American Bureau of Shipping

Rules for Building and Classing Reinforced Plastic Vessels

1978

Notices No. 1 and No. 2

At the meeting of the Technical Committee held 13 November 1991 the following changes were approved and become effective on 13 May 1992 unless another date is given.

American Bureau of Shipping

Rules for Building and Classing Reinforced Plastic Vessels

1978

Notice No. 2

At the meeting of the Technical Committee held 13 November 1991 the following changes were approved and become effective on 13 May 1992 unless another date is given.

American Bureau of Shipping

Rules for Building and Classing

Reinforced Plastic Vessels

1978

Notice No. 1

At the meeting of the Technical Committee held 10 November 1987 the following changes were approved and become effective 10 May 1988 unless another date is given.

Rule Changes

Subsection 22.1.2 and 22.1.4 are revised/deleted to eliminate the "Year of Grace" survey and to provide for a five (5) year Special Periodical Survey interval in line with the "Rules for Building and Classing Steel Vessels, 1992."

Section 22 Surveys After Construction

22.1 Conditions for Surveys After Construction

22.1.2 Special Periodical Surveys

A Special Periodical Survey is to be completed within five years after the date of build or after the crediting date of the previous Special Periodical Survey. 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 five 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 Periodical Survey requirements in the case of vessels of unusual design, in layup or in unusual circumstances. The Committee reserves the right to authorize extensions of Rule required Special Periodical Surveys under extreme circumstances.

Special Periodical Survey may be commenced at the fourth annual survey and be continued with a view to completion by the due date. In connection with the preparation for the Special Periodical Survey, thickness gaugings as required for the forthcoming Special Periodical Surveys are to be taken to the extent accessible and practical in connection with the fourth annual survey.

Where the Special Periodical Survey is commenced prior to the fourth annual survey the entire survey is normally to be completed within 12 months if such work is to be credited to the Special Periodical Survey.

22.1.4 (No text)

Rule Changes

Section 2 Definitions

2.4 Draft for Scantlings

d is either the vertical distance in meters or feet measured from the rabbet line at its lowest point to the designed load waterline or $0.66D$, whichever is greater.

Section 7 Bottom Structure

The definition of u was modified to allow for core materials other than plastic.

7.1.3 Sandwich Panels

a ***Displacement Vessels*** Where sandwich construction is used for the bottom shell in a displacement vessel, the moment of inertia of both skins of a strip of the sandwich panel 25 m (1 in.) wide is to be not less than the moment of inertia of an equal-width strip of a single-skin laminate that satisfies 7.1.2.a. The total thickness of the sandwich panel is to be not less than obtained from the following equation.

$d = 0.0015k_2hs/u$ mm $\qquad d = 0.666k_2hs/u$ in.

d = total thickness in mm or in.

k_2 = coefficient that varies inversely to the relative thickness of the core as shown in Figure 7.8, where t and t_i are the thicknesses in m or in. of the other or inner skins

h = distance in m or ft from lower edge of sandwich to the freeboard deck at side

s = span of shorter side of sandwich panel in mm or in.

u = shear strength of core in kg/mm^2 or psi

b ***Planning Vessels*** Where sandwich construction is used for a bottom shell in a planning vessel, the moment of inertia of both skins of a strip of the sandwich panel 25 mm (1 in.) wide is to be not less than the moment of inertia of an equal-width strip of a single-skin laminate that satisfies 7.1.2b. The total thickness of the sandwich panel is to be not less than obtained from the following equations.

1 where speed of vessel is less than or equal to 31 knots

$d = 0.00041k_2Vs/u$ mm $\qquad d = 0.586k_2Vs/u$ in.

2 Where speed of vessel is greater than 31 knots

$d = 0.000013k_2Vs/u$ mm $\qquad d = 0.019k_2V^2s/u$ in.

d = total thickness in mm or in
k_2 = coefficient that varies inversely to the relative thickness of the core as shown in Figure 7.8, where t and t_i are the thicknesses in mm or in. of the outer and inner skins
V = sea speed of vessel in knots
s = span of shorter side of sandwich panel in mm or in.
u = shear strength of core in kg/mm^2 or psi

Section 9 Tanks

9.1 General

Boundary bulkheads and tight divisions of all FRP integral tanks are to be constructed in accordance with the requirements of this section. The arrangement of all integral tanks, their intended service, and the heights of the overflow pipes are to be indicated clearly on the drawings submitted for approval. Where integral tanks are of sandwich construction, the cores are to be end grain balsa or closed cell PVC foam. With balsa, each block is to be individually set onto the laminate with the gaps between each block filled with resin. No stiffeners within integral tanks are to penetrate the tank boundaries. Gasoline or potable water tanks are not to be fitted integrally.

All internal surfaces of FRP tanks are to be covered with fiberglass mat or chopped strand weighing at least 600 grams per square meter (2 ounces per square foot). This covering is to be in addition to the scantlings required in this section. A heavy coat of the laminating resin, or other suitable coating, is to be applied to this covering. Resins are to be compatible with the contents of the tanks.

The remainder of sub-section is unchanged.

Section 10 Watertight Bulkheads

10.1 General

All vessels having length L, as defined in Section 2, of 15 m (50 ft) or above are to be provided with watertight bulkheads in accordance with this section. The location, extent, and arrangement of each watertight bulkhead are to be indicated clearly on the plans submitted for approval.

10.2 Arrangement of Watertight Bulkheads

10.2.2 Collision Bulkheads

Collision bulkheads are to be fitted not less than $0.05L$ abaft the stem at the designed load waterline. The bulkheads are to be intact except for penetrations as permitted in 10.5, and are to extend to the freeboard deck, preferably in one plane. In vessels having long superstructures at the forward end, the bulkheads are to be extended weathertight to the superstructure deck. Provided the extensions of the bulkhead are not less than $0.05L$ abaft the stem at the designed load waterline, they need not be fitted directly over the collision bulkhead; in such cases, the part of the freeboard deck that forms the step is to be made weathertight.

Special consideration will be given to alternative arrangements for non-commercial craft. Watertight doors or watertight openings may be fitted in collision bulkheads of non-commercial craft less than 24.4 m (80 ft) in length. These doors and openings are to be kept closed at all times while the vessel is at sea.

Section 11 Decks and Deck Openings

11.6.6 Miscellaneous Openings in Exposed Decks

a ***Manholes and Scuttles*** Manholes and flush scuttles in Position 1 or 2 are to be closed by substantial covers capable of being made watertight. Unless secured by closely spaced bolts, the covers are to be permanently attached.

b ***Other Openings*** Openings in freeboard decks and first decks above freeboard decks in unrestricted-service and fishing-service vessels, other than cargo hatchways, machinery-space openings, manholes, and flush scuttles, are to be protected by superstructures, deckhouses, trunk cabins, or weathertight companionways fitted with doors that are in accordance with 11.6.5.

