$, for Shell Plating, for Sub-section 7.1 and Paragraph 7.3.1

**Metric Units**

\[
\frac{s - 254}{54.2L + 556} = C_r
\]

**Inch Ft. Units**

\[
\frac{s - 10}{0.65L + 22} = C_r
\]

<table>
<thead>
<tr>
<th>$C_r$</th>
<th>$F$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0 and greater</td>
<td>0.25</td>
</tr>
<tr>
<td>0.9</td>
<td>0.26</td>
</tr>
<tr>
<td>0.8</td>
<td>0.32</td>
</tr>
<tr>
<td>0.7</td>
<td>0.36</td>
</tr>
<tr>
<td>0.6</td>
<td>0.42</td>
</tr>
<tr>
<td>0.5</td>
<td>0.49</td>
</tr>
<tr>
<td>0.4</td>
<td>0.57</td>
</tr>
<tr>
<td>0.3</td>
<td>0.67</td>
</tr>
<tr>
<td>0.2</td>
<td>0.77</td>
</tr>
<tr>
<td>0.1</td>
<td>0.88</td>
</tr>
<tr>
<td>0.05</td>
<td>0.94</td>
</tr>
<tr>
<td>0 and negative values</td>
<td>1.00</td>
</tr>
</tbody>
</table>

$s$ = spacing in mm or in., as defined in 7.1 or 7.3.1, but is not to be taken as greater than 1270 mm (50 in.)

$L$ = scanning length in m or ft, as defined in 2.1
### TABLE 7.5
Co-efficients \( F \) and \( F_s \), for Deck Plating, for Sub-section 7.1, Paragraph 7.3.1, and Equation 7.3.2d

<table>
<thead>
<tr>
<th>Metric Units</th>
<th>Inch Ft Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>( F ) and ( F_s = 1.0 ) where ( s \leq 254 \text{ mm} )</td>
<td>( F ) and ( F_s = 1.0 ) were ( s \leq 10 \text{ in.} )</td>
</tr>
<tr>
<td>( F ) and ( F_s = 1.102 - 0.0004 s )</td>
<td>( F ) and ( F_s = 1.102 - 0.0102 s )</td>
</tr>
<tr>
<td>( F_{se} = 0.59 )</td>
<td>( F_{se} = 0.59 )</td>
</tr>
<tr>
<td>( F_{se} = 0.59 )</td>
<td>( F_{se} = 0.59 )</td>
</tr>
</tbody>
</table>

\( s \) = spacing in mm or in. as defined in 7.1 or 7.3.1

### TABLE 7.6
Coefficient \( \nu \) for Equation 7.3.2d

<table>
<thead>
<tr>
<th>Panel Aspect Ratio ( \ell/s )</th>
<th>( \nu )</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;2.0</td>
<td>0.500</td>
</tr>
<tr>
<td>1.9</td>
<td>0.499</td>
</tr>
<tr>
<td>1.8</td>
<td>0.499</td>
</tr>
<tr>
<td>1.7</td>
<td>0.494</td>
</tr>
<tr>
<td>1.6</td>
<td>0.490</td>
</tr>
<tr>
<td>1.5</td>
<td>0.484</td>
</tr>
<tr>
<td>1.4</td>
<td>0.478</td>
</tr>
<tr>
<td>1.3</td>
<td>0.466</td>
</tr>
<tr>
<td>1.2</td>
<td>0.455</td>
</tr>
<tr>
<td>1.1</td>
<td>0.437</td>
</tr>
<tr>
<td>1.0</td>
<td>0.420</td>
</tr>
</tbody>
</table>

### TABLE 7.7
Coefficient \( F_s \) for Shell Plating for Equation 7.3.2d

<table>
<thead>
<tr>
<th>SI/Metric Units</th>
<th>Inch Ft. Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>( F_s = 1.017 - 0.00059s )</td>
<td>( F_s = 1.017 - 0.015s )</td>
</tr>
<tr>
<td>( F_{se} = 0.40 )</td>
<td>( F_{se} = 0.40 )</td>
</tr>
<tr>
<td>( F_{se} = 0.40 \ell/24.4 )</td>
<td>( F_{se} = 0.40 \ell/80 )</td>
</tr>
</tbody>
</table>

\( s \) = spacing in mm or in., as defined in 7.1 or 7.3.1.

\( L \) = Scantling length in m or ft as defined in 2.1
## TABLE 7.8
Sandwich Shell Plating Outer Skin—Minimum Weight of Reinforcement

<table>
<thead>
<tr>
<th>Reinforcement Type</th>
<th>Weight Equation</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>E-Glass Reinforcement with Polyester or Vinyl Ester Resin</td>
<td>( W_i = 105L_i + 138 \text{ g/m}^2 )</td>
<td>( W_i = 0.944L_i + 4.08 \text{ oz./yd}^2 )</td>
</tr>
<tr>
<td>S or R-Glass Reinforcement with Epoxy or Vinyl Ester Resin</td>
<td>( W_i = 90.2L_i + 125 \text{ g/m}^2 )</td>
<td>( W_i = 0.813L_i + 3.58 \text{ oz./yd}^2 )</td>
</tr>
<tr>
<td>Kevlar Reinforcement with Epoxy or Vinyl Ester Resin</td>
<td>( W_i = 59.0L_i + 80.2 \text{ g/m}^2 )</td>
<td>( W_i = 0.530L_i + 2.40 \text{ oz./yd}^2 )</td>
</tr>
<tr>
<td>High Strength Carbon Fiber with Epoxy or Vinyl Ester Resin</td>
<td>( W_i = 73.5L_i + 100 \text{ g/m}^2 )</td>
<td>( W_i = 0.664L_i + 2.94 \text{ oz./yd}^2 )</td>
</tr>
</tbody>
</table>

\( W_i = \text{minimum required weight of reinforcement in g/m}^2 \text{ (oz./yd}^2 \) \)

\( L_i = \text{Length L as defined in 2.1 but not to be taken as less than 9.15 m (30 ft.)} \)

Notes:
1. Thicknesses apply where chopped strand mat weight is less than 50% of the total laminate weight.
2. For this material, \( W_i \) is not to be taken as less than 1450 g/m\(^2\) (42.8 oz./yd\(^2\)) for bottom shell nor less than 1250 g/m\(^2\) (36.9 oz./yd\(^2\)) for topsides shell on Whitbread 60 yachts.
3. Ratio of minimum ultimate tensile strength to tensile modulus not less than 0.014.
FIGURE 7.1
Profile at Centerline
SECTION 8

Internals

8.1 Aluminum, Steel and Fiber-Reinforced Plastic

8.1.1 Aluminum or Steel Structural Arrangement

In general the hull is to be longitudinally framed with the deck and shell longitudinals supported by transverse web rings, transverse bulkheads or a combination of both. Provided they are in turn effectively supported and of adequate strength, the vertical boundaries of cabin houses and cockpits may be considered to support plating and internals. Transversely framed hulls in association, as necessary, with longitudinally girders, transverse webs and transverse bulkheads, will also be considered.

Web frames or transverse bulkheads are to be fitted in way of masts and elsewhere, as necessary, where the mast is deck-stepped, special consideration will be given to the deck and internal structure under the mast. Transverse web rings, transverse bulkheads or deep brackets are to be provided as necessary, in way of the chain plates.

Transverse structural bulkheads with large openings are to have scantlings not less than required for internals in the same location.

Floors, in line with transverse webs or transverse frames, are to be fitted in way of the keel; alternatively the floors may terminate on longitudinal girders, extended forward and aft of the keel and supported by deep web rings or transverse bulkheads. Other arrangements for transmitting the keel loads into the hull, such as torsion boxes, will be specially considered.

