INTLREG
INTERNATIONAL REGISTER OF SHIPPING

RULES FOR CLASSIFICATION OF FRP VESSELS

PART 2
Materials

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CHANGES HISTORY

Refer Part 1 for Changes

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CHAPTER 1 MATERIAL DESCRIPTION AND PROPERTIES

CONTENTS

SECTION 1 GENERAL

Contents

1.1 General

Scantlings obtained from these Rules are applicable to FRP laminates composed of alternate layers of chopped-strand mat and woven roving. Fabrication is to be by the contact or hand-Layup process. Use of materials not specified in these Rules will be subject to special consideration.

Definitions

The following definitions apply throughout these Rules.

- **Length**

  L is the distance in meters or feet on the designed load waterline from the forward side of the bow to the after side of the stern. For planning vessels L is measured in the zero-speed condition.

- **Breadth**

  B is the greatest breadth, excluding appendages, in meters or feet.

- **Depth**

  D is the depth in meters or feet measured at the middle of the length

  L from the rabbet line to top of the freeboard deck at the side of the vessel.

- **Draft for Scantlings**

  D is either the vertical distance in meters or feet measured at the middle of the length L from the rabbet line to the. designed load waterline or 0.66D, whichever is greater.

- **Freeboard Deck**

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

- **Superstructure Deck**

  The superstructure deck is the first deck above the freeboard deck to which the side shell plating extends.

- **Bulkhead Deck**

  The bulkhead deck is the deck to which watertight bulkheads extend.

- **Rabbet Line**

  For the purposes of these Rules, the rabbet line is the line of intersection between the outside of a vessel's bottom and the vessel's keel. Where there is no keel, the rabbet line is the bottom of the vessel.

- **Sheer Line**

For purposes of these Rules, the sheer line is the line of intersection between the side of a vessel and the top of a deck.

- **Displacement Vessel**

For purposes of these Rules, the phrase "displacement vessel" covers all craft in which deflection of the bottom structure due to hydrostatic head is greater than deflection of the bottom structure due to hydrodynamic forces.

- **Planning Vessel**

For purposes of these Rules, the phrase "planning vessel" covers all craft in which deflection of the bottom structure due to hydrodynamic forces is greater than deflection of the bottom structure due to hydrostatic head.

- **Fiberglass-Reinforced Plastic (FRP)**

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

- **Glass**

The fibrous-glass reinforcing material used in FRP vessels is a limealumina- silicate composition having a low alkali content. Included in this category is the material known as E glass.

a. Filament A single, hairlike fiber of glass.

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

c. Chopped-Strand Mat A blanket of randomly oriented chopped-glass strands held together with a binder.

d. Roving A band or ribbon of parallel strands grouped together.

e. Woven Roving A coarse fabric woven from rovings.

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

g. Cloth A thin fabric woven from yarn.

h. Warp The roving or yarn running lengthwise in woven fabric.

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

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

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

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

- **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 semisolid state similar to gelatin in consistency. Not to be confused with gel coat.

i. Gel Time The time required to change a flowable, liquid resin into a nonflowing gel.

j. Inhibitor A material that retards activation or initiation of resin, thus extending shelf life or influencing exothermic heat or gel time.

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

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

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

n. Tack the degree of stickiness of the resin.

o. 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.

- **Laminate**

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

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

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

c. 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.

d. Hand Layup The process of applying to a mold by hand 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.

e. Layup A description of the component materials and geometry of a laminate. Also, a laminate that has been assembled but not cured.

f. 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.

g. Secondary bonding the practice of bonding fresh material to a cured or partially cured laminate.

1.2 Resins

Resins, 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. The properties of a resin, where listed, 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.

Wherever possible, blending of additives and fillers is to be done by the resin manufacturer. Where blending is done by the laminator, the manufacturer's recommendations are to be followed, and blending is to be accomplished carefully and thoroughly in a manner minimizing aeration.

Gel-coat resins are to be compatible with the laminating resins. Color pigments, where added, are not to inhibit cure or affect the properties of the cured system.

1.3 Reinforcing Materials

Fiberglass reinforcing materials are to be as defined in Pt.2-Ch.1-Sc.1/1.3. Binders, where used, are to be soluble polyester resin. Sizes and finishes are to be of the silage type, and are to be compatible with the laminating resins.

SECTION 2 LAMINATES

Contents

2.1 Basic FRP Laminate

All FRP scantling requirements in these Rules are based on a laminate consisting 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.

2.2 Minimum Physical Properties of the Basic Laminate

The basic FRP laminate is to have the following minimum physical properties. Unless otherwise noted, the properties are in the warp direction.

	kg/mm2
Flexural strength	17.5
Flexural modulus	770
Tensile strength	12.6
Tensile modulus	700
Compressive strength	11.9
Compressive modulus	700
Shear strength perpendicular to warp	7.7
Shear strength parallel to warp	6.3
Shear modulus parallel to warp	315
Interlaminar shear strength	0.7

2.3 Exemptions from the Basic Laminate

Gel coats and skin coats of either fiberglass mat weighing less than 300 grams per square meter (1.0 ounces per square foot) or fiberglass cloth of any weight are considered to be nonstructural, and therefore are not to be included when calculating basic laminate scantlings.

2.4 Laminate Thicknesses

All FRP laminate thickness requirements in these Rules 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 thicknesses equal to 0.16 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 have been known to 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 Pt.2-Ch.1-Sc.2/2.3, are to be deducted from the actual thicknesses to determine the effective thicknesses.

2.5 Composites Differing from the Basic Laminate

a. **Plating** Where reinforced-plastic materials other than the basic laminate are used for plating, the thickness is to be increased or may be reduced in accordance with the following equation.

$t_2 = t_1 \sqrt[3]{(770/E)}$ mm

t_2 = thickness of alternate laminate in mm or in.

t_1 = thickness of basic laminate in mm or in.

E = verified flexural modulus of elasticity of alternate laminate in kg/mm2

b. **Stiffeners** Where stiffeners are laminated from reinforced-plastic materials other than the basic laminate, the section modulus and moment of inertia are to be increased or may be reduced in accordance with the following equations.

$SM_2 = SM_1(17.5/u)$ cm3

$I_2 = I_1(770/E)$ cm4

SM_2 = section modulus of alternate laminate

SM_1 = section modulus of basic laminate

I_2 = moment of inertia of alternate laminate

I_1= moment of inertia of basic laminate

u = verified flexural strength of alternate laminate in kg/mm2 or psi

E = verified flexural modulus of elasticity of alternate laminate in kg/mm2 or psi

2.6 Laminates Utilizing Unidirectional Reinforcing Materials

Where unidirectional reinforcing materials are employed, a sufficient balance of properties in the warp and fill directions is to be maintained to prevent laminate failure due to other than primary stresses. The minimum allowable laminate strengths in the fill direction are to be obtained by multiplying the verified minimum laminate strengths in the warp direction by the following factors.