The closing appliances of escape openings are to be readily operable from each side.

Section 18 Shafting and Propellers

18.4.2 Propeller-end Bearings

a Water-lubricated Bearings

1 **Wood Bearings** resinous, dense hardwoods
The length of the bearing, next to and supporting the propeller, is to be not less than four times the required tail shaft diameter.

2 **Synthetic Bearings** rubber, reinforced resins, plastic materials
The length of the bearing, next to and supporting the propeller, is to be not less than four times the required tail shaft diameter.

For a bearing design substantiated by experimental tests to the satisfaction of the Bureau, consideration may be given to a bearing length of less than four times but not less than two times the required tail shaft diameter.

b Oil-lubricated Bearings

1 **White Metal Lined** The length of white-metal-lined, oil-lubricated propeller-end bearings fitted with an approved oil-seal gland is to be on the order of two times the required tail shaft diameter. The length of the bearing may be less provided the nominal bearing pressure is not more than 0.0815 kg/mm^2 (116 psi) as determined by static bearing reaction calculation taking into account shaft and propeller weight, which is deemed to be exerted solely on the aft bearing, divided by the projected area of the shaft. The minimum length, however, is not to be less than 1.5 times the actual diameter.

2 **Synthetic Bearings** rubber, reinforced resins, plastic etc.
The length of synthetic rubber, reinforced resin or plastic oil lubricated propeller end bearings fitted with an approved oil-seal gland is to be on the order of two times the required tail shaft diameter. The length of bearing may be less provided the nominal bearing pressure is not more than 0.0611 kg/mm^2 (87 psi) as determined by static bearing reaction calculation taking into account shaft and propeller weight, which is deemed to be exerted solely on the aft bearing, divided by the projected area of the shaft. The minimum length, however, is not to be less than 1.5 times the actual diameter.

Where the material has demonstrated satisfactory testing and operating experience, consideration may be given to increased bearing pressure.

Rules for Building and Classing

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SECTION 1

Conditions of Classification

1.1 Application

Except where specifically mentioned otherwise, these Rules are applicable to reinforced-plastic vessels under 61 meters (200 feet) in length that are intended to be classed for unrestricted ocean service.

1.2 Interpretation

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

1.3 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 over-all safety and strength standards of the Rules. The Committee will consider arrangements or details of hull, equipment, or machinery which can be shown to comply with standards recognized in the country in which the vessel is registered or built provided they are not less effective than these Rules.

1.4 Novel Features

Vessels containing novel hull, equipment, or machinery design features to which the provisions of these Rules are not directly applicable may be classed, when approved by the Committee, on the basis that the Rules insofar as applicable have 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 Changes to the Rules

1.5.1 Six-month Rule

Changes to these Rules are to become effective six months from the date on which The Technical Committee approves them. However, the Bureau may bring into force individual changes before that date if necessary or appropriate.

1.5.2 Implementation of Rule Changes

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

1.6 Classification Symbols

1.6.1 Unrestricted Service

Vessels built under the supervision of the Surveyors to the Bureau to the full requirements of these Rules, or to their equivalent, when approved for unrestricted ocean service, will be classed and distinguished in the Record by the symbols ✠A1. Unless otherwise stipulated, sailing vessels intended for either commercial or recreational use are to be built and classed for unrestricted service.

1.6.2 Special-Purpose Vessels

Vessels built under the supervision of the Surveyors to the Bureau to the requirements contained in these Rules for special types of vessels, or to special-purpose arrangements or scantlings, when approved, will be classed and distinguished in the Record by the symbols ✠A1 followed by appropriate notations such as Yachting Service, Fishing Service, Towing Service, Launch, etc.

1.6.3 Geographical Limitations

Vessels built under the supervision of the Surveyors to the Bureau to special modified requirements for limited geographical service, when approved for that particular service, will be classed and distinguished in the Record by the applicable symbols and notations in 1.6.1 and 1.6.2 followed by an appropriate service limitation.

1.6.4 Vessels not Built under Survey

Vessels not built under the supervision of the Surveyors to the Bureau, but submitted for classification, will be subjected to special classification surveys. When found satisfactory and thereafter approved by the Committee, such vessels will be classed and distinguished in the Record by the applicable symbols and notations in 1.6.1, 1.6.2, and 1.6.3, but the mark ✠ signifying supervision during construction will be omitted.

1.6.5 Equipment Symbol

The symbol Ⓔ added to the symbols and notations in 1.6.1, 1.6.2, and 1.6.3, e.g. ✠A1Ⓔ **Launch**, signifies that a vessel's anchors and anchor cables comply with the requirements in 16.4 and have been tested in the presence of a Surveyor in accordance with the Rules.

1.6.6 ✠AMS Symbols
Machinery constructed, tested, and installed under the supervision of the Surveyors to the Bureau to the full requirements of these Rules, or their equivalent, when found satisfactory after trial and approved by the Committee, will be classed and distinguished in the Record by the symbols ✠AMS.

1.6.7 AMS Symbols
Machinery not constructed, tested, and installed under the supervision of the Surveyors to the Bureau, but submitted for classification, will be subjected to special classification surveys. When found satisfactory and thereafter approved by the Committee, the machinery will be classed and distinguished in the Record by the symbols AMS. The mark ✠ signifying supervision during construction will be omitted.

1.6.8 Other Conditions
The Committee reserve the right to refuse classification of any vessel that in any way is not in accordance with the requirements of these Rules.

1.7 Plans

1.7.1 Hull Plans
Prints of plans clearly showing the arrangements, scantlings, and details of principal parts of the hull structure of each vessel to be built under special survey are to be submitted and approved before construction is commenced. Three prints of each plan is the minimum number required. Where plans are to be approved at a Bureau office other than the Bureau's New York headquarters, where construction is to be carried out at a plant other than that of the shipbuilder, or where a record of Bureau approval of plans is requested by an organization other than the Bureau or the shipbuilder, additional prints may be required.

The plans are to include details of all joints, foundations, and connections; they also are to include such particulars as the draft to the designed load waterline (summer load line), the displacement at the designed load waterline (full-load dispiacement), and the intended sea speed. Where provision is to be made for any special type of cargo or for any exceptional conditions of loading, particulars of the weights and of their distribution are also to be given. In general the plans are to include the following items.