Care is to be taken to ensure structural continuity and hard spots are to be avoided; by transverse or longitudinal continuity or by other means, the structural arrangement is to provide the internals with end fixity.

8.1.2 Fiber Reinforced Plastic Structural Arrangement

a Single Skin Laminate In general the single skin laminate deck and shell are to be longitudinally framed with the deck and shell longitudinals supported by transverse web rings or transverse bulkheads. Provided they are in turn effectively supported and of adequate strength, the vertical boundaries of cabin houses and cockpits may be considered to support plating and internals. Other internal members such as bunks, bulkheads, shelves, etc. may be considered as internal supporting structures provided they are of an approved material, are of adequate strength and are effectively glassed into the deck or shell and are also effectively glassed into the members that support them. Consideration will be given to transversely framed decks or shell. Depending on shell plating panel size, shell stringers may be required in the slamming area, extending not less than 0.35 \( L_{WL} \) aft from the forward end of the design water line and effectively supported by transverse members.

Web frames or transverse bulkheads are to be fitted in way of masts and elsewhere as necessary; where the mast is deck-stepped, special consideration will be given to the deck and internal structure under the mast. Transverse web rings, transverse bulkheads or deep brackets are to be provided, as necessary, in way of the chain plates.

Transverse structural bulkheads with large openings are to have scantlings not less than required for internals in the same location.

Floors, in line with transverse webs or transverse frames, are to be fitted in way of the keel, alternatively the floors may terminate on longitudinal girders, extended forward and aft of the keel and supported by deep web rings or transverse bulkheads. For small boats without winged or bulbed keels, the floors may be extended outboard and gradually tapered up into the side shell at not less than one half the half-girth from centerline. Care is to be taken to run the floors smoothly into the shell and avoid hard spots. Other arrangements for effectively transmitting the keel loads into the hull will be considered.

Care is to be taken to ensure structural continuity and hard spots are to be avoided; by transverse or longitudinal continuity or by other means, the structural arrangement is to provide the internals with end fixity.

b Sandwich Laminate The sandwich laminate deck and shell are to be stiffened as necessary by transverse web rings or transverse bulkheads, in association as necessary with longitudinal girders and longitudinal or transverse beams or frames. Where the sandwich laminate is stiffened by longitudinal frames, the longitudinal frames are to be supported by transverse web rings or transverse bulkheads. Provided they are of adequate strength and are in turn effectively supported the vertical boundaries of cabin houses and cockpits may be considered to support the deck or shell laminate. Internal members such as bunks, bulkheads, shelves, etc. may be considered as internal supporting structures, provided they are of an approved material, of adequate strength, and are effectively glassed into the shell or deck and into the members supporting them. In general, at least two stringers or longitudinals are to be provided between the bottom at centerline and gunwale in the slamming area, extending not less than 0.35 \( L_{WL} \) aft from the forward end of the design waterline and effectively supported by transverse members.

Transverse rings or transverse bulkheads are to be fitted in way of masts and elsewhere as necessary; where the mast is deck-stepped, special consideration is to be given
to the deck and internal structure under the mast. Transverse web rings, transverse bulkheads or deep brackets are to be provided in way of chain plates.

Transverse structural bulkheads with large openings are to have scantlings not less than required for internals in the same location.

Floors, in line with transverse webs or transverse bulkheads are to be fitted in way of the keel, alternatively the floors may terminate on longitudinal girders, extended forward and aft of the keel and supported by deep web rings or transverse bulkheads. For small boats without winged or bulbed keels, the floors may be extended outward and gradually tapered up into the side shell at not less than one half the half-girth from centerline. Care is to be taken to run the floors smoothly into the shell and avoid hard spots. Other arrangements for effectively transmitting the keel loads into the hull will be considered.

In general, single skin laminate is to be used for the bottom shell in way of the keel; the thickness is in general not to be less than 75% of the overall thickness of the adjacent sandwich shell nor is the thickness to be less than obtained using the design heads given in Figures 7.1 and 7.2 for the extent shown, including a suitable distance outboard of and below the tangent points of the keel to canoe hull radii. Where floors in way of the keel are gradually tapered outboard to provide a smooth transition into the shell or where floors in way of the keel terminate on longitudinal girders, the points of termination of the floors are to be kept suitably clear of the transition of the single skin laminate into the sandwich laminate. Special consideration will be given to sandwich construction in way of the keel, provided the inner and outer skins are suitably increased in thickness, a high density core material is used and the keel loads are directly transmitted to, supported by, and effectively distributed into the hull by the floors and side girders. It is recommended that the required shell reinforcement in way of the keel be extended forward to the mast step structure.

Single skin laminate or laminate with structurally effective cores are to be used in way of load carrying fittings and locally in the deck in way of masts, see also 6.3 for details in way of fastenings.

Care is to be taken throughout to ensure structural continuity and hard spots are to be avoided; by transverse or longitudinal continuity, or by other means, the structural arrangement is to provide the internals with end fixity.

8.1.3 Scantlings
The section modulus of each floor, girder, stringer, longitudinal, frame, beam and stiffening member, in association with the plating to which it is attached, is to be not less than given by the following equation.

\[ SM = \frac{Chs\ell^3}{\sigma_s} + SM_t \text{ cm}^3 \text{ or in}^3 \]

where
\( C = \) for floors at centerline; 1800 (SI), 183 (metric), 141 (ft-in.)
\( = \) for floors at the connection to transverse frames, for girders, stringers transverse frames, shell longitudinals, deck beams and deck longitudinals; 817 (SI), 83.3 (metric), 64 (ft-in)
\( = \) for bulkhead stiffeners; 619 (SI), 63.1 (metric), 48.6 (ft-in)
\( h = \) the design head as given in Table 8.1a in m or ft
\( \ell = \) for floors, the chord length between support points of the transverse side frame or the floor, whichever is greater, in m or ft, see Figures 8.1 and 8.2
\( = \) for transverse side frames, the chord length between support points in m or ft, see Figures 8.1 and 8.2
\( s = \) for girders, stringers, longitudinal frames, beams and bulkhead stiffeners, the length between support points in m or ft
\( \sigma_s = \) the design stress in N/mm² (kgf/mm², psi) as given in Table 8.2
\( SM_t = \) the required increase in section modulus, in cm³ or in³
\( = \frac{NW_Y^t}{n\sigma_s} \text{ cm}^3 \text{ or in}^3 \) for floors and frames in way of the ballast keel
\( \sigma_s = \) the design stress in N/mm² (kgf/mm², psi)
\( N = 1.00 \) at centerline reducing linearly to 0.5 at 3/4 of the girth from the centerline to gunwale and not less than 0.5 from this point to the gunwale
\( W_t = \) the weight of the ballast keel in N (kgf, lbf)
\( Y_t = \) vertical distance from mid-depth of floor at centerline to center of gravity of ballast keel, in m or in
\( n = \) number of floors in way of keel, recommended not less than three.

With transverse framing, the required section modulus of floors is to be as given above, the section modulus of the floor is also not to be less than required above for the frame to which it is attached.

Where the floors in way of keels terminate on girders, the girders are to be appropriately increased for the keel loads.