Member	*Fill Strength/Warp Strength*
Panel, aspect ratio = 1.0	0.80
Panel, aspect ratio > 2.0	0.33
Stiffener	0.25

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 multiplying the required scantlings obtained from these Rules by the following factors.

	kg/mm2
Single-skin laminate thickness	√(17.5/F)
Sandwich-panel skin thickness stiffener section modulus	24.5/(T+C)
Stiffener area	7.7/S
Stiffener inertia	770/E

F = verified flexural strength of the unidirectional laminate in kg/mm2

T = verified tensile strength of the unidirectional laminate in kg/mm2

C = verified compressive strength of the unidirectional laminate in kg/mm2

S = verified shear strength of the unidirectional laminate in kg/ m2

E = verified flexural modulus of the unidirectional laminate in kg/mm2

SECTION 3 WOOD

Contents

All wood scantling requirements in these Rules are based on northwest United States coast-region Douglas fir or equal having an average bending modulus of elasticity equal to 1125 kg/mm2 (1.6 x 106 psi) and the following basic allowable design stresses.

	kg/mm2
Extreme fiber in bending	1.41
Compression parallel to grain	1.03

The allowable design stresses and moduli of other woods are listed below.

	Extreme Fiber in Bending		*Compression Parallel to Grain*		*Modulus of Elasticity*	
Species	*kg/mm²*	*psi*	*kg/mm²*	*psi*	*kg/mm²*	*psi x 10⁶*
Ash, white	1.31	1866	1.03	1466	1055	1.5
Cedar, Alaska	1.03	1466	0.75	1066	845	1.2
Elm, American	1.03	1466	0.75	1066	845	1.2
Elm, British	0.70	1000	0.56	800	705	1.0
Elm, rock	1.41	2000	1.12	1600	915	1.3
Mahogany, 560 kg/m^3 ($35 lb/ft^3$) min.	1.64	2330	0.94	1333	915	1.3
Oak, white	1.31	1866	0.94	1333	1055	1.5
Pine, longleaf yellow	1.41	2000	1.03	1466	1125	1.6
Spruce, Sitka	1.03	1466	0.75	1066	845	1.2
Teak	1.05	1500	0.84	1200	1265	1.8

All wood is to be of the best quality, well-seasoned, clear, free of defects adversely affecting its strength, and with grain suitable for the purpose intended.

3.1 Use of Woods Other than Douglas Fir

a. Decking Where a wood other than Douglas fir is used for decking, the thickness is to be increased or may be reduced in accordance with the following equation.

$t2 = t1 \sqrt{(1.41/f_b)}$ mm

t2 = thickness of alternate wood in mm

t1 = thickness of Douglas fir in mm

f_b = extreme fiber in bending of alternate wood in kg/mm2

b. Stiffeners Where a wood other than Douglas fir is used for stiffeners, the section modulus and moment of inertia are to be increased or may be reduced in accordance with the following equations.

$SM_2 = SM_1(1.41/f_b)$ cm3

$I_2 = I_1(1125/E)$ cm4

SM_2 = section modulus of alternate wood

SM_1 = section modulus of Douglas fir

I_2 = moment of inertia of alternate wood

I_1 = moment of inertia of Douglas fir

f_b = extreme fiber in bending of alternate wood in kg/mm2

E = modulus of elasticity of alternate wood in kg/mm2

c. **Stanchions** Where a wood other than Douglas fir is used for stanchions, the permissible load is to be reduced or may be increased in accordance with the following equation.

$W_{a2} = W_{a1}$ (f_c/ 1.03) metric tons

$W_{a2} = W_{a1}$ (f_c /1466) long tons

W_{a2} = permissible load on alternate wood in metric or long tons

W_{a1} = permissible load on Douglas fir in metric or long tons

f_c = compression parallel to grain of alternate wood in kg/mm2

3.2 Wood Preservatives

The treatment of all wood members with preservative is suggested. Wood encapsulated in FRP is not to be treated with a preservative of a type that will prevent adhesion of polyester resin.

3.3 Wood Glues

Wood glues, where used, are to be of a waterproof type. The moisture content of the wood at the time of gluing is to be neither less than 7% nor more than 16%. The variation in moisture content of the lamina is not to exceed 5%. The lamina joining surfaces are to be clean, dry, and free of dust and grease. Sufficient pressure is to be applied to obtain thin, uniform, effective joints.

3.4 Encapsulation

With the exception of balsa, hardwoods are not to be used as core materials. Softwoods encapsulated in FRP are considered to be effective structural materials where used above the waterline. Softwoods used below the waterline should not be encapsulated; where softwoods below the waterline are encapsulated, they are considered to be ineffective, nonstructural materials.

SECTION 4 PLYWOOD

Contents

All plywood scantling requirements in these Rules are based on Exterior or Marine Exterior Douglas fir plywood or equivalent having an average bending modulus of elasticity equal to 1125 kg/mm2 (1.6 X 106 .psi) and an allowable tensile stress in bending equal to 0.70 kg/mm2 (1000 psi).

4.1 Use of Other Plywoods

Where a plywood other than Exterior or Marine Exterior Douglas fir plywood is used, the alternate plywood is to be at least equal in grade to the Douglas fir plywoods.

a. Plating Where a plywood other than Douglas fir plywood is used for plating, the thickness is to be increased or may be reduced in accordance with the following equation.

$t_2 = t_1 \sqrt{(0.70/f_b)}$ mm

t2 = thickness of alternate plywood in mm or in.

t1 = thickness of Douglas fir plywood in mm or in.

fb = allowable tensile stress in bending of alternate plywood in kg/mm2 or psi

b. Stiffeners Where a plywood other than Douglas fir plywood is used for stiffeners, the section modulus and moment of inertia are to be increased or may be reduced in accordance with the following equations.

$SM_2 = SM_1(0.70/f_b)$ cm3

$I_2 = I_1(1125/E)$ cm4

SM2 = section modulus of alternate plywood

SM1 = section modulus of Douglas fir plywood

I_2= moment of inertia of alternate plywood

I_1 = moment of inertia of Douglas fir plywood

fb = allowable tensile stress in bending of alternate plywood in kg/mm2 or psi

E = modulus of elasticity of alternate plywood in kg/mm2 or psi

4.2 Encapsulation

Plywood encapsulated in FRP is considered to be an effective structural material. Where plywood is encapsulated, the thickness of the encapsulated plywood is considered to be the thickness of the plywood plus the encapsulating material.

SECTION 5 CORE MATERIAL

5.1 All core scantling requirements in these Rules are based on materials having the following minimum allowable shear strengths.