General arrangement
Midship and framing sections
Scantling profile and scantling deck plans
Bottom construction
Inner bottom
Shell plating or expansion, including layup schedule

Stanchions and girders
Watertight and deep-tank bulkheads
Miscellaneous nontight bulkheads used as structural supports
Shaft tunnels
Machinery casings
Engine and main auxiliary foundations
Bow framing
Stern framing
Rudders and steering gear
Shaft struts
Superstructure and deckhouses, and their closing appliances
Cargo hatches and hatch-closing arrangements
Ventilation systems exposed to weather
Anchor handling arrangements

1.7.2 Loading Conditions

The Rules of the Bureau are published on the understanding that responsibility for stability and trim, for reasonable handling and loading, and for avoidance of distributions of weight that are likely to set up abnormally severe stresses in vessels does not rest upon the Committee. Where it is desired to provide for exceptional conditions of loading, or cargoes of unusual character, full particulars are to be given in connection with the submission of drawings as outlined in 1.7.1.

1.7.3 Machinery Plans

Prints of plans showing the principal parts of the machinery installation are to be submitted and approved before proceeding with the work. For the number of prints required see 1.7.1. In general the plans are to show the following details.

Engine installation and particulars, including make and model, two or four-stroke cycle, type of fuel, number and dimensions of cylinders, revolutions per minute, maximum continuous brake horsepower, and gear ratio
Shafting, including stuffing boxes, stern tubes, stern bearings, and propellers
Exhaust system, including materials, method of cooling, and (if water-cooled) method of draining
Starting-air system
Pumps, including sizes and purposes of pump suction and discharge connections
All auxiliaries, generators, motors, and switchboards
Wiring diagram, including feeder list, loads, wire sizes and types, and circuit-breaker and fuse ratings
Piping diagrams, including sizes, wall thicknesses, maximum working pressures, and material of all pipes, and types, sizes and material of valves and fittings. The following systems are to be diagrammed:

sanitary; vent, sounding, and overflow; fuel-oil filling, transfer, and service; lubricating oil; hydraulic power; sea water; fresh water; fire main and fire extinguishing; steering-gear piping.

1.8 Process Description

In addition to the foregoing, the builder is to submit a process description before construction is commenced. The following items are to be included.

Description of construction facilities, including environmental control and material storage and handling
Specifications for resins, reinforcing products, and core materials
Approximate resin gel times and method of control
Layup procedures, including type, orientation of reinforcements, sequence, resin mixing methods, and resin pot-life limits
Secondary bonding procedures
Inspection and quality-control systems
Laminate properties derived from destructive qualification testing

Determination of laminate properties (specific gravity, glass content, tensile strength and modulus, flexural strength and modulus, shear strength, and, where glass content is 40% or more, interlaminar shear strength) is to be made on the basis of destructive qualification tests of panels assembled by the fabricator under environmental conditions and using resin formulations and process techniques simulating the conditions, formulations, and techniques to be used in actual production. The fabricator is to lay up the test panels at an angle of about 45°. All panels are to be tested in the as-cured condition. Test procedures are to be in accordance with American Society for Testing and Materials (ASTM) specifications or equivalent. All test results are to be reported. Bureau review of laminate design will be predicated on the quality of laminate produced by the fabricator.

Below are listed, in numerical order, pertinent ASTM specifications with their respective year designations. Note that each designation listed indicates the year of issue last reviewed and adopted by the Bureau, and does not necessarily represent the latest issue of that specification.

C273-76	D638-72	D790-71	D2563-70
C393-70	D732-75	D792-75	D2733-70

1.9 Fees for Plan Approval

Fees, proportional to the work involved, may be charged for the consideration of new designs of special character that are submitted for approval. Fees may also be charged for the consideration of designs in cases where the vessels to which they relate are not constructed under the Bureau's survey.

1.10 Trials

A final underway trial is to be made of all machinery, including the steering gear and anchor windlass, to the satisfaction of the Surveyor in attendance.

1.11 Conditions for Surveys after Construction

1.11.1 Damage

Damage to hull, machinery, or equipment, which affects or may affect seaworthiness or classification, is to be submitted by the Owners or their representatives for examination by the Surveyor. All repairs found necessary by the Surveyor are to be carried out to his satisfaction.

1.11.2 Notification and Availability for Survey

The Surveyors are to have access to classed vessels at all reasonable times. The Owners or their representatives are to notify the Surveyors on all occasions when a vessel can be examined in dry dock or on a slipway.

The Surveyors are to undertake all surveys on classed vessels 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.

1.12 Fees for Surveys

Fees will be charged for all surveys and for testing material. When the attendance of a Surveyor is required to suit the convenience of the Owners or their representatives outside of normal working hours, an extra fee will be charged. Traveling and other expenses incurred in connection with these services will be charged in addition to the fees.

1.13 Other Regulations, Standards, and Recommended Practices

While these Rules cover the minimum requirements for the classification of new vessels, the attention of designers, builders, and Owners is directed to the regulations, standards, and recommended practices of governmental, canal, and other authorities that control or provide guidance for important design, construction, equipment, and maintenance features not covered specifically in these Rules.

1.14 Responsibility

The Bureau, being a technical society, can act only through Surveyors or others who are believed by it to be skilled and competent. It is understood and agreed by all who avail themselves in any way of the services of the Bureau that neither the Bureau nor any of its Committees and employees will, under any circumstances whatever, be responsible or liable in any respect for any act or omission, whether negligent or otherwise, of its Surveyors, agents, employees, officers, or Committees, nor for any inaccuracy or omission in the Record or any other publication of the Bureau, or in any report, certificate, or other document issued by the Bureau, its Surveyors, agents, employees, or Committees.

1.15 Disagreement

In case of disagreement between the builder or Owner and the Surveyor regarding the material, workmanship, extent of repairs, or application of these Rules relating to any vessel classed or proposed to be classed by the 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 appealing party.

1.16 Termination of Classification

The continuance of the classification of any vessel is conditional upon the Rule requirements for periodical, damage, and other surveys being duly carried out. The Committee reserve the right to reconsider, withhold, or suspend the class of any vessel for noncompliance with the Rules, for defects reported by the Surveyors which have not been rectified in accordance with their recommendations, or for nonpayment of fees that are due on account of classification and other surveys.

SECTION 2

Definitions

The following definitions apply throughout these Rules.

2.1 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 planing vessels L is measured in the zero-speed condition.

2.2 Breadth

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

2.3 Depth

D is the depth in meters or feet measured at the middle of the length L from the rabbet line (see Figure 2.1) to top of the freeboard deck at the side of the vessel.

2.4 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.

2.5 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.

2.6 Superstructure Deck

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

2.7 Bulkhead Deck

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

2.8 Rabbet Line

For the purposes of these Rules, the rabbet line (see Figure 2.1) 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.

2.9 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.

2.10 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.

2.11 Planing Vessel

For purposes of these Rules, the phrase "planing 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.

2.12 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.

2.12.1 Glass

The fibrous-glass reinforcing material used in FRP vessels is a lime-alumina-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.

2.12.2 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 semisolid state similar to gelatin in consistency. Not to be confused with gel coat (see 2.12.3c).