In addition, for reinforced plastic construction, the moment of inertia of each floor, frame and beam, in association with the plating to which it is attached is not to be less than the following equation.

\[ I = \frac{C_h\ell^4}{1000E} \text{ cm}^4 \text{ or in}^4 \]

where
\( C_h = \) for floors at centerline; 562 (SI), 57.3 (metric), 5.32 (ft-in)
\( = \) for floors at the connection to transverse frames and for girders, stringers, transverse frames, shell longitudinals, deck beams and deck longitudinals; 255 (SI), 26.0 (metric), 2.42 (ft-in)
\( = h, \ell, s\) and \( \sigma_s \) are as defined above

SECTION 8 | 2 Internals
### TABLE 8.1a
Design Heads for Internals

<table>
<thead>
<tr>
<th>Internal</th>
<th>Design Head</th>
</tr>
</thead>
<tbody>
<tr>
<td>a Shell Frames, longitudinals, stringers, girders, transverse webs and floors</td>
<td>$F \times$ design head for the shell plating given in Table 7.1 for the mid-length location of the internal</td>
</tr>
<tr>
<td>b Main Weather Deck, Cockpit, Cabin House Top, Front, Sides and End Beams, longitudinals, traverse webs and girders</td>
<td>$F \times$ design head for the deck, cabin house or cockpit plating given in Table 7.1</td>
</tr>
<tr>
<td>c Bulkhead Stiffeners</td>
<td>Design head given in Table 7.1</td>
</tr>
</tbody>
</table>

See Table 8.1b for values of $F$

### TABLE 8.1b
$F$ for Design Head for Internals

<table>
<thead>
<tr>
<th>Shell Internals</th>
<th>Feet Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\frac{\ell - 0.254}{0.0542L + 0.559} = C_r$</td>
<td>$\frac{\ell - 0.833}{0.0542L + 1.833} = C_r$</td>
</tr>
</tbody>
</table>

**SI/Metric Units**

<table>
<thead>
<tr>
<th>$C_r$</th>
<th>$F$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0 and greater; $\ell \geq 0.054L + 0.813m$</td>
<td>0.25</td>
</tr>
<tr>
<td>$\geq 0.054L + 2.666$ ft.</td>
<td>0.28</td>
</tr>
<tr>
<td>0.90</td>
<td>0.32</td>
</tr>
<tr>
<td>0.80</td>
<td>0.36</td>
</tr>
<tr>
<td>0.70</td>
<td>0.42</td>
</tr>
<tr>
<td>0.60</td>
<td>0.49</td>
</tr>
<tr>
<td>0.50</td>
<td>0.57</td>
</tr>
<tr>
<td>0.40</td>
<td>0.67</td>
</tr>
<tr>
<td>0.30</td>
<td>0.77</td>
</tr>
<tr>
<td>0.20</td>
<td>0.88</td>
</tr>
<tr>
<td>0.10</td>
<td>0.94</td>
</tr>
<tr>
<td>0 or negative; $\ell &lt; 0.254m$</td>
<td>1.00</td>
</tr>
<tr>
<td>0.833 ft.</td>
<td>1.00</td>
</tr>
</tbody>
</table>

Interpolate between tabular values

**Main Weather Deck, Cockpit and Cabin House Internals**

<table>
<thead>
<tr>
<th>$\ell \geq 1.93m$</th>
<th>$\ell \geq 6.33$ ft.</th>
<th>$\ell \leq 0.254m$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\ell \geq 2.264m$</td>
<td>$\ell \leq 0.833$ ft.</td>
<td>$\ell \geq 6.33$ ft.</td>
</tr>
</tbody>
</table>

$E = \text{the modulus of elasticity in N/mm}^2 \ (\text{kgf/mm}^2, \text{psi})$. Where the shell and internal member laminates have different moduli of elasticity, $E$ is the base value used to calculate the moment of inertia of the combined shell and internal member; where the shell and internal member are of the same laminate, $E$ may be taken as the mean value of the tensile and compressive modulii.

In the way of the ballast keel the moment of inertia $I$, in cm$^4$ or in.$^4$, is to be increased in proportion to the increase in required section modulus, where $SM_i$ is obtained using $N = 0.50$.**
### TABLE 8.2
Design Stress $\sigma_n$ for Internals

<table>
<thead>
<tr>
<th>Internal</th>
<th>Steel and Aluminum$^1$</th>
<th>Reinforced Plastic</th>
<th>Non-laminated Wood$^2$</th>
<th>Laminated Wood$^3$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deck beam, deck longitudinal, transverse frame, shell longitudinal web frame, floor or stringer</td>
<td>0.5 minimum ultimate tensile strength</td>
<td>0.5 minimum ultimate strength$^1$</td>
<td>0.375 modulus of rupture</td>
<td>0.42 modulus$^2$ of rupture</td>
</tr>
<tr>
<td>W.T. Bhd stiffener</td>
<td>0.5 minimum ultimate tensile strength</td>
<td>0.5 minimum ultimate strength$^1$</td>
<td>0.375 modulus of rupture</td>
<td>0.42 modulus$^2$ of rupture</td>
</tr>
<tr>
<td>Tk Bhd stiffener</td>
<td>0.32 minimum ultimate tensile strength</td>
<td>0.32 minimum ultimate strength$^1$</td>
<td>0.375 modulus of rupture</td>
<td>0.42 modulus$^2$ of rupture</td>
</tr>
</tbody>
</table>

**Notes:**
1. For aluminum the minimum ultimate strength is for the as-welded condition.
2. To be considered a laminated frame, the grain is to follow the shape of the member.
3. Design stresses given are for construction with the grain parallel to the direction of the bending stress. For cold-molded wood laminate the design stress to the plating is to be given as in Table 7.2.
4. To outer surface of shell, deck or bulkhead use ultimate tensile strength, to inner surface of crown or inner edge of internal, use ultimate compressive strength.

In calculating the section modulus and moment of inertia of FRP internals, consideration is to be given, as necessary where the laminates forming the internal, and the deck or shell plating to which it is attached have different moduli of elasticity. Also, where the laminates of the internal and the plating to which it is attached have different tensile or compressive strengths, care is to be taken that the different design stresses $\sigma_n$ are not exceeded in the different strength laminates.

#### 8.3 Wood, Cold-molded Laminate and Carvel

#### 8.3.1 Cold-molded Laminate Structural Arrangement
In general, the deck and shell are to be longitudinally framed with the longitudinals supported by transverse web rings or transverse bulkheads, and with the laminate construction in accordance with 5.5.2b.1. Provided they are of adequate strength and are in turn effectively supported, the vertical sides of cabin houses and cockpits may be considered to support the deck or shell laminate or internals. Special consideration will be given to transverse framing, see also 5.5.2b.

Transverse web rings or transverse bulkheads are to be fitted in way of masts and elsewhere as necessary; where the mast is deck-stepped special consideration will be given to the deck and internal structure under the mast. Transverse web rings, transverse bulkheads or deep brackets are to be provided in way of chain plates.

Transverse structural bulkheads with large openings are to have scantlings not less than required for internals in the same location.

Floors are to be fitted in way of the keel, in line with transverse web rings; alternatively the floors may terminate outboard on longitudinal girders, with the girders extending forward and aft of the keel and supported by deep web rings or transverse bulkheads. Other arrangements that effectively transmit the keel loads into the hull will be specially considered.

Care is to be taken throughout to ensure structural continuity, hard spots are to be avoided; by transverse or longitudinal continuity, or by other means, the structural arrangement is to provide the internals with end fixity. It is recommended that in way of bulkheads or other similarly rigid supporting structures, the thickness of the laminate be doubled locally to reduce the hard-spot effect.

#### 8.3.2 Carvel Structural Arrangement
With single skin carvel construction the deck and shell are in general to be transversely framed, see also 5.5.2a. Transverse web rings or transverse bulkheads are to be fitted in way of the mast and elsewhere as necessary; where the mast is deck-stepped special consideration will be given to the deck and internal structure under the mast. Transverse web rings, transverse bulkheads or deep brackets, effectively attached to the shell, are to be provided in way of chain plates.

Transverse structural bulkheads with large openings are to have scantlings not less than required for internals in the same location.

Floors are to be fitted in way of the keel in line with the transverse frames. Care is to be taken throughout to ensure structural continuity, by transverse continuity or other means, the structural arrangement is to provide the internals with end fixity.