	Density		*Shear Strength*	
Materials	*kg/m³*	*lb/ft³*	*kg/mm²*	*psi*
Balsa, end-grain	128	8	0.18	250
Polyvinyl chloride, thermosetting	64	4	0.08	113
Polyvinyl chloride, thermosetting	96	6	0.12	170
Polyvinyl chloride, thermoplastic	80	5	0.07	94
Polyvinyl chloride, thermoplastic	160	10	0.16	231

SECTION 6 METALS

Contents

6.1 Steel

All steel used in vessels built to these Rules and its welding are to comply with the requirements in the "RULES AND REGULATIONS FOR CLASSIFICATION OF STEEL VESSELS".

6.2 Fastenings

Mechanical fastenings are to be of materials suitable for the service intended and are to be galvanically compatible with the materials being fastened. Brass fastenings are not to be used. Non-corrosion-resistant ferrous fastenings are to be galvanized. Fastenings used with aluminum alloys are to be austenitic corrosion-resistant (stainless) steel.

CHAPTER 2 FABRICATION AND QUALITY CONTROL

CONTENTS

SECTION 1 FACILITY REQUIREMENTS

Contents

1.1 General

The use of fabricating procedures differing from those specified in these Rules will be subject to special consideration.

1.2 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.

1.3 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.

SECTION 2 FABRICATION PROCEDURES

Contents

2.1 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 graduated at a pitch sufficient to prevent stress concentrations.

2.2 Sandwich Panel Layup

Sandwich panels may be laminated with cores that either are 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).

Joints in effective core materials are to be scarphed and bonded, or connected by similar effective means. Joints in ineffective core materials may be butted, and the seams need not be bonded.

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

Transitions between sandwich panels and single-skin laminates in general are to be effected by tapering the thickness of the core material to zero at a pitch not greater than 1 in 3.

2.3 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.

SECTION 3 QUALITY CONTROL

Contents

3.1 General

A quality-control system is to be set up in accordance with the process description (1.8). 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 Surveyors. Prior to conducting the tests described in Pt.2-Ch.2-Sc.3/3.6, the dates of the tests are to be given to the Surveyors by the builder.

3.2 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.

3.3 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.

3.4 Laminate Proportions

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

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.

No defects are to be allowed that exceed American Society for Testing Materials (ASTM) Acceptance Level III or equivalent. Defects deemed by the Surveyors 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 Surveyors.

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 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 are to be included in the process description. In series production, maintenance of laminate quality in vessels subsequent to the prototype vessel is to be demonstrated by assembling and testing panels, in accordance with the following frequency schedule or as required by the Surveyors.

Length (L)		
m	*ft*	*Frequency of Testing*
Under 9.1	Under 30	Every 12th vessel
9.1 to 12.2	30 to 40	Every 10th vessel
12.2 to 15.2	40 to 50	Every 8th vessel
15.2 to 18.3	50 to 60	Every 6th vessel
18.3 to 21.3	60 to 70	Every 4th vessel
21.3 to 24.4	70 to 80	Every other vessel
24.4 and over	80 and over	Every vessel

CHAPTER 3 DETAILS AND FASTENINGS

CONTENTS

SECTION 1 GENERAL

Contents

1.1 General

Structural details shown and described in this section are offered for general guidance. Where details differing from those shown are submitted, they will be subject to special consideration.

1.2 Holes And Raw Edges

All exposed edges of FRP single-skin 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 stiffeners for drains or wire penetrations are to be set in bedding compound.

1.3 Piping And Wiring In Foam

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

SECTION 2 STIFFENERS

Contents

2.1 General

Stiffeners (frames, girders, deck beams, bulkhead stiffeners, etc.) used to support FRP panels 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.

2.2 Stiffeners with Hollow or Nonstructural Cores

Unless otherwise specifically approved, stiffeners with hollow cores and stiffeners laid over nonstructural cores or forms, including ineffective wood cores are to conform with Figure 3.8.1, and the widths and heights of the stiffeners are to be not greater than obtained from the following equations.

$w = 20t_1$ *mm or in.* $h = 30t$ *mm or in.*

w = width of stiffener crown in mm or in.

h = height of stiffener webs in mm or in.

t1 = thickness of stiffener crown in mm or in.

t = thickness of stiffener webs and flanges in mm or in.

Hat-section stiffeners constructed by laying FRP over premolded FRP forms (Figure 3.8.2.a) are to conform with Figure 3.8.1 and the above equations; the premolded forms may be considered structurally effective if their physical properties are at least equal to those of the overlay laminates.

Premolded stiffeners bonded to laminates with FRP angles (Figure 3.8.2.b) also are to conform with Figure 3.8.1 and the above equations. The thickness of each bonding angle is to be not less than the thickness of the webs of the stiffener, and the bonding-angle legs are to be of equal length in accordance with Pt.2-Ch.3-Sc.6. Joints in premolded stiffeners are to be scarphed and spliced or otherwise reinforced to maintain the full strength of the stiffeners.

The heights of bottom stringers and girders may exceed the heights obtained from the above equation if these members are stabilized laterally by approved means. The required minimum flange laps on such members, as shown in Figure 3.8.1, if greater than 50 mm (2 in.), need not exceed 6t.

2.3 Stiffeners with Wood or Plywood Cores

The use of encapsulated wood or plywood (Figure 3.8.2.c) is to be in accordance with Pt.2-Ch.1-Sc.3 or Pt.2-Ch.1-Sc.4. FRP webs and crowns encapsulating plywood cores and effective wood cores are not subject to the thickness limitations in Pt.2-Ch.3-Sc.2/2.2. The minimum thickness of the webs and crowns is to be 3 mm (0.125 in.). The widths of the flanges are to conform with Figure 3.8.1. The thicknesses of the flanges are to be not less than obtained from the following equation.

t = 0.033 h mm or in.

t = thickness of stiffener flanges in mm or in.

h = height of stiffener webs in mm or in.

2.4 Stiffeners Used as Girders and Longitudinal Frames

Girders and longitudinal frames are to be continuous through floors and web frames. Except in way of integral-tank end bulkheads, girders and longitudinal frames are to be continuous through transverse bulkheads. An acceptable type of girder and longitudinal-frame FRP connection is shown in Figure 3.8.3. The laps of the connections onto the supporting structure are to be not less than the over-all widths of the structural members including flanges, and the thicknesses of the connections are to be not less than the thicknesses of the structural-member flanges.

SECTION 3 FASTENINGS

Contents

3.1 General

Components may be fastened with bolts, machine screws, self-tapping screws, or rivets. Where machine screws or self-tapping screws are used, they are not to have countersunk heads. Shanks of all threaded fastenings are to be long enough to pass through the joints. Where watertight joints are required, suitable sealants or bedding compounds are to be used in addition to the fastenings.