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.

2.12.3 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 (see 2.12.2h).

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 goemetry 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.

2.13 Physical Properties

2.13.1 Load

The total force acting on a plate or stiffener.

2.13.2 Plate

A smooth, relatively thin piece of material.

2.13.3 Stiffener

The generic word for all structural supporting members such as frames, webs, stringers, stiffeners, beams, and girders.

2.13.4 Flexural Strength

The measure of the capability of a plate or stiffener to withstand a bending load without failing (see Figure 2.2).

2.13.5 Flexural Modulus

The number used to calculate the distance a plate or stiffener will bend or deflect under a given load (see Figure 2.2).

2.13.6 Tensile Strength

The measure of the capability of a plate or stiffener to withstand a stretching load without failing (see Figure 2.3).

2.13.7 Tensile Modulus

The number used to calculate the amount a plate or stiffener will increase in length when a stretching load is applied to it (see Figure 2.3).

2.13.8 Compressive Strength

The measure of the capability of a plate or stiffener to withstand a compressing load without crushing (see Figure 2.4).

2.13.9 Compressive Modulus

The number used to calculate the amount a plate or stiffener will decrease in length when a compressing load is applied to it (see Figure 2.4).

2.13.10 Shear Strength

The measure of the capability of a body such as a plate or stiffener to withstand a shearing load without one part of the body being forced to slide past the other (see Figure 2.5).

2.13.11 Shear Modulus

The measure of the stiffness of a plate or stiffener when a shearing load is applied to it (see Figure 2.5). Also called the modulus of rigidity.

2.13.12 Interlaminar Shear

The shear strength of the bond between plies of reinforcing material. The measure of the capability of the bond to withstand a shearing load without delamination (see Figure 2.6).