#### 8.3.3 Scantlings
The section modulus of each floor, frame, beam, shell or deck longitudinal and bulkhead stiffener is to be no less than given by the following equation. For single-skin carvel construction the required section modulus is to be that of the floor, frame, beam or bulkhead stiffener without the plating. With cold-molded wood laminate construction the
section modulus of the floor, frame, beam or bulkhead stiffener may include an effective width of plating as given in 3.5.4.

\[
SM = \frac{Chs\ell^2}{\sigma_s} + SM_t \text{ cm}^3 \text{ or in.}^3
\]

\(C, h, s, \ell\) and \(SM_t\) are as defined in 8.1.3.

\(\sigma_s\) = the design stress in N/mm² (kgf/mm², psi) for single-skin carvel construction, as given in Table 8.2

\(=\) the design stress in N/mm² (kgf/mm², psi) for cold-molded wood laminate construction, as given in Table 8.2 for the required \(SM\) to the extreme fiber of the floor, frame, beam or bulkhead stiffener, for the required \(SM\) to the outer fiber of the cold-molded wood laminate shell or deck plating the design stress is to be as given in Table 7.2.

In calculating the section modulus and moment of inertia of a cold-molded wood internal and the plating to which it is attached, consideration is to be given, as necessary, where the internal and plating are formed of laminates having different moduli of elasticity. Also where the cold-molded wood laminates of the internal and the plating to which it is attached have different tensile or compressive strengths, care is to be taken that the different design stresses, \(\sigma_s\), are not exceeded in the different strength laminates.
FIGURE 8.1
Transverse Section
FIGURE 8.2
Transverse Section
Floor with Horizontal Top
SECTION 9

Rudders, Rudder Supports, and Keels

9.1 Rudder Stocks

9.1.1 Solid Stocks
The rudder stock diameter, \( d \), is to be not less than required by the following equation.
\[
d = \sqrt[3]{\frac{32}{\pi\sigma_r}} (0.5M + 0.5\sqrt{M^2 + 4T^2}) \quad \text{cm or in.}
\]

where
\[
\sigma_r = \frac{U}{1.75} \quad \text{or} \quad Y, \text{ whichever is lesser, for metals}
\]
\[
= \frac{U}{2.33} \quad \text{or} \quad \frac{Y}{1.33}, \text{ whichever is lesser, for other accepted materials}
\]

\( U \) = the minimum ultimate tensile strength of the material in N/cm² (kgf/cm², psi)
\( Y \) = the minimum yield strength of the material in N/cm² (kgf/cm², psi)
\( M \) and \( T \) = respectively the bending moments and torques, in N-cm (kgf-cm, lbf-in) imposed on the rudder stock, determined as given in 9.1.3 and 9.1.4

Changes in rudder stock diameter are to be gradual; notches are to be avoided.

9.1.2 Tubular Stocks
Where tubular stocks are fitted, the outer and inner diameters, \( d_o \) and \( d_i \), are to comply with the following equation.
\[
d = \sqrt[3]{\frac{d_o^3 - d_i^3}{d_o^{1/3}}} \quad \text{cm or in.}
\]

where
\( d \) = the required diameter of solid stock given in 9.1.1 in cm or in.
\( d_o \) = the required external diameter of stock in cm or in.
\( d_i \) = the required internal diameter of stock in cm or in.

The wall thickness of tubular stock is also to provide adequate local strength for the loads imposed at the lower end of the neck bearing.

9.1.3 Spade Rudders
The bending moment and torque to be used in 9.1.1 are given by the following equation.
\[
M_s = P \left( h_b - h + h_c \right) \quad \text{N-cm (kgf-cm, lbf-in)}
\]
\[
T_s = P \ell_c \quad \text{N-cm (kgf-cm, lbf-in)}
\]
\[
P = k CL_{wl} AN \quad \text{N (kgf, lbf)}
\]

where
\( M_s \) = the bending moment at the neck bearing in N-cm (kgf-cm, lbf-in)
\( T_s \) = the torque at the neck bearing in N-cm (kgf-cm, lbf-in)
\( k \) = 984 (SI), 100.4 (metric), 6.25 (lbf-in)
\( \ell_c \) = 0.33\ell - x_t \ell_c \text{, is not to be taken as less than 0.125\ell}
\( \ell \) = the horizontal length of the rudder in cm or in. at the centroid of the total projected area of the rudder, see Figures 9.1 and 9.1a
\( x_t \) = the distance in cm or in. at the same position, from the leading edge of the rudder to the centerline of the rudder stock, see Figures 9.1 and 9.1a
\( C \) = the lift co-efficient of the rudder and is to be taken as 1.5 for rudders having both \( \frac{h_b}{\ell} \) between 2 and 6 and \( \frac{W}{\ell} \geq 0.06.

\( h_b \) = the vertical distance from the top of the rudder at the center of the stock to becentroid of area of the blade. For trapezoidal profile rudders, \( h_b \) may be taken as \( [h + (\ell_c + 2\ell_d)]/(3(\ell_c + \ell_d)) \). See Figures 9.1 and 9.1a.

\( h_c, h_b, h, \ell_c \), and \( \ell_d \) are the distances in cm or in. as indicated in Figures 9.1 and 9.1a
\( L_{wl} \) = as defined in 2.1
\( A \) = the total projected area of rudder in m² or ft²
\( W \) = maximum width in cm or in. of ... rudder at \( \ell \)

\[ N = 1.0; \quad \text{where} \quad \frac{\Delta}{(0.01L_{wl})^3} \geq 4304 \text{ SI/metric units} \]
\[ \frac{\Delta}{(0.01L_{wl})^3} \geq 120 \text{ inch ft units} \]
\[ \frac{\Delta}{(0.01L_{wl})^3} \leq \frac{0.0265L_{wl}}{\sqrt{\ell^2}} \quad \text{where} \quad \frac{\Delta}{(0.01L_{wl})^3} < 4304 \text{ SI/metric units} \]
\[ \frac{\Delta}{(0.01L_{wl})^3} \leq \frac{0.00243L_{wl}}{\sqrt{\ell^2}} \quad \text{where} \quad \frac{\Delta}{(0.01L_{wl})^3} < 120 \text{ inch ft units} \]
\[ \Delta = \text{maximum estimated displacement, in metric tons or long tons} \]

The required rudder stock diameter at and in the neck bearing is to be obtained from 9.1.1 using \( M_s \) and \( T_s \) for \( M \) and \( T \) respectively. Above the neck bearing the required rudder stock diameter is to be obtained using \( T_s \) and a value of \( M \) reducing linearly from \( M_s \) at the top of the neck bearing to zero at the rudder carrier bearing.

Below the neck bearing the required stock diameter may be gradually reduced but at a distance 0.2h from the bottom of the rudder it is to be no less than 0.46 times the required diameter at the neck bearing.

### 9.1.4 Semi-spade Rudders

The bending moment and torque to be used in 9.1.1 are given by the following equation.

\[
M_s = \frac{F_1h_c^2}{2} \quad \text{N-cm (kgf-cm, lb-in)}
\]

\[
M_s = \frac{F_1(h_b^2 - h_c^2)(1 + \frac{x}{2} + \frac{h_c}{h_b})}{1 + x \left( 1 + \frac{h_c}{h_b} \times \frac{I_x}{I_x} \times \frac{E_x}{E_c} \right)} \quad \text{N-cm (kgf-cm, lb-in)}
\]

\[
x = \frac{h_c}{3I_x/E_{h_c} \frac{E_x}{E_c}}
\]

\[
T_s = \frac{P(A_1 + A_2)}{A(h_b - h_c)} \quad \text{N-cm (kgf-cm, lb-in)}
\]

\[
T_s = \frac{P(A_3 + A_4)}{A \ell_s} \quad \text{N-cm (kgf-cm, lb-in)}
\]

where

\( M_s \) = the bending moment at the pintle, in N-cm (kgf-cm, lb-in)

\( M_s \) = is the bending moment at the neck bearing in N-cm (kgf-cm, lb-in)

\( T_s \) = the torque at the top of the rudder in N-cm (kgf-cm, lb-in)

\( T_s \) = the torque at the pintle in N-cm (kgf-cm, lb-in)

For the above locations see Figure 9.4.