3.2 Bolts and Machine Screws

Bolts or machine screws are to be used where accessibility permits. The diameter of each fastening is to be at least equal to the thickness of the thinner component being fastened. Bolts and machine screws less than 6.5 mm (0.25 in.) in diameter are not to be used. Where d is the fastening diameter, fastening centers are to be spaced a minimum of 3d apart and are to be set in from edges of laminates a minimum of 3d.

In way of bolts and machine screws, low-density core materials are to be replaced with structurally effective inserts. Diameters of fastening holes are not to exceed fastening diameters by more than 0.4 mm (0.0156 in.).

Washers or backing plates are to be installed under all fastening heads and nuts that otherwise would bear on laminates. Washers are to measure not less than 2.25d in outside diameter and 0.1d in thickness. Nuts are to be either of the self-locking type or peened to prevent backing off.

3.3 Self-tapping Screws

Self-tapping screws having straight shanks may be used for lightly loaded connections where lack of accessibility prohibits the use of through fastenings. Self-tapping screws are not to be used for joining laminates either of which is less than 5 ram (0.1875 in.) thick. Where used, self-tapping screws are to have coarse threads.

3.4 Expanding Rivets

Rivets of the expanding type (blind or "pop" rivets) may be used for lightly loaded connections where lack of accessibility prohibits the use of through fastenings. Such rivets are not to be used for joining components having a total thickness exceeding 12.5 mm (0.50 in.), and are not to be used for joining decks to hulls except as temporary or unstressed fastenings installed for the sake of convenience or speed during assembly.

3.5 Conventional Rivets

Conventional rivets, where used, are to be subject to special consideration, and are to be of the cold-driven type. Washers, essentially of the same material as the rivets, are to be installed under both the heads and the points.

SECTION 4 JOINTS IN WOOD OR PLYWOOD LONGITUDINALS

4.1 Glued joints in wood or plywood girders, shelves, clamps, and other longitudinals are to be scarphed. Bolted joints in wood members are to be scarphed and nibbed, and may be hooked, key-locked, or hooked and key-locked. The slopes of the scarphs are to be not greater than 1 in 12. The depth of each nib and hook and the width and depth of each key are to approximate 25% of the depth of the member (see Figure 3.8.4). In a member having two or more scarphs, the scarphs are to be not less than 1.5 m (5 ft) apart.

In a bolted joint the bolt diameter is to approximate 17% of the width of the member. Each scarph is to be fastened with at least four bolts. Washers, essentially of the same material as the bolts, are to be installed under all bolt heads and nuts. Bolt holes are to be prebored and are to provide neat, smooth, tight fits so bolts can be inserted by tapping lightly.

SECTION 5 FOUNDATIONS

Contents

5.1 Engine Foundations

Engines are to be bedded on strong girders that are efficiently stiffened and supported to resist tripping. The engine beds are to be of thicknesses and widths appropriate to the holding-down bolts, are to be set in mat or resin putty to assure uniform bearing against the girders, and are to be bolted through the webs of the girders. Figure 3.8.5 shows several typical, acceptable engine foundations.

5.2 Power-transmission Units Penetrating Hulls

Mounting systems for power-transmission units penetrating hulls (outdrives, jet-drives, bow thrusters) are to have watertight seals. All transom and hull openings for such units are to be framed and stiffened in such a manner that the structure with the units in place is at least equivalent in strength to the unpenetrated structure.

5.3 Auxiliary Machinery Foundations

Foundations for auxiliary machinery such as generators, refrigeration equipment, and evaporators are to provide for secure attachment of the equipment and are to be rigidly attached to the hull structure.

5.4 Deck Fittings

Deck fittings such as cleats and chocks are to be bedded in sealing compound or gaskets, through-bolted, and supported by either oversize washers or metal, plywood, or wood backing plates. Where washers are used, the laminate in way of the fittings is to be increased at least 25% in thickness.

SECTION 6 BOUNDARY ANGLES

Contents

6.1 FRP to FRP

Secondary bonding of FRP components by means of double boundary angles is to be in accordance with Pt.2-Ch.2-Sc.2/2.3. Typical boundary angles for FRP components are shown in Figure 3.8.6. The thickness of each boundary angle is to be not less than obtained from the following: -

a Single-Skin to Single-Skin One-half the thickness of the thinner of the two laminates being joined

b Sandwich to Sandwich The thickness of one skin of the thinner of the sandwich panels

c Sandwich to Single Skin Either one-half the thickness of the single-skin laminate or the thickness of one skin of the sandwich panel, whichever is less.

The thickness of each FRP-to-FRP boundary angle also is to be not less than obtained from the following.

- Where L as defined in Section 2 is less than 18 m (60 ft), the minimum thickness is to be 4 mm (0.16 in.)
- Where L is 18 m to 27.5 m (60 ft to 90 ft), the minimum thickness is to be 5 mm (0.20 in.)
- Where L is 27.5 m to 36.5 m (90 ft to 120 ft), the minimum thickness is to be 6 mm (0.24 in.)

The width of each flange including end taper is to be not less than 15 times the thickness obtained above.

6.2 Plywood or Wood to FRP

Plywood or wood girders in all vessels and plywood floors and bulkheads in limited-service vessels are to be bedded in foam, a slow-curing polyester putty, a microballoon-and-resin mixture, or other approved material. Boundary angles of FRP are to be applied over fillets made of the bedding material. The nominal size w of each fillet is to be 9.5mm to 12.5mm (0.375 in. to 0.50 in.). The boundary angles are to be at least equal in thickness to one-half the thickness of the laminate, and the width of each flange is to be as shown in Figure 3.8.7.a. Secondary bonding of these angles to FRP is to be in accordance with Pt.2-Ch.2-Sc.2/2.3.

Plywood floors and structural bulkheads in unrestricted-service vessels over 15 m (49 ft.) in length are to be secured with boundary angles and bolts or machine screws as shown in Figure 3.8.7.b. Each boundary angle is to be at least equal in thickness to one-half the thickness of the laminate, secondary-bonded to the laminate, and both bonded and bolted to the plywood. Fastening diameters are to be in accordance with Pt.2-Ch.3-Sc.3/3.2. Where d is the fastening diameter, the minimum width of the boundary-angle bolted flange is to be 6d. The minimum width of the other flange is to be as shown in Figure 3.8.7.b. Bolts are to be single-spaced; the maximum spacing is to be in accordance with Table 3.8.1. Intermediate values may be obtained by interpolation.

SECTION 7 CHAIN PLATES

Contents

7.1 General

Chain plates may be internal or external, but in either case are to be secured to the hull structure with bolts and so-arranged that loads are transmitted to the laminates through shear in the bolts. Where a chain plate penetrates a deck, the penetration is to be made watertight with a flexible sealant. At the time of fastening, each chain plate (except where mounted on an internal plywood bulkhead) is to be set in resin-saturated mat to insure a proper fit.