FIGURE 2.1
Rabbet Line

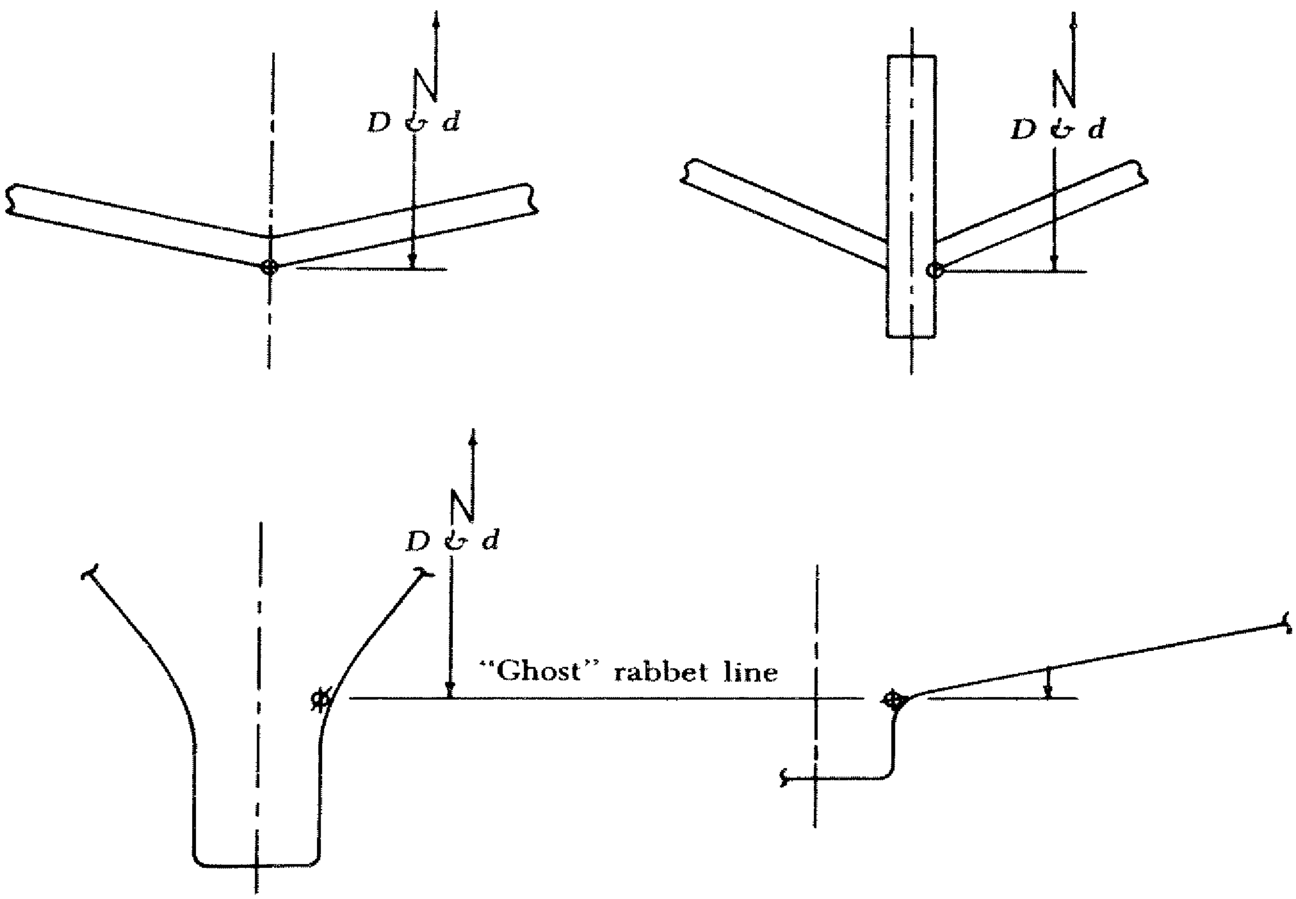


FIGURE 2.2
Flexural Strength and Modulus

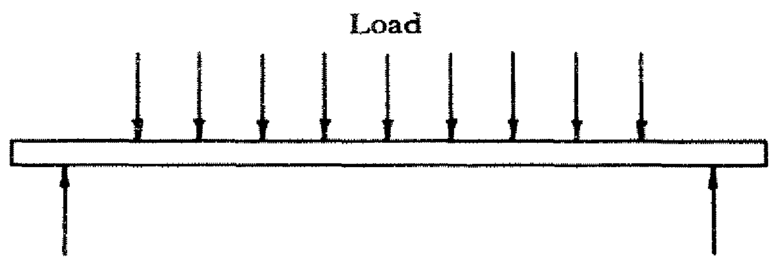


FIGURE 2.3
Tensile Strength and Modulus

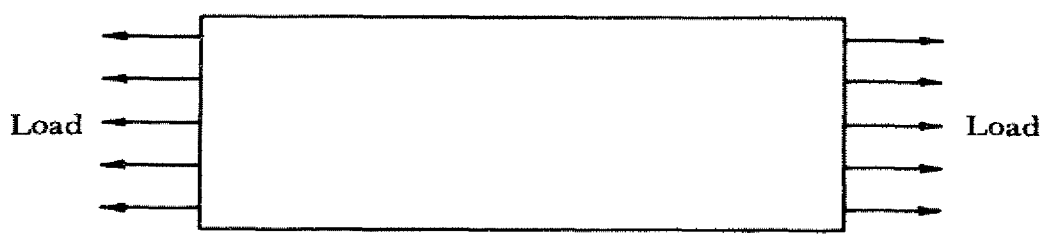


FIGURE 2.4
Compressive Strength and Modulus

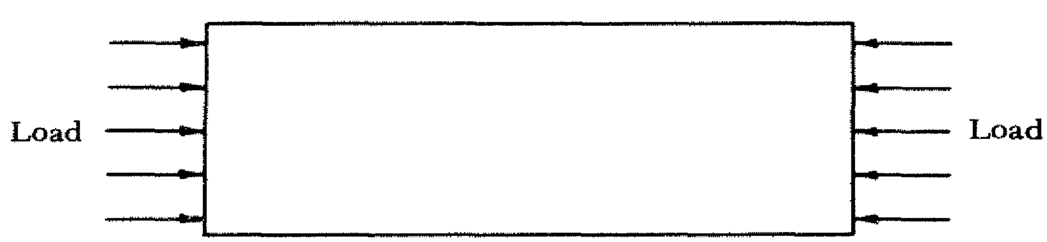


FIGURE 2.5
Shear Strength and Modulus

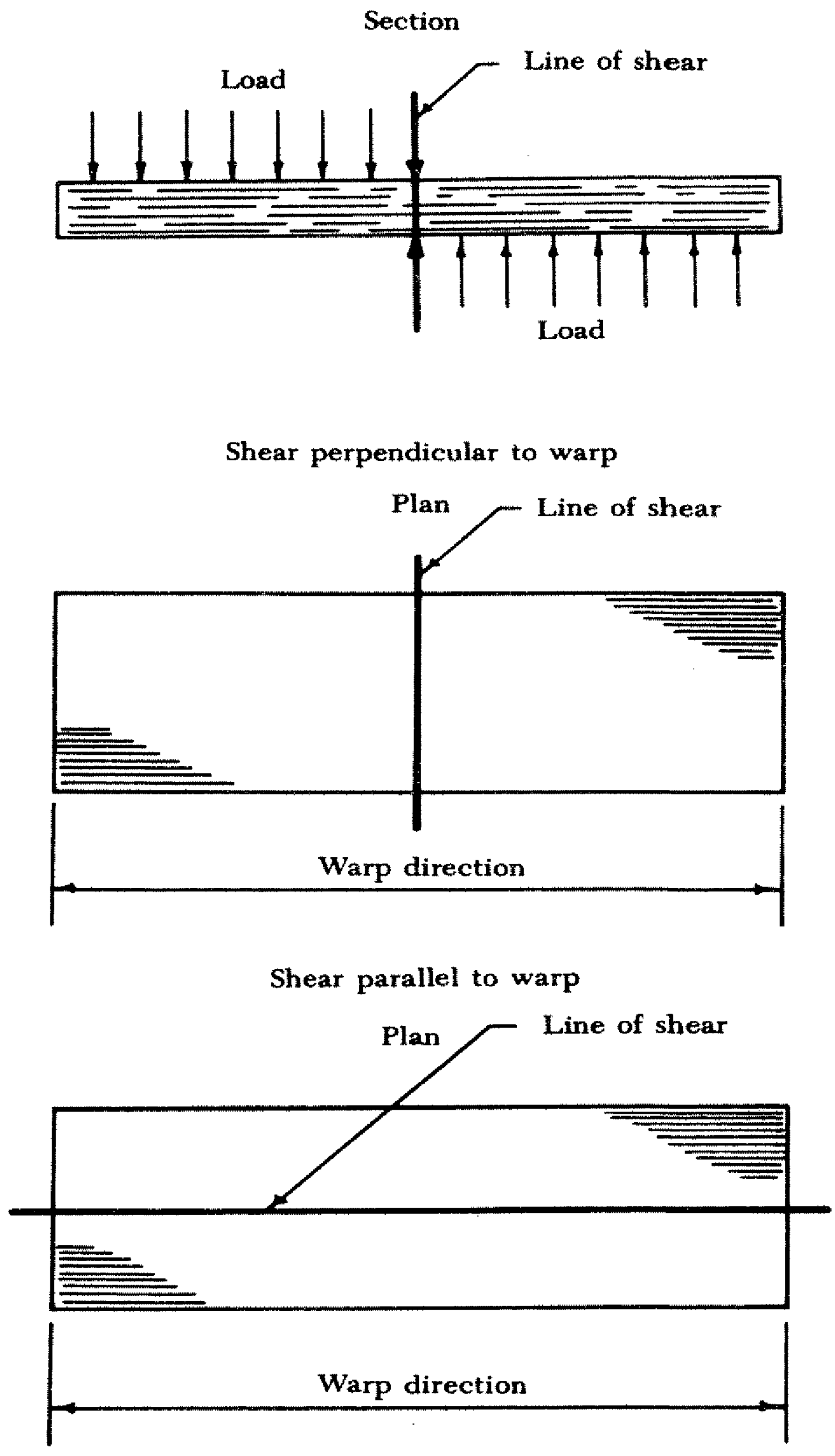
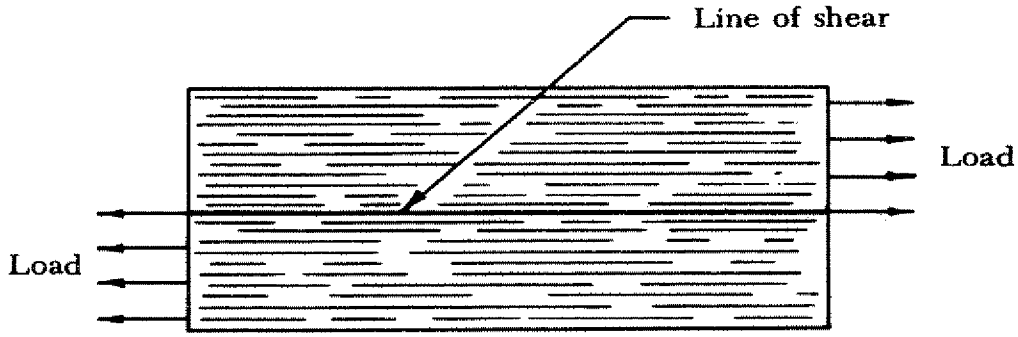


FIGURE 2.6
Interlaminar Shear



Section through laminate

SECTION 3

General

3.1 Longitudinal Strength

Although the necessary midship-section modulus to insure sufficient longitudinal strength in vessels of normal form usually is obtained if the longitudinal-member and laminate requirements in these Rules are satisfied, the Bureau may require that longitudinal hull-strength calculations be submitted, especially where vessels are shallow in depth, have wide hatch openings, or are subject to unusually high hydrodynamic forces.