\( \ell_1 \) and \( \ell_2 \) = 0.20\( \ell \) - \( x \), cm or in. but not to be taken as less than 0.125\( \ell \)

\( \ell_3 \) = 0.33\( \ell \) - \( x \), cm or in. but not to be taken as less than 0.125\( \ell \)

\( \ell \) = the horizontal length of the rudder in cm or in. at the centroid of areas \( A_1 \), \( A_2 \), or \( A_3 \) as appropriate and \( x \) is the horizontal distance at the same position from the leading edge of the rudder to the centerline of the pintle.

\( h, h_b, h_c, h_a, h_e \) and \( \ell_a \) are the dimensions in cm or in. as shown on Figure 9.3

\( P \) and \( A \) are as defined in 9.1.3

\( A_1 \), \( A_2 \) and \( A_3 \) are the areas, in m² or ft² as shown on Figure 9.3.

\( I_b \) is the mean moment of inertia in cm⁴ or in⁴ of the upper rudder stock

\( I_a \) is the mean moment of inertia in cm⁴ or in.⁴ of the rudder above the pintle

\( I_a \) is the mean moment of inertia in cm⁴ or in.⁴ of the rudder horn

\( J_a \) is the polar moment of inertia in cm⁴ or in.⁴ of the rudder horn at the support point

\[
= \frac{4 a^2 t}{s} \quad \text{cm}^4 \text{ or in.}^4
\]

\( a \) is the mean horizontal area in cm² or in² enclosed by the outer surface of the rudder horn plating

\( t \) is the mean plate thickness in cm or in. of the rudder horn

\( s \) is the median rudder horn wall circumference in cm or in.

\( \ell_a \) = horizontal distance in cm or in. from center of stock to center of a.

\( E_u \) = flexural modulus of elasticity of the upper stock, in N/cm² (kgf/cm², psi)

\( E_b \) = flexural modulus of elasticity of the lower stock or rudder body, in N/cm² (kgf/cm², psi)

\( G_a \) = shear modulus of the horn in N/cm² (kgf/cm², psi)

\( E_h \) = flexural modulus of elasticity of the horn in N/cm² (kgf/cm², psi)

The required rudder stock diameter at the neck bearing is to be obtained using \( M_s \) and \( T_s \). Above the neck bearing, the required rudder stock diameter is to be obtained using \( T_s \) and a value of \( M \), reducing linearly from \( M_s \) at the neck bearing to zero at the rudder carrier bearing. At the pintle, the required rudder stock diameter is to be obtained using \( M_s \) and \( T_s \). Below the pintle, the required stock diameter may be gradually reduced but at a distance 0.2h from the bottom of the rudder it is to be no less than 0.46 times the required diameter at the neck bearing.

### 9.3 Rudder Structure

Where the rudder stocks do not extend to the bottom of the rudder, the rudder structure in way of the axis of the stock is to have bending and torsional strength, and stiffness no less than required for the stock in the same location, as required in 9.1.3 and 9.1.4; below 0.2h from the bottom of the rudder, the strength and stiffness may be gradually
reduced until at the bottom of the rudder they correspond to that of a stock having a diameter 0.33 times the required stock diameter at the neck bearing. Where rudders are of elliptical profile, the strength and stiffness of the rudder below 0.2h from the bottom of the rudder may be gradually reduced until at a point 0.1h from the bottom of the rudder, they correspond to a stock having a diameter of 0.39 times the required diameter at the neck bearing. Strength and stiffness are to be gradually reduced below from this point to the bottom of the rudder.

Where FRP rudder is unstiffened internally, PVC foam of no less than 64 kg/m³ (4 lbs/ft³) is to be used.

9.5 Rudder Bearings, Pintles and Gudgeons

9.5.1 Rudder Bearings

Rudder bearings are in general to be arranged as shown in Figures 9.1 and 9.3. The neck bearing is to be fitted as near to the top of the rudder as practicable. The bearings are to be adequately supported and effectively attached to the hull.

The bearing pressure on rudder stock and rudder pindle bearings is to be not greater than obtained from the following equation.

\[ p = \frac{R}{A_b} \text{ N/cm}^2 (\text{kgf/cm}^2, \text{psi}) \]

where

\[ p = \text{the allowable bearing pressure in N/cm}^2 (\text{kgf/cm}^2, \text{psi}) \]

\[ R = \text{for spade rudders} \]

- at the carrier bearing is \( R_c = \frac{M_o}{h_b} \text{ N (kgf, lbf)} \)
- at the neck bearing is \( R_n = P + R_c \text{ N (kgf, lbf)} \)

\[ R = \text{for semi-spade rudders} \]

- at the carrier bearing is \( R_c = \frac{M_o}{h_a} \text{ N (kgf, lbf)} \)
- at the neck bearing is \( R_n = P + R_c \text{ N (kgf, lbf)} \)

\[ R_n = R_c(1 + h_j/h_b) + \frac{F_1}{2h_b}(h_b - h_j)^2 - M_o/h_a \text{ N (kgf, lbf)} \]

at the pindle bearing is \( R_p = P + R_c - R_n \text{ (kgf, lbf)} \)

\[ A_b = \text{the bearing area, } d \text{ times the bearing length, in cm}^2 \text{ or in}^2 \]

\[ d = \text{the actual diameter of the rudder stock or pindle in the bearing, in cm or in} \]

\[ P = \text{as defined in 9.1.3} \]

for spade rudders, \( M_o, h_b \) are as defined in 9.1.3 for semi-spade rudders \( M_o, M_p, F_1, h_a, h_b, h_j \) and \( h_o \) are as defined in 9.1.4

In general the length of the bearing is to be not less than 1.20d nor more than 1.5d, where \( d \) is the diameter of the stock or pindle in the bearing. The bushings are to be effectively secured in the bearings. Roller bearings will be specially considered.

9.5.2 Rudder Pintles

Pintles are in general to be cast or forged steel, other bearing materials will be specially considered. In the housing, the length of the pindle is to be not less than 1.2 times the pindle diameter and in the housing, the pindle is to be tapered about 1 in 6 on the diameter. The pindle nut is to be effectively locked to the pindle.

Where sleeves are fitted, they are to be shrunk onto the pindle; other methods of efficiently securing the sleeves will be specially considered.

9.5.3 Pintles, Gudgeons and Housings

Pintles, gudgeons and housings are to have a depth not less than 1.2 times the diameter of the pindle and a thickness outside the bore of not less than 0.5 times the diameter of the pindle. Compliance with this thickness requirement for tapered pindle housings may be based on the thickness outside the bore at the half depth of the housing.

9.7 Rudder Stock Couplings

9.7.1 Bolts

Where bolted rudder stock couplings are used, each coupling bolt is to be of steel or other approved material and is to have a diameter, \( d_b \) at the bottom of the thread not less than the following equation.

\[ d_b = \sqrt{\frac{0.382d^2}{n\pi}} \text{ cm or in.} \]

where

\[ d = \text{the required solid rudder stock diameter in cm or in. obtained from 9.1.1 using the minimum ultimate tensile and minimum yield strengths of the bolt material,} \]

\[ r = \text{the pitch circle radius of the coupling bolts in cm or in.} \]

\[ n = \text{the number of coupling bolts, generally not less than four.} \]

The coupling bolts are to be fitted and coupling bolt nuts are to be effectively locked.