7.2 Material

Chain plates and bolts are to be made of mild steel, stainless steel, silicon bronze, nickel copper, or other compatible metal having over 16 kg/mm2 (23,000 psi) shear yield strength.

7.3 Bolts

The diameter of the bolts securing chain plates is to be approximately equal to the shell thickness. The shell thickness is to be in accordance with Pt.3-Ch.2-Sc.1/1.2f. Where external bolt heads or nuts are set in counterbores in the shell, additional layers of the laminate are to be added to the interior of the hull to compensate for the counterbores. The added plies are to extend a minimum of 25mm (1.0 in.) all around the chain plate and are to taper beyond that minimum at a rate of 12.5mm (0.5 in.) for each added ply.

The number of bolts in each chain plate is to be not less than obtained from the following equation.

$N = P/6.33d^2$ metric units

N = number of bolts

P = breaking strength of attached shroud or stay in kg or lb

d = diameter of bolts in mm or in.

7.4 Sandwich Panels

Where chain plates are bolted through sandwich panels, low-density core materials are to be replaced with structurally effective inserts. The skin of the sandwich bearing against a chain plate is to be increased in thickness so it approximately equals the diameter of the bolts. The reinforcing plies added to increase the thickness of the skin are to be extended beyond the chain plate in accordance with Pt.2-Ch.3-Sc.7/7.3.

SECTION 8 DECK-TO-HULL JOINTS

Contents

8.1 Weather Joints

Typical acceptable deck-to-hull weather joints are shown in Figure 3.8.8. Where joints differing from those shown are submitted, they will be subject to special consideration.

All joints are to be lapped and bolted unless otherwise specifically approved. Where flanges are used, the hull flanges are to be equal in thickness to the hull laminates and the deck flanges are to be equal in thickness to the deck laminates. Faying surfaces are to be set in bedding compound, polyester putty, or other approved material. Widths of overlaps, bolt diameters, and bolt spacing are to be in accordance with Tables 3.8.1 and 3.8.2. Intermediate values may be obtained by interpolation.

FRP bonding angles, where used, are to have flanges that are at least one-half as thick as the hull or deck laminate, whichever is thicker. The widths of the flanges are to be in accordance with the widths of overlaps in Table 3.8.2.

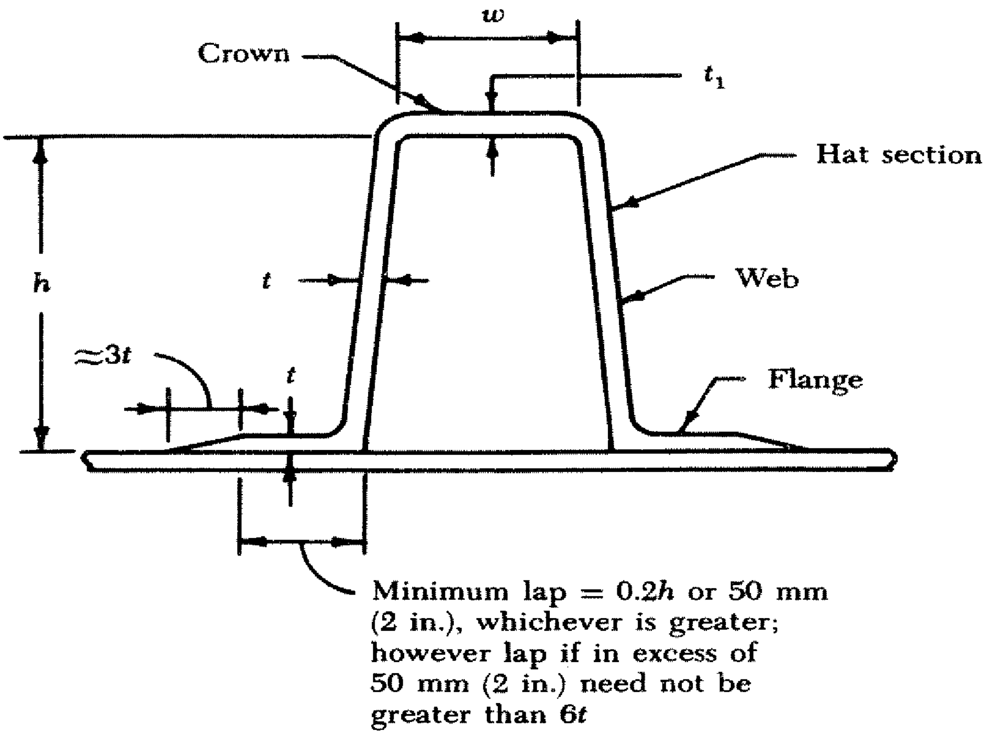
Each joint is to be protected by a guard, molding, fender, or rail cap of metal, wood, rubber, plastic, or other approved material. The size and ruggedness of this protective strip are to be consistent with the severity of the service for which the vessel is intended. The strip is to be installed in such a manner that it may be removed for repair or replacement without endangering the integrity of the deck-to-hull joint.

8.2 Interior Joints

Interior decks are to be attached to hulls by shelves, stringers, or other structural devices that resist vertical and horizontal loads.

FIGURE 3.8.1

Proportions of Stiffeners



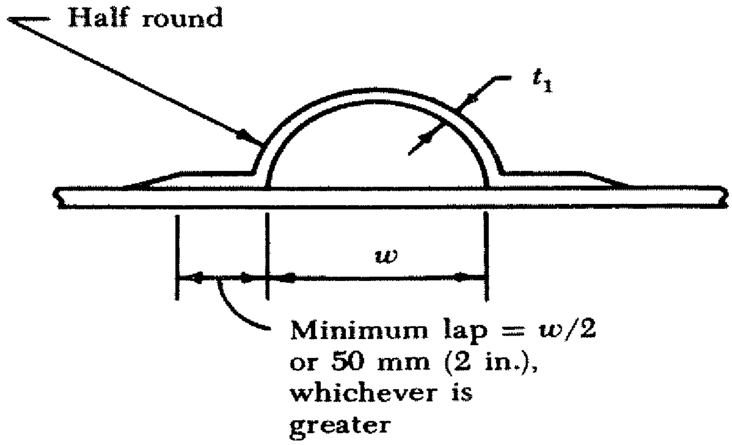
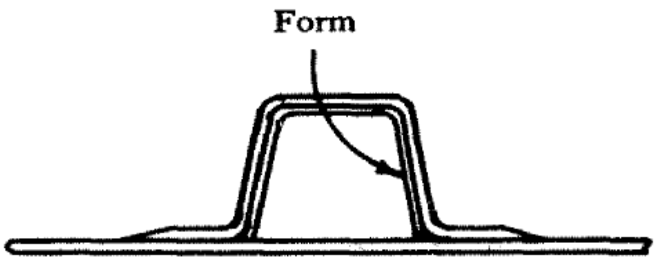
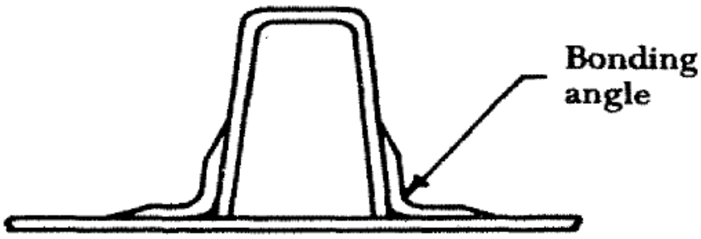