3.2 Continuity

Care is to be taken to provide structural continuity. Changes in scantlings are to be gradual. Where major longitudinal members end at transverse structural members, tapering may be required forward or aft of the transverses. Stanchions and bulkheads are to be aligned to provide support and to minimize eccentric loading. Major appendages outside the hull and strength bulkheads in superstructures and deckhouses are to be aligned with major structural members within the hull.

3.3 Openings

Major openings such as doors, hatches, and large vents are to be avoided in the hull in close proximity to the freeboard deck and in the freeboard deck immediately inboard of the deck edge. Corners of openings in strength structures are to have generous radii. Compensation may be required for openings.

3.4 Effective Width of Plating

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

3.4.1 FRP Laminates

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

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

w = effective width of plating in mm or in.
t = thickness of plating in mm or in.
b = net width of stiffener in mm or in.

Where the plating is an FRP sandwich laminate with an 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 stiffener along an opening, the effective width of plating is to equal either one-half the stiffener spacing in millimeters or inches or the width obtained from the following equation, whichever is less.

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

w = effective width of plating in mm or in.
t = thickness of plating in mm or in.
b = net width of stiffener in mm or in.

The section modulus and moment of inertia of a stiffener not attached to plating are those of the stiffener only.

3.4.2 Plywood Plating

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

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

w = effective width of plating in mm or in.
t = thickness of plating in mm or in.

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

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

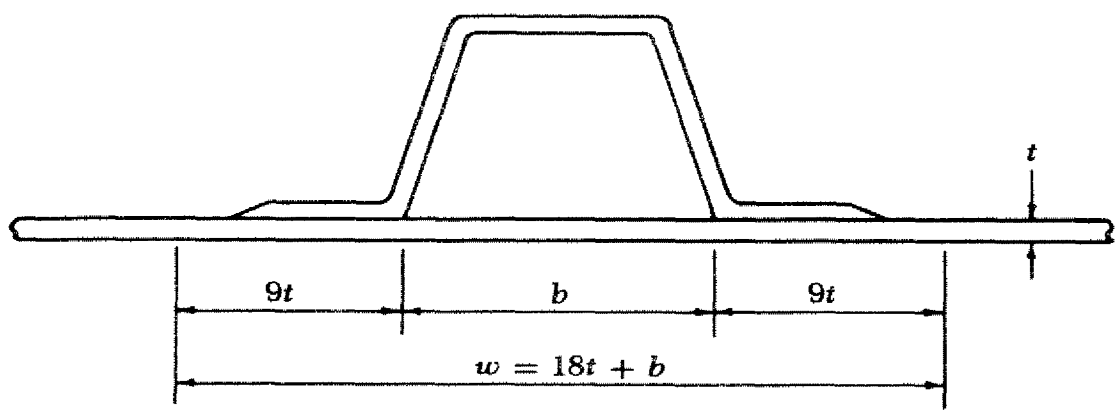
w = effective width of plating in mm or in.
t = thickness of plating in mm or in.

The section modulus and moment of inertia of a stiffener not attached to plating are those of the stiffener only.

3.4.3 Wood Plating

Where the plating is wood, the section modulus and moment of inertia of a stiffener are those of the stiffener only.

FIGURE 3.1
Effective Width of FRP Plating



SECTION 4

Materials

4.1 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.

4.2 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.

4.3 Reinforcing Materials

Fiberglass reinforcing materials are to be as defined in 2.12.1. Binders, where used, are to be soluble polyester resin. Sizes and finishes are to be of the silane type, and are to be compatible with the laminating resins.

4.4 Laminates

4.4.1 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.

4.4.2 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	*psi*
Flexural strength	17.5	25000
Flexural modulus	770	1.1×10^6
Tensile strength	12.6	18000
Tensile modulus	700	1.0×10^6
Compressive strength	11.9	17000
Compressive modulus	700	1.0×10^6
Shear strength perpendicular to warp	7.7	11000
Shear strength parallel to warp	6.3	9000
Shear modulus parallel to warp	315	0.45×10^6
Interlaminar shear strength	0.7	1000

4.4.3 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.

4.4.4 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 4.4.3, are to be deducted from the actual thicknesses to determine the effective thicknesses.

4.4.5 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.

$$t_2 = t_1 \sqrt[3]{770/E} \text{ mm} \qquad t_2 = t_1 \sqrt[3]{1.1(10^6)/E} \text{ in.}$$

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 or psi

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.

$$SM_2 = SM_1(17.5/u)\ \text{cm}^3 \qquad SM_2 = SM_1(25000/u)\ \text{in.}^3$$

$$I_2 = I_1(770/E)\ \text{cm}^4 \qquad I_2 = I_1[1.1(10^6)/E]\ \text{in.}^4$$

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/mm^2 or psi
E = verified flexural modulus of elasticity of alternate laminate in kg/mm^2 or psi

4.4.6 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 $\geq$ 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	*psi*
Single-skin laminate thickness	$\sqrt{\frac{17.5}{F}}$	$\sqrt{\frac{25000}{F}}$
Sandwich-panel skin thickness stiffener section modulus	$\frac{24.5}{T + C}$	$\frac{35000}{T + C}$
Stiffener area	$\frac{7.7}{S}$	$\frac{11000}{S}$
Stiffener inertia	$\frac{770}{E}$	$\frac{1.1 \times 10^6}{E}$

F = verified flexural strength of the unidirectional laminate in kg/mm^2 or psi

T = verified tensile strength of the unidirectional laminate in kg/mm^2 or psi
C = verified compressive strength of the unidirectional laminate in kg/mm^2 or psi
S = verified shear strength of the unidirectional laminate in kg/mm^2 or psi
E = verified flexural modulus of the unidirectional laminate in kg/mm^2 or psi

4.5 Wood

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/mm^2 (1.6×10^6 psi) and the following basic allowable design stresses.

	kg/mm^2	*psi*
Extreme fiber in bending	1.41	2000
Compression parallel to grain	1.03	1466

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/mm^2*	*psi*	*kg/mm^2*	*psi*	*kg/mm^2*	*psi x 10^6*
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.