9.7.2 Coupling Flanges

Where bolted rudder stock couplings are used, the flanges are to be of steel or other approved material. Where the flanges are of material having strength properties no less than those of the coupling bolts, the thickness of the coupling flanges is to be not less than \( d_f \) in cm or in. and the minimum width of flange material outside the bolt holes is to be not less than \( \frac{3}{4} d_f \) in cm or in.

9.9 Tillers

Tillers and their connections to the stocks are to have strength equivalent to that required for the rudder stock at the rudder carrier.
9.11 Rudder Horns

The rudder horn is to be of a material having a modulus of elasticity comparable to that of the material of which the rudder stock is made. Special consideration will be given where this is not the case. The rudder horn is to be an integral part of the hull with the rudder horn structure effectively developed into the canoe hull, floors are to be arranged in the hull, in line with those in the horn. The combined stress, \( \sigma_r \) in the rudder horn at any section as determined by the following equation is to be not more than \( \sigma_r \) as defined below.

\[
\sigma_r = 0.5\sigma_b + 0.5\sqrt{\sigma_b^2 + 4\tau^2} \text{ N/cm}^2 \left( \text{kgf/cm}^2, \text{psi} \right)
\]

where

\( \sigma_b = \) combined stress at any horizontal section of the rudder horn.
\( \sigma_r = \) allowable combined stress
  = for metals, \( U/2.1 \) or \( Y/1.2 \) whichever is lesser
  = for other approved materials, \( U/2.8 \) or \( Y/1.6 \) whichever is lesser
\( U = \) minimum ultimate tensile strength of the material in N/cm\(^2\) (kgf/cm\(^2\), psi)
\( Y = \) minimum yield strength of the material in N/cm\(^2\) (kgf/cm\(^2\), psi)
\( \sigma_b = \frac{R_b \times h_b}{SM_b} \text{ N/cm}^2 \left( \text{kgf/cm}^2, \text{psi} \right) \)
\( \tau = \frac{R_b \times \ell_b/2a}{SM_b} \text{ N/cm}^2 \left( \text{kgf/cm}^2, \text{psi} \right) \)
\( R_b = \) the force on the rudder pintle, in N (kgf, lbf) as given in 9.5.1
\( SM_b = \) section modulus of the rudder horn about the longitudinal axis, in \(^2\) or in \(^3\) at the horizontal section being considered
\( t = \) minimum wall thickness of the rudder horn in cm or in. at the section being considered
\( a = \) area in cm\(^2\) or in.\(^4\) enclosed in the horizontal plane by the outside lines of the rudder horn at the section being considered
\( h_b = \) vertical distance in cm or in. from the center of the pintle bearing to the section of the rudder horn at the section being considered
\( \ell_b = \) horizontal distance in cm or in. from the center of the pintle bearing to the center of area of the horizontal plane of the rudder horn at the section being considered

9.13 Keels

As stated in 1.5, this Guide is not intended as a substitute for the independent judgment of professional designers, which judgment covers various aspects not addressed in this Guide. This is particularly appropriate for those aspects of keels and their attachment not addressed in this subsection or elsewhere in this Guide for which the designers are solely responsible.

9.13.1 Continuity

Where fitted, floors within ballast keels and in spacer structure between the ballast keel and the underside of the hull are to be in line with the floors in the hull. Internal load carrying members within the ballast keel are to be aligned and connected with floors in adjacent structure.

9.13.2 Connections

Where fitted, bolts connecting ballast keels or spacer structure to adjacent structures are to be in accordance with 6.3.1. Other types of connections will be specially considered.

9.13.3 Structure

All keel components including spacer structure are to meet the requirements of the following paragraphs. Where lead keels are fitted with wings or bulbs, consideration is to be given to providing internal support.

a. Transverse Load

The shear and primary stresses at any location of the keel structure under the following assumed load are not to exceed the respective allowable stresses given below.

Assumed Load:

- Acting Transversely: Weight of the keel below the section of the keel under consideration acting at its center of gravity.

- Allowable stress:
  - shear stress: \( 0.5\tau \)
  - primary stress: \( 0.5\sigma_r \)

where

\( \sigma_r = \) minimum tensile yield strength of the material but is not to be taken as greater than 70% of the ultimate tensile strength of the material. Where steel is used, \( \sigma_r \) is also not to be taken as greater than 390 N/mm\(^2\) (40 kgf/mm\(^2\), 57,000 psi).

\( \tau = \) minimum shear yield strength of the material but is not to be taken as greater than 40% of the ultimate tensile strength of the material.

b. Grounding Conditions

The shear and primary stresses at any location of the keel structure under the following assumed loads acting separately are not to exceed the respective allowable stresses given below.

Assumed Loads:

- Acting aft: Load as indicated below on the centerline of the yacht at the bottom leading edge of the keel.

  - For \( L_{WL} \geq 20 \text{ m} \) (66 ft.): \( 3F_5 \)
  - For \( L_{WL} \leq 10 \text{ m} \) (33 ft.): \( 1.5F_5 \)
Linear interpolation is to be used to determine Grounding loads for vessels with intermediate values of $L_{ML}$.

<table>
<thead>
<tr>
<th>Acting upward</th>
<th>$1.5F_A$ on the bottom of the keel.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Allowable stress:</td>
<td></td>
</tr>
<tr>
<td>Steel and aluminum</td>
<td>shear stress $0.75\tau_u$</td>
</tr>
<tr>
<td>Fiber Reinforced Plastic</td>
<td>shear stress $0.35\tau_u$</td>
</tr>
</tbody>
</table>

where

- $F_A$ = Force corresponding to the maximum displacement of the yacht.
- $\tau_u$ = minimum ultimate shear strength of the laminate
- $\sigma_u$ = minimum ultimate tensile or compressive strength

of the laminate as appropriate

$\sigma_u$ and $\tau_u$ are as defined in 9.13.3a.

It is recommended that radii or other effective means be provided at the intersection with the canoe hull to avoid hard spots. Buckling strength is also to be considered.

### 9.13.4 Minimum Plate Thickness

The thickness of the keel side, end, and bottom plating is to be sufficient to meet the requirements in 9.13.3, but in no case less than required by equation 7.1 or 7.3.1a using $h$ and $F$ as defined below:

- $h = 0.187LH \text{ m}$
- $0.057LH \text{ ft}$
- but not less than 1.2 times the basic head in Table 7.1.
- $F = 1.0$
- $L$ = length as defined in 2.1
- $H$ = depth of the keel below the underside of the canoe hull in m or ft. see Figure 7.2.
FIGURE 9.1A
Elliptical Profile Spade Rudder
SECTION 10

Closing Appliances for Hull, Decks and Deckhouses

10.1 Hatches and Doors

Exposed hatches and doors are to be of substantial construction, of strength no less than the structure in which the opening is located, and effectively and permanently connected to the adjoining deck or deckhouse structure and provided with adequate, positive, securing devices. Exposed hatches and doors are to open outward unless specially approved otherwise.

The exposed hatches and doors are to be weathertight. All doors are to operable from both sides, as are hatches that are intended for escape purposes.

10.2 Portlights and Windows

Portlights and windows are to be of a type suitable for the location, substantially framed and effectively secured to the hull or deckhouse structure.

Portlights below the weather deck are to be watertight; those in and above the weather deck are to be weathertight.