FIGURE 3.8.2

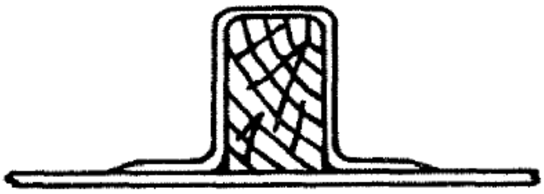
Stiffener Variations



a Premolded
FRP form



b Premolded
stiffener



c Encapsulated
wood or plywood

FIGURE 3.8.3

Connection of Longitudinals to Transverses

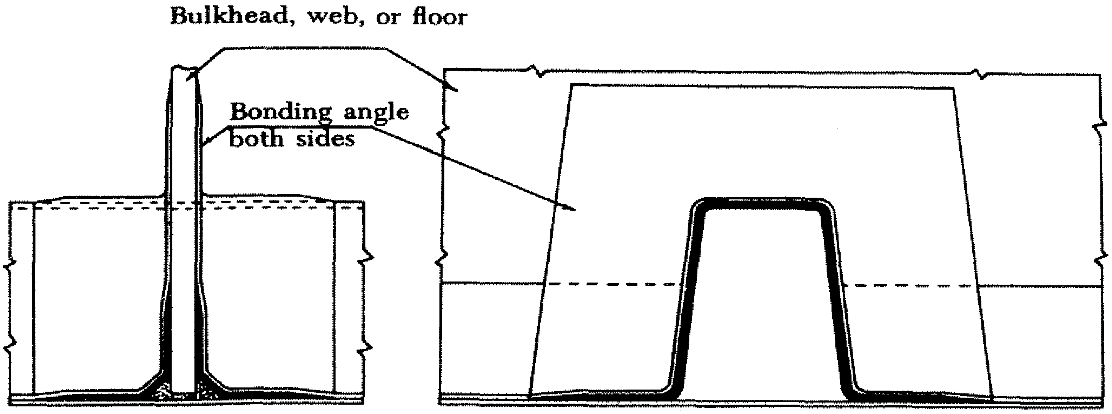


FIGURE 3.8.4

Bolted Scarph Joints

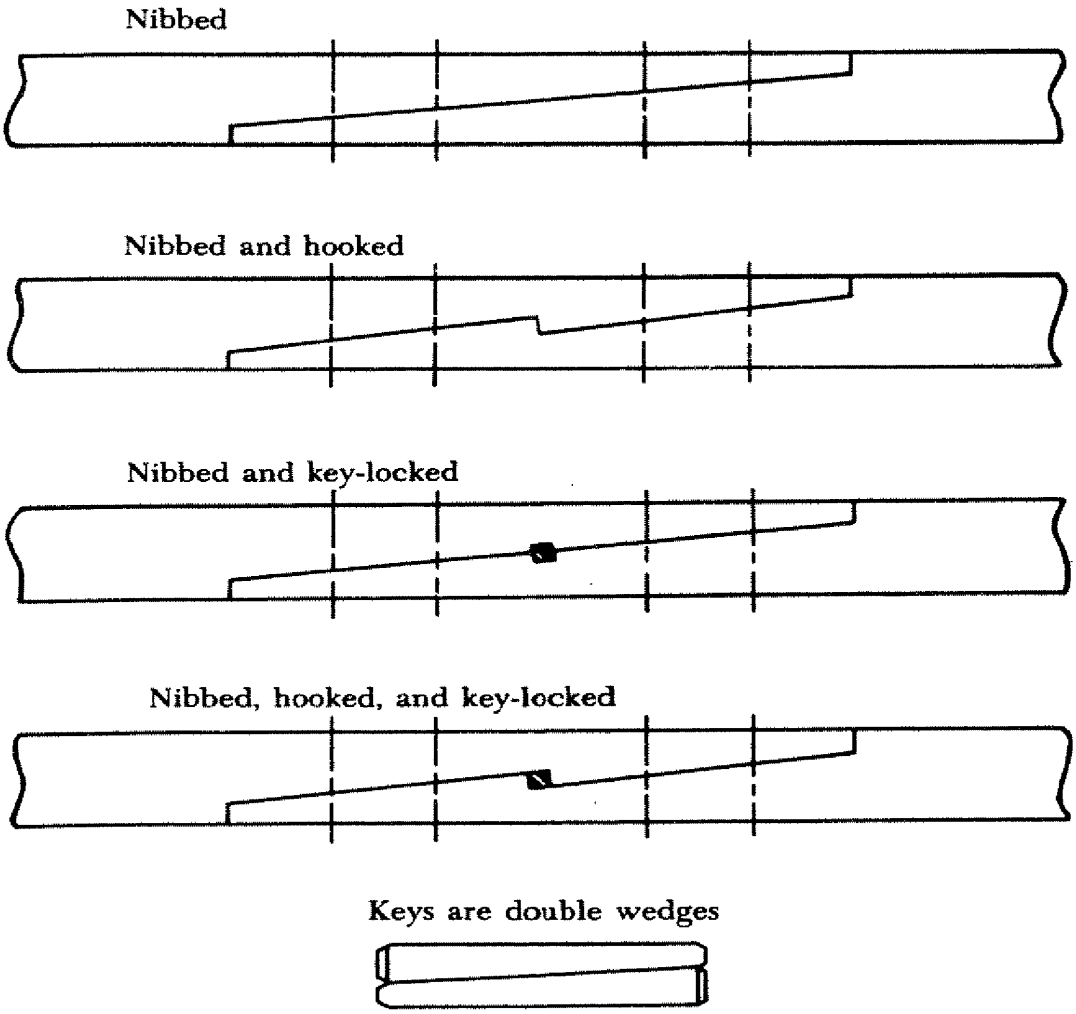


FIGURE 3.8.5

Engine Foundations

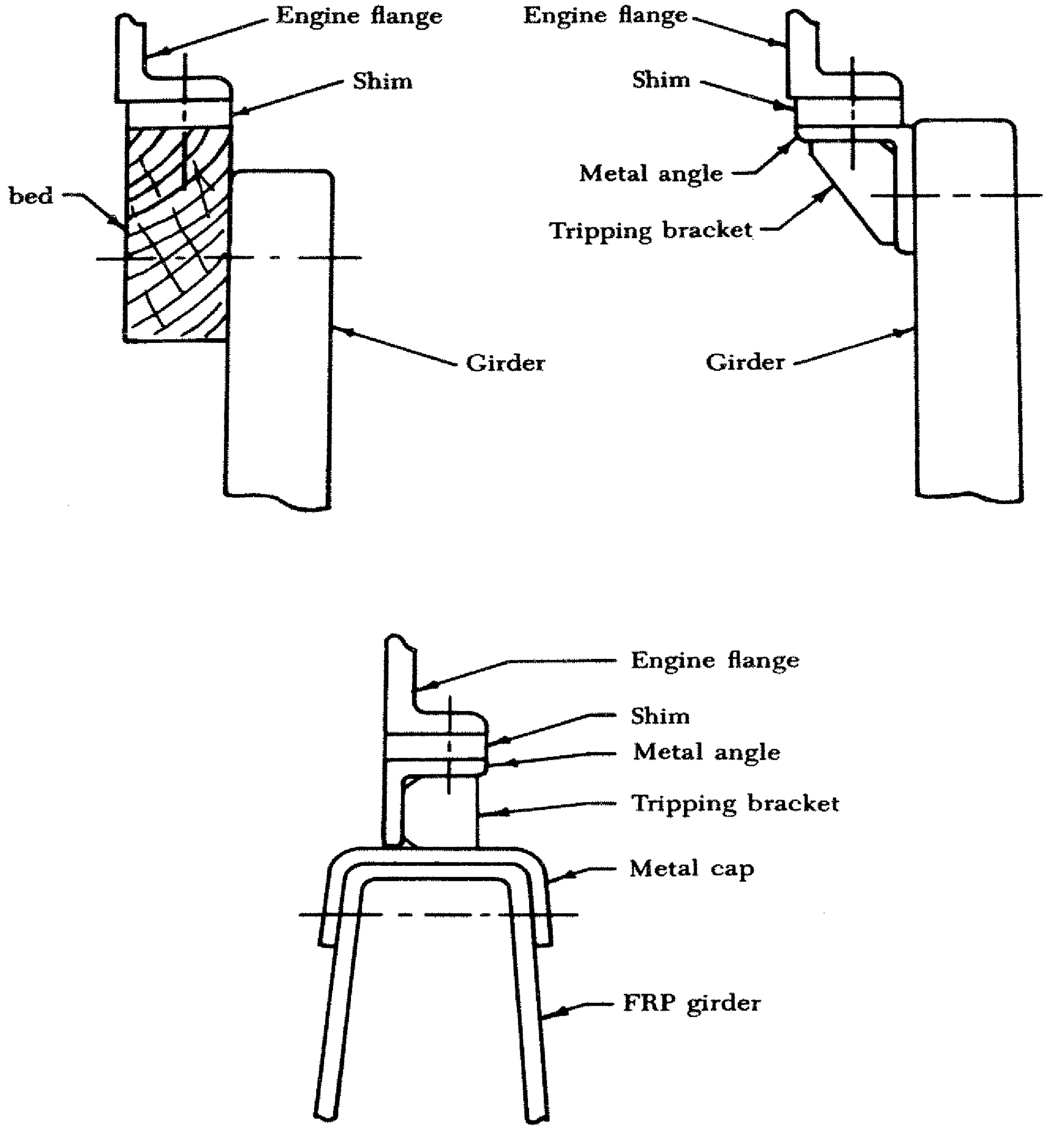