4.5.1 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.

$$t_2 = t_1 \sqrt{1.41/f_b} \text{ mm} \qquad t_2 = t_1 \sqrt{2000/f_b} \text{ in.}$$

t_2 = thickness of alternate wood in mm or in.
t_1 = thickness of Douglas fir in mm or in.
f_b = extreme fiber in bending of alternate wood in kg/mm^2 or psi

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.

$$SM_2 = SM_1(1.41/f_b)\ \text{cm}^3 \qquad SM_2 = SM_1(2000/f_b)\ \text{in.}^3$$
$$I_2 = I_1(1125/E)\ \text{cm}^4 \qquad I_2 = I_1[1.6(10^6)/E]\ \text{in.}^4$$

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/mm^2 or psi
E = modulus of elasticity of alternate wood in kg/mm^2 or psi

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.

$$W_{a2} = W_{a1}(f_c/1.03)\ \text{metric tons}$$
$$W_{a2} = W_{a1}(f_c/1466)\ \text{long tons}$$

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/mm^2 or psi

4.5.2 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.

4.5.3 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.

4.5.4 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.

4.6 Plywood

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/mm^2 (1.6 $\times$ 10^6 psi) and an allowable tensile stress in bending equal to 0.70 kg/mm^2 (1000 psi).

4.6.1 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.

$$t_2 = t_1\sqrt{0.70/f_b}\ \text{mm} \qquad t_2 = t_1\sqrt{1000/f_b}\ \text{in.}$$

t_2 = thickness of alternate plywood in mm or in.
t_1 = thickness of Douglas fir plywood in mm or in.
f_b = allowable tensile stress in bending of alternate plywood in kg/mm^2 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.

$$SM_2 = SM_1(0.70/f_b)\ \text{cm}^3 \qquad SM_2 = SM_1(1000/f_b)\ \text{in.}^3$$

$$I_2 = I_1(1125/E)\ \text{cm}^4 \qquad I_2 = I_1[1.6(10^6)/E]\ \text{in.}^4$$

SM_2 = section modulus of alternate plywood
SM_1 = section modulus of Douglas fir plywood
I_2 = moment of inertia of alternate plywood
I_1 = moment of inertia of Douglas fir plywood
f_b = allowable tensile stress in bending of alternate plywood in kg/mm^2 or psi
E = modulus of elasticity of alternate plywood in kg/mm^2 or psi

4.6.2 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.

4.7 Core Material

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

Materials	Density		Shear Strength	
	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

4.8 Metals

4.8.1 Steel

All steel used in vessels built to these Rules and its welding are to comply with the requirements in the "Rules for Building and Classing Steel Vessels".

4.8.2 Aluminum Alloys

All aluminum alloys used in vessels built to these Rules and the welding of these alloys are to comply with the requirements in the "Rules for Building and Classing Aluminum Vessels".

4.8.3 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. Noncorrosion-resistant ferrous fastenings are to be galvanized. Fastenings used with aluminum alloys are to be austenitic corrosion-resistant (stainless) steel.

SECTION 5

Fabrication and Quality Control

5.1 General

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

5.2 Facility Requirements

5.2.1 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.

5.2.2 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 Fabrication Procedures

5.3.1 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.

5.3.2 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.

5.3.3 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.

5.4 Quality Control

5.4.1 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 to the Bureau. Prior to conducting the tests described in 5.4.6, the dates of the tests are to be given to the Surveyors by the builder.

5.4.2 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.

5.4.3 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.

5.4.4 Laminate Proportions

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

5.4.5 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.

5.4.6 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, as described in 1.8, 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

SECTION 6

Details and Fastenings

6.1 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.

6.2 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.

6.3 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.

6.4 Stiffeners

6.4.1 General

Stiffeners (frames, girders, deck beams, bulkhead stiffeners, etc.) used to support FRP panels may be entirely of FRP, FRP laid over non-structural cores or forms, or composites of FRP and other approved structural materials such as plywood or wood.

6.4.2 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 (see 4.5.3), are to conform with Figure 6.1, and the widths and heights of the stiffeners are to be not greater than obtained from the following equations.

$$w = 20t_1 \text{ mm or in.} \qquad h = 30t \text{ mm or in.}$$

w = width of stiffener crown in mm or in.
h = height of stiffener webs in mm or in.
t_1 = 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 6.2.a) are to conform with Figure 6.1 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 6.2.b) also are to conform with Figure 6.1 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 6.8. 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 6.1, if greater than 50 mm (2 in.), need not exceed $6t$.

6.4.3 Stiffeners with Wood or Plywood Cores

The use of encapsulated wood or plywood (Figure 6.2.c) is to be in accordance with 4.5 or 4.6. FRP webs and crowns encapsulating plywood cores and effective wood cores are not subject to the thickness limitations in 6.4.2. 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 6.1. The thicknesses of the flanges are to be not less than obtained from the following equation.

$$t = 0.033\,h \text{ mm or in.}$$

t = thickness of stiffener flanges in mm or in.
h = height of stiffener webs in mm or in.

6.4.4 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 6.3. 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.

6.5 Fastenings

6.5.1 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.

6.5.2 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.

6.5.3 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 mm (0.1875 in.) thick. Where used, self-tapping screws are to have coarse threads.

6.5.4 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.

6.5.5 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.

6.6 Joints in Wood or Plywood Longitudinals

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 6.4). 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.

6.7 Foundations

6.7.1 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 6.5 shows several typical, acceptable engine foundations.

6.7.2 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.

6.7.3 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.

6.7.4 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.

6.8 Boundary Angles

6.8.1 FRP to FRP

Secondary bonding of FRP components by means of double boundary angles is to be in accordance with 5.3.3. Typical boundary angles for FRP components are shown in Figure 6.6. 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.

6.8.2 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 6.7.a. Secondary bonding of these angles to FRP is to be in accordance with 5.3.3.

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 6.7.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 6.5.2. 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 6.7.b. Bolts are to be single-spaced; the maximum spacing is to be in accordance with Table 6.1. Intermediate values may be obtained by interpolation.

6.9 Chain Plates

6.9.1 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.

6.9.2 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/mm^2 (23,000 psi) shear yield strength.

6.9.3 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 8.1.2f. 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 $\qquad N = P/9{,}000d^2$ inch/pound 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.

6.9.4 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 6.9.3.

6.10 Deck-to-Hull Joints

6.10.1 Weather Joints

Typical acceptable deck-to-hull weather joints are shown in Figure 6.8. 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 6.1 and 6.2. Intermediate values may be obtained by interpolation.

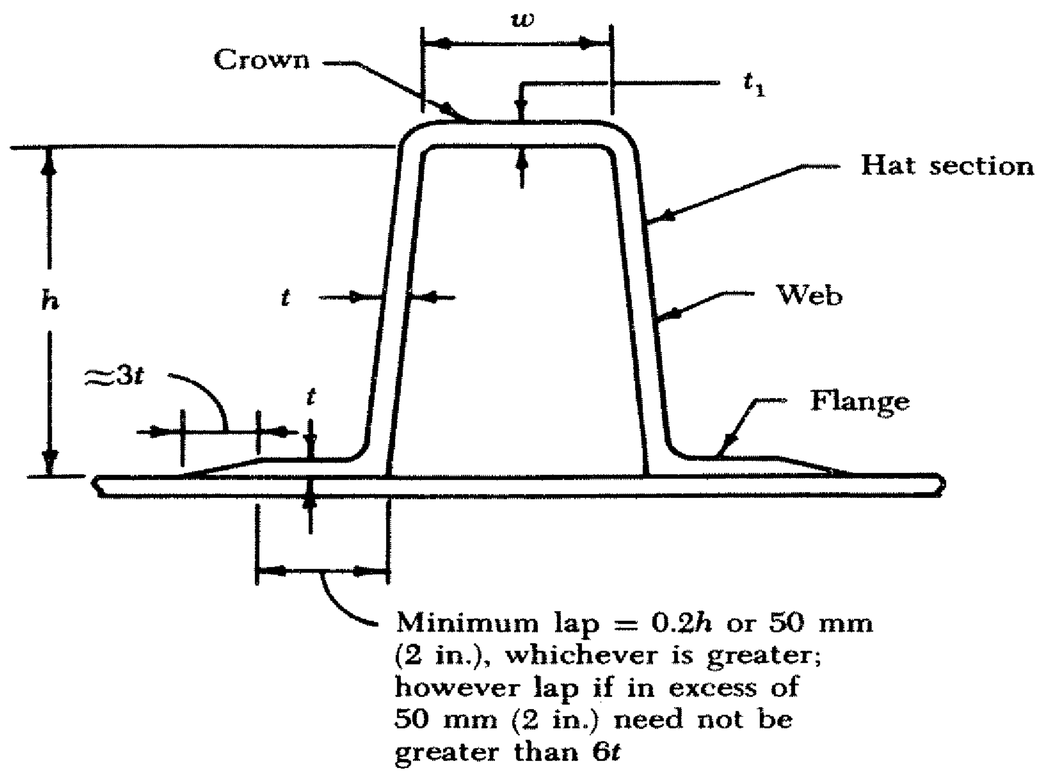
FRP bonding angles, where used, are to have flanges that are at least one-half as thick as the hull or deck laminate, whichever is thicker. The widths of the flanges are to be in accordance with the widths of overlaps in Table 6.2.

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.

6.10.2 Interior Joints

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

FIGURE 6.1
Proportions of Stiffeners



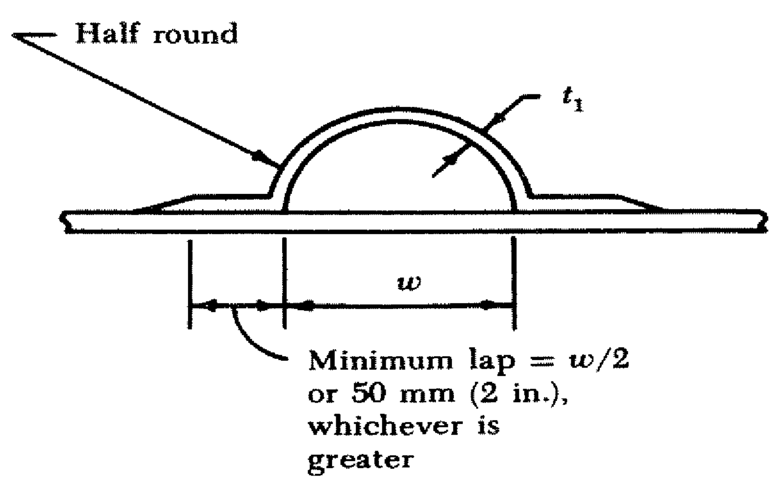
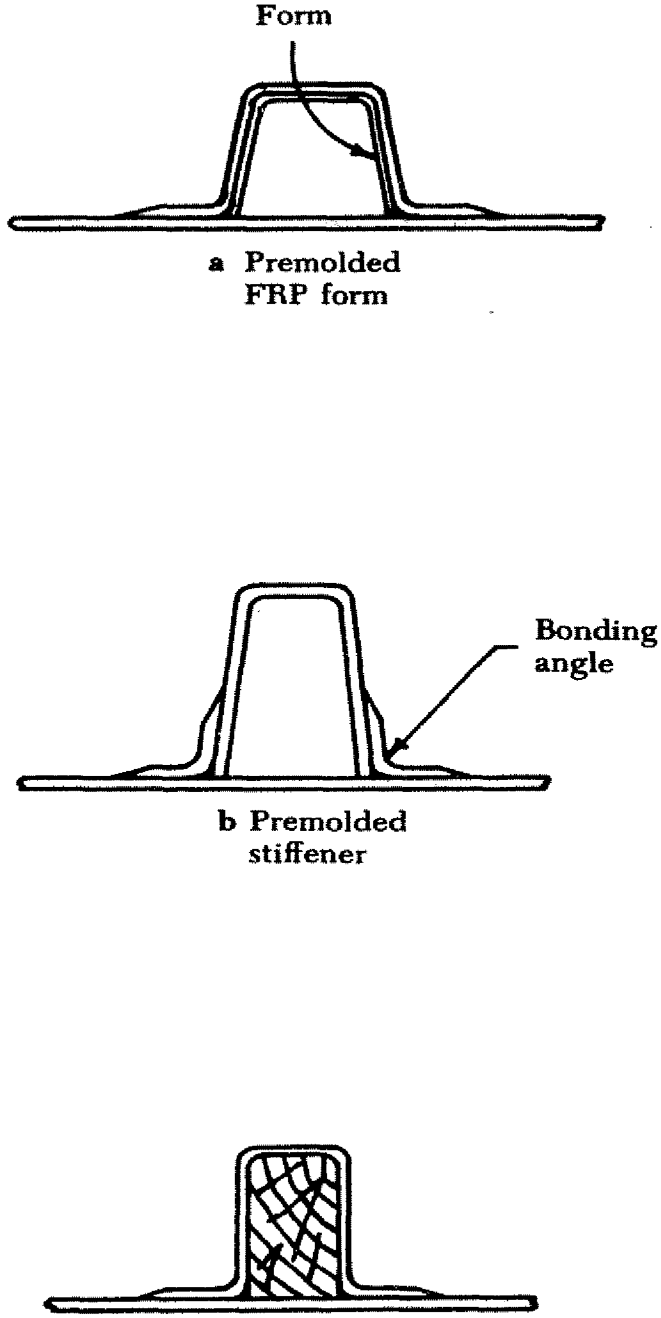


FIGURE 6.2
Stiffener Variations



a Premolded FRP form

b Premolded stiffener

c Encapsulated wood or plywood

FIGURE 6.3
Connection of Longitudinals to Transverses