10.3 Hull-side Valves and Fittings

All sea inlet and overboard discharges are to have shut-off valves or cocks located as close to the shell as practicable and so positioned as to be readily accessible. All shell valves, cocks, inlet chests, distance pieces and other sea connections are to be of suitable corrosion-resistant material or are to be suitably protected against corrosion. Particular attention is to be paid to reinforcement at hull penetration and, in general, hose connections between hull penetrations and shut-off valves or cocks are not to be fitted.
SECTION 11

Surveys After Construction

11.1 Conditions for Surveys after Construction

11.1.1 Damage to the hull or which affects or may affect classification, is to be submitted by the Owners or their representatives for examination by the Surveyor at first opportunity. All repairs, found necessary by the Surveyor, are to be carried out to his satisfaction. Nothing contained in this section or in a rule or regulation of any government or other administration, or the issuance of any report or certificate pursuant to this section or such a rule or regulation, is to be deemed to enlarge upon the representations expressed in 1.1.1 through 1.1.5 hereof and the issuance and use of any such reports or certificates are to be in all respects be governed by 1.1.1 through 1.1.5 hereof.

11.1.2 Notification and Availability of Survey
The Surveyors are to have access to classed yachts at all reasonable times. The Owners or their representatives are to notify the Surveyors on all occasions when a yacht can be examined while out of water in drydock or on a slipway. The Surveyors are to undertake all surveys on classed yachts upon request, with adequate notification, of the Owners or their representatives and are to report thereon to the Committee. Should the Surveyors find occasion during any survey to recommend repairs or further examination, notification is to be given immediately to the Owners or their representatives in order that appropriate action may be taken. The Surveyors are to avail themselves of every convenient opportunity for carrying out periodical surveys in conjunction with surveys of damages and repairs in order to avoid duplication of work.

11.1.3 Biennial Classification Surveys
Biennial Class Surveys of Hull are to be made every two years within three months either way of the anniversary date of the crediting of the previous Special Periodical Survey of Hull or original construction date.

11.1.4 Special Periodical Surveys
Special Periodical Surveys of Hull are to be completed six years after the date of build or after the crediting date of the previous Special Periodical Survey, except as noted below. The interval between Special Periodical Surveys may be reduced by the Committee. If a Special Periodical Survey is not completed at one time, it will be credited as of the completion date of the survey but no later than six years from date of build or from the date recorded for the previous Special Periodical Survey. If the Special Periodical Survey is completed prematurely but within three months prior to the due date, the Special Periodical Survey will be credited to agree with the effective due date. Special consideration may be given to Special Survey requirements in the case of yachts of unusual design, in lay-up or in unusual circumstances. The Committee reserves the right to authorize extensions of Rule required Special Periodical Surveys under extreme circumstances.

11.1.5 Continuous Surveys
At the request of the Owner, and upon approval of the proposed arrangements, a system of Continuous Surveys may be undertaken whereby the Special Periodical Survey requirements are carried out in regular rotation to complete all the requirements of the particular Special Periodical Survey within a six-year period. If the Continuous Survey is completed beyond the six-year period, the completion date will be recorded to agree with the original due date of the cycle. Each part (item) surveyed becomes due again for survey approximately six years from the date of its survey. For Continuous Surveys, a suitable notation will be entered in the Record and the date of completion of the cycle published. If any defects are found during the survey, they are to be dealt with to the satisfaction of the Surveyor.

11.1.6 Lay-up and Reactivation

a The Bureau is to be notified by the Owner that a yacht has been laid-up. This status will be noted in the Record, and surveys falling due during lay-up may then be held in abeyance until the yacht reactivates. Lay-up procedures and arrangements for maintenance of conditions during lay-up may be submitted to the Bureau for review and verification by survey.

b In the case of yachts which have been laid up for an extended period (i.e., six months or more) the requirements for surveys on reactivation are to be specially considered in each case, due regard being given to the status of surveys at the time of the commencement of the lay-up period, the length of the period and the conditions under which the yacht has been maintained during that period.

c Where the lay-up preparations and procedures have been submitted to the Bureau for review and verified by Annual Lay-up Surveys, consideration may be given to deducting part or all of the time in lay-up from the progression of
survey intervals.

d  For yachts returning to active service, regardless of whether the Bureau has been informed previously that the yacht has been in lay-up, a Reactivation Survey is required.

11.1.7 Incomplete Surveys
When a survey is not completed, the Surveyor is to report immediately upon the work done in order that Owners and the Committee may be advised of the parts still to be surveyed.

11.1.8 Alterations
No alterations which affect or may affect classification are to be made to the hull of a classed yacht, unless plans of the proposed alterations are submitted and approved by an ABS Technical Office before the work of alterations is commenced; and such work, when approved, is carried out to the satisfaction of the Surveyor. Nothing contained in this section or in a rule or regulations of any government or other administration, or the issuance of any report or certificate pursuant to this section or such a rule or regulation, is to be deemed to enlarge upon the representations expressed in 1.1.1 through 1.1.5 hereof and the issuance and use of any such reports or certificates are to in all respects be governed by 1.1.1 through 1.1.5 hereof.

d  The following items are to be examined, together with their closing appliances, placed in satisfactory condition and reported upon:

1  Superstructures
2  Hatches
3  Companionways
4  Ventilator and air pipe coamings
5  Skylights
6  Flush deck scuttles
7  All openings in yacht sides including freeing ports.

e  All accessible parts of the steering gear including associated equipment and control systems are to be examined and placed in satisfactory condition. Steering gear to be operationally tested while the yacht is not under way.

f  Anchoring equipment to be examined and placed in satisfactory condition.

11.2 Biennial Surveys
At each Biennial Survey the following items are to be examined and placed in satisfactory condition:

a  The yacht is to be placed in drydock or on a slipway and the keel, stem, stern frame, rudder and outside of side and bottom are to be cleaned as necessary, examined and placed in satisfactory condition together with rudder pintles, gudgeons and their securing arrangements. For those yachts constructed of aluminum, underwater plating in close proximity to dissimilar metal is to be examined both internally and externally as far as practicable. Rudder bearing clearances are to be ascertained and reported upon.

b  The yacht is to be generally examined externally and internally, so far as can be seen, and placed in satisfactory condition.

c  All openings to the sea, including sanitary and other overboard discharges, together with the valves connected therewith, are to be examined internally and externally while the vessel is in drydock; and the fastenings to the shell plating are to be renewed when considered necessary by the Surveyor. For those vessels constructed of aluminum insulating material in joints of shell connections between dissimilar metals is to be examined and renewed if necessary.

c  All decks, casings and superstructures are to be examined. Particular attention is to be paid to the corners of openings and other discontinuities in way of decks and topsides.

e  The interior of the yacht is to be opened out by the removal of lining, ceiling, portable tanks and ballast as may be required by the Surveyor to satisfy himself as to the condition of all parts of the structure. Integral tanks and other spaces including chain lockers are to be cleaned for examination. When examining tanks internally, the Surveyor is
to see that a striking plate or other additional reinforcement is fitted below each sounding pipe.

All integral tanks are to be tested with a head of liquid to the highest point that liquid will rise under service conditions.

Anchor windlass and hawse pipes are to be examined. Anchors and cables are to be ranged and examined.

Exposed hatch covers not fitted with tarpaulins are to be hose tested or otherwise proven weathertight.

All fastenings, including those through the ballast keel are to be hammer tested to ascertain their soundness and drawn for examination as considered necessary by the attending Surveyor.

Wood decks or sheathing are to be examined and the caulking is to be tested and re-caulked as necessary. If decay or rot is found or the wood is excessively worn, the wood is to be renewed. Attention is to be given to the condition of the structure under wood decks, and to fabric deck coverings. If it is found that such coverings are damaged or are not adhering closely to the deck, sections are to be removed as necessary to ascertain the condition of the deck under.

The masts, spars and standing and running rigging are to be examined. Where possible, masts are to be unshipped for survey, failing which the mast wedges are to be removed, the mast examined aloft and special care taken to ascertain that the masts are sound. The whole of the standing rigging, including rigging screws, bolts, pins and fittings, is to be dismantled as considered necessary by the Surveyor. The sails are to be laid out so that they can be properly examined.