FIGURE 3.8.6

Boundary Angles for FRP Components

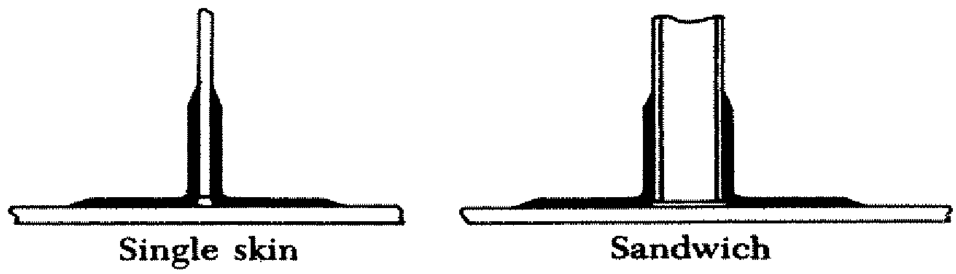


FIGURE 3.8.7

Boundary Angles Connecting Plywood or Wood to FRP

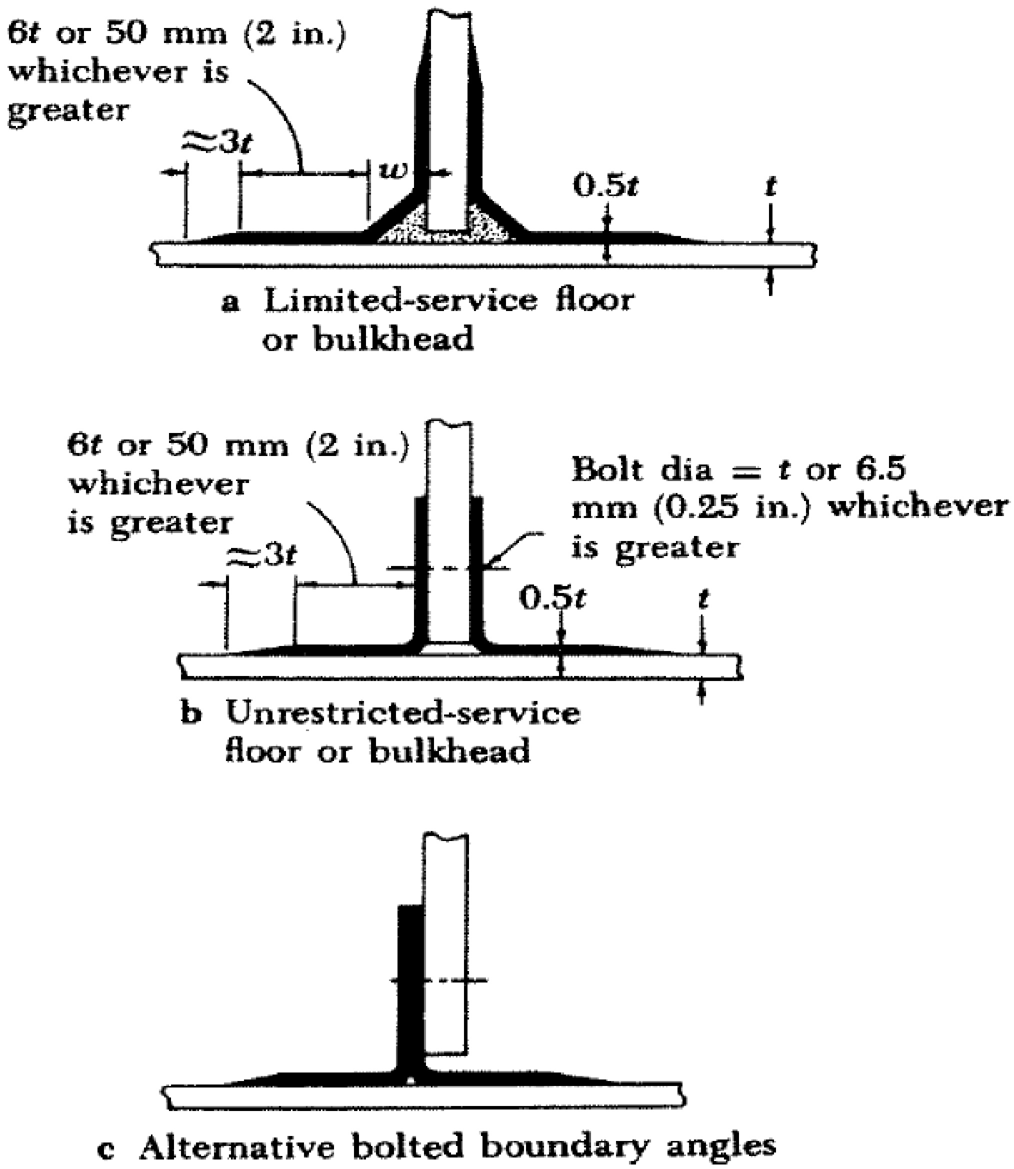


FIGURE 3.8.8

Deck-to-Hull Weather Joints

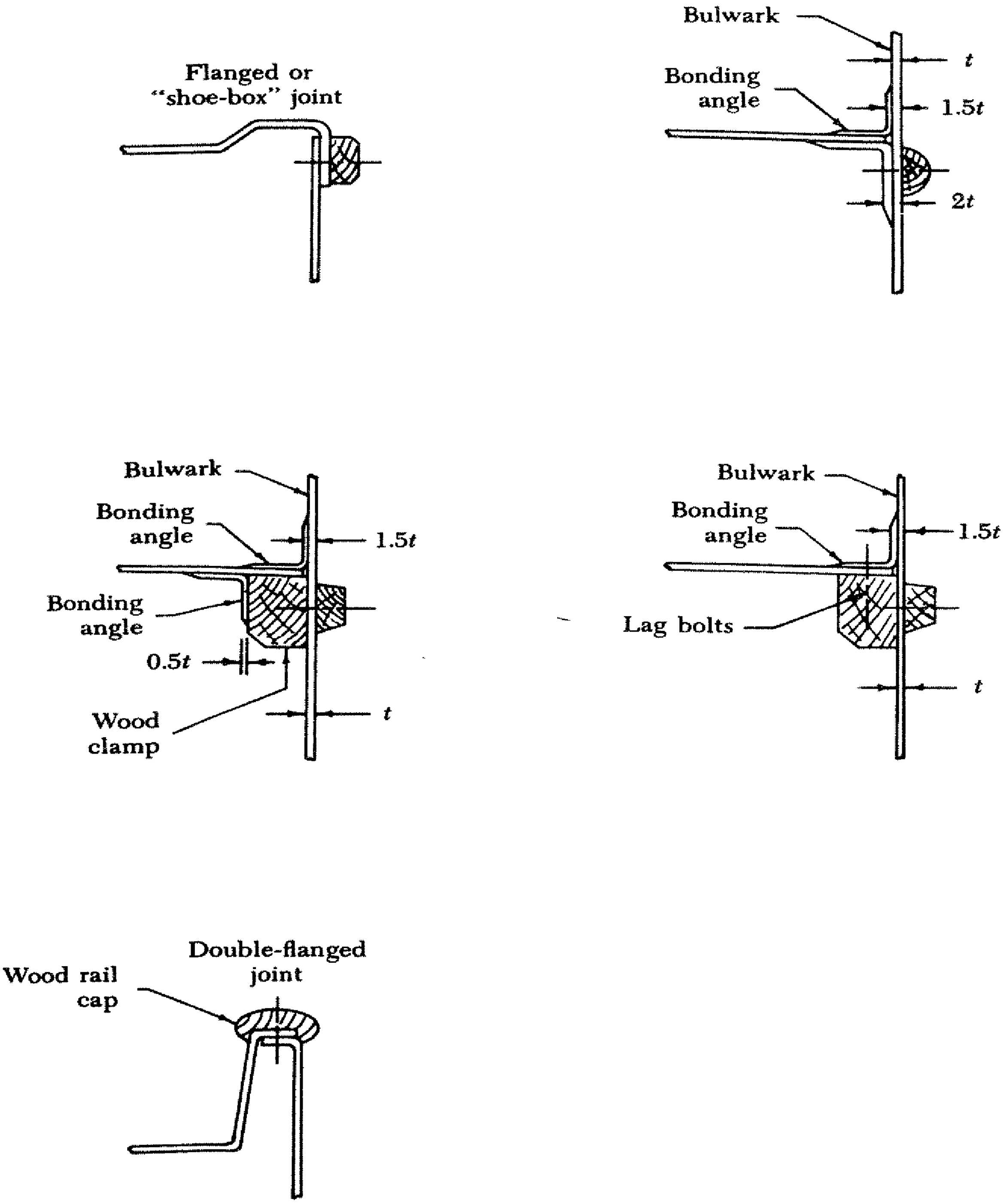


TABLE 3.8.1

Maximum Bolt Spacing

Metric Units

Length of Vessel L, m	Bolt Spacing, mm	
	Unrestricted Service	Limited Service
9	152.5	228.5
12	165.0	241.5
15	177.5	254.0
18	190.5	266.5
21	203.0	279.5
24	216.0	292.0
27	228.5	305.0
30	241.5	317.5
33	254.0	330.0
36	266.5	343.0

TABLE 3.8.2

Deck-to-Hull Joints

Metric Units

Length of Vessel L, m	Minimum Width of Overlap, mm	Minimum Bolt Diameter, mm
9	63.5	6.50
12	75.0	7.75
15	87.5	9.00
18	100.0	10.25
21	112.5	11.50
24	125.0	12.75
27	137.5	14.00
30	150.0	15.25
33	162.5	16.50
36	175.0	17.75