Any part of the yacht where wastage is evident or suspect, the Surveyor may require thickness gauging and repair of the affected parts. See Table 11.1

In addition, the following requirements 1 through 4 apply to those yachts constructed of reinforced plastic:

1. The framing and holds, hull laminate of the 'tween deck, deep tanks, peaks, bilges and drain wells, and machinery spaces are to be cleaned and examined. Linings, ceiling, tanks, and portable ballast are to be removed as considered necessary by the attending Surveyor.

2. Where there is evidence of cracking, distortion, wetness, or delamination, destructive or non-destructive testing and removal and repair of the defect is to be carried out to the satisfaction of the attending Surveyor.

3. Engine foundations and their attachment to the hull are to be examined.

4. The hull, fastenings, and backing reinforcements in way of hull fittings and attachments are to be examined. Fastenings are to be withdrawn as considered necessary by the attending Surveyor.

In addition the following requirements 1 and 2 apply to those yachts constructed of wood:

1. Where the planking is sheathed with metal, such portions are to be removed as the Surveyor may direct. If sheathed with reinforced plastics or similar material, the sheathing is to be examined to ensure it is adhering satisfactory and that there is no possibility of water seepage occurring along plank edges.

2. The caulking of the outside and deck planking is to be tested and re-caulked as necessary.

11.3 Special Periodical Survey No. 2

Special Periodical Survey No. 2 is to include compliance with all requirements for Special Periodical Survey No. 1 with those which follow:

a. Yachts of steel or aluminum are to be gauged in accordance with Table 11.1

b. Plating, in way of portlights is to be examined. In this and any other part of the structure where wastage is evident or suspect, the Surveyor may require thickness gauging in order to obtain the actual thickness of material.

c. The anchor cables are to be ranged and examined together with anchors, chain locker, and holds. Chain cables are to be renewed in cases where it is found that the links have been so far worn that their mean diameter is 12% below the original required nominal size.

d. On all yachts fitted with a ballast keel, fastenings are to be drawn for examination as may be required by the Surveyor.

e. If a wood yacht is sheathed with metal, such sheathing as will at least permit an examination of the wood keel, garboards, plank ends, stem and sternpost is to be removed as requested by the Surveyor.

f. In wood yachts, fastenings as may be required by the Surveyor are to be drawn for examination.

11.3 Special Periodical Survey No. 3

Special Periodical Survey No. 3 is to include compliance with all requirements for Special Periodical Survey No. 2. Yachts of steel or aluminum are to be gauged in accordance with Table 11.1.
11.3.4 Special Periodical Surveys No. 4 and 5
There surveys are to be at least as comprehensive as Special Periodical Survey No. 3. Yachts of steel or aluminum are to be gauged in accordance with Table 11.1.

11.3.5 Special Periodical Survey No. 6
This survey is to be at least as comprehensive as Special Periodical Survey No. 4. Yachts of steel or aluminum are to be gauged in accordance with Table 11.1.

11.3.6 Special Periodical Surveys Subsequent to No. 6
These surveys are to be at least as comprehensive as Special Periodical Survey No. 6. Yachts of steel or aluminum are to be gauged in accordance with Table 11.1.
**TABLE 11.1**
Table of Minimum Requirements for Thickness Gauging

<table>
<thead>
<tr>
<th>Special Periodical Survey No. 1</th>
<th>Special Periodical Survey No. 2</th>
<th>Special Periodical Survey No. 3</th>
<th>Special Periodical Survey No. 4 and Subsequent</th>
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</thead>
<tbody>
<tr>
<td>1) Areas considered suspect by the Surveyor, throughout the vessel.</td>
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<tr>
<td>2) Two girth belts of shell and deck within the midship half-length together with internals in way as deemed necessary by the Surveyor.</td>
<td></td>
<td>2) Three girth belts of shell and deck within the midship half-length, together with internals in way.</td>
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<tr>
<td>3) Two wind-and-water strakes, port and starboard, for the midship half-length.</td>
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<tr>
<td>4) All exposed main deck and superstructure deck plating.</td>
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<tr>
<td>5) Flat keel plating full length, plus extensive bottom plating.</td>
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</tr>
</tbody>
</table>
Technical Publications

Requests for publications should be made to
American Bureau of Shipping
Book Order
Two World Trade Center
106th Floor
New York, N.Y. 10048 USA

Classification Register:
RECORD of the American Bureau of Shipping
(annual)

Note: The Record contains only vessels classed by ABS or with an ABS assigned loadline.

Rules for Building and Classing:
Steel Vessels (annual)
CD-ROM Version of Steel Vessels (annual)
Underwater Vehicles, Systems, and Hyperbaric Facilities (1990)
Mobile Offshore Drilling Units (1994) also available on CD-ROM
Steel Barges (1991) also available on CD-ROM
Steel Vessels Under 61 Meters (200 Feet) in Length (1983)
Steel Vessels for Service in Southeast Asia (1982)
Offshore Installations (1983)
Steel Vessels for Service on Rivers and Intracoastal Waterways (1980)
Bulk Carriers for Service on the Great Lakes (1978)
Reinforced Plastic Vessels (1978)
Steel Floating Drydocks (1977)
Aluminum Vessels (1975)
Single Point Moorings (1975)

Rules for:
Certification of Cargo Containers (1987)
Nondestructive Inspection of Hull Welds (1986)

Preliminary Rules for:
Building and Classing Accommodation Barges and Hotel Barges
(May 1989)

Guide for:
Building and Classing Facilities on Offshore Installations (1991)
Building and Classing Undersea Pipeline Systems and Risers (1991)

Strength Assessment of Container Carriers (1991)
Certification of Cranes (1991)
Cargo Vapor Emission Control Systems on Board Tank Vessels (1991)
The Certification of Drilling Systems (1990)
The Use of Refrigerated (Low Pressure) Carbon Dioxide as a Fire Extinguishing Medium on Board Ship (1989)
Building and Classing Fishing Vessels (1989)
Survey Based on Preventative Maintenance Techniques (1987)
The Certification of Offshore Mooring Chain (1986)
Building and Classing Offshore Racing Yachts (1994)
Classing Vessels for Standby Service (1986)
Line-Up and for Reactivation of Laid-Up Ships (1986)
Line-Up and for Reactivation of Mobile Offshore Drilling Units (1986)
Underwater Inspection in Lieu of Drydocking Survey (1986)
Ultrasonic Examination of Carbon Steel Forgings for Tail Shafts (1983)
Building and Classing Fire Fighting Vessels (1981)
Ships Burning Coal (1980)
Repair and Cladding of Shafts (1980)
Burning Crude Oil and Slops in Main and Auxiliary Boilers (1978)
Construction of Shipboard Elevators (1993)
List of Type Approved Equipment (1994)
Notes on Heavy Fuel Oil (1984)
Controlled Atmosphere Systems (1992)
The Fatigue Strength Assessment of Tankers (1993)
One Man Bridge Operated (OMBO) Ship, (1992)
Certification of Oil Spill Recovery Equipment (1993)
Dynamic Based Design and Evaluation of Tanker Structures (1993)
Building and Classing Oil Recovery Vessels (1993)
Dynamic Based Design and Evaluation of Bulk Carrier Structures (1994)

Guidance Manual for:
Preparing Fishing Vessels’ Stability Booklet (1990)
Bronze and Stainless Steel Propeller Castings (1984)

Requirements for:
Certification of Self-Unloading Cargo Gear on Great Lakes Vessels (1991)
Certification of the Construction and Survey of Cargo Gear on Merchant Vessels (1975)

Approved Welding Electrodes, Wire-Flux and Wire-Gas Combinations, with Appendix on Rules for Approval (annual)

Other Publications:
Annual Report
Activity Report (bi-monthly)
Surveyor (quarterly)
International Directory of Offices (semi-annual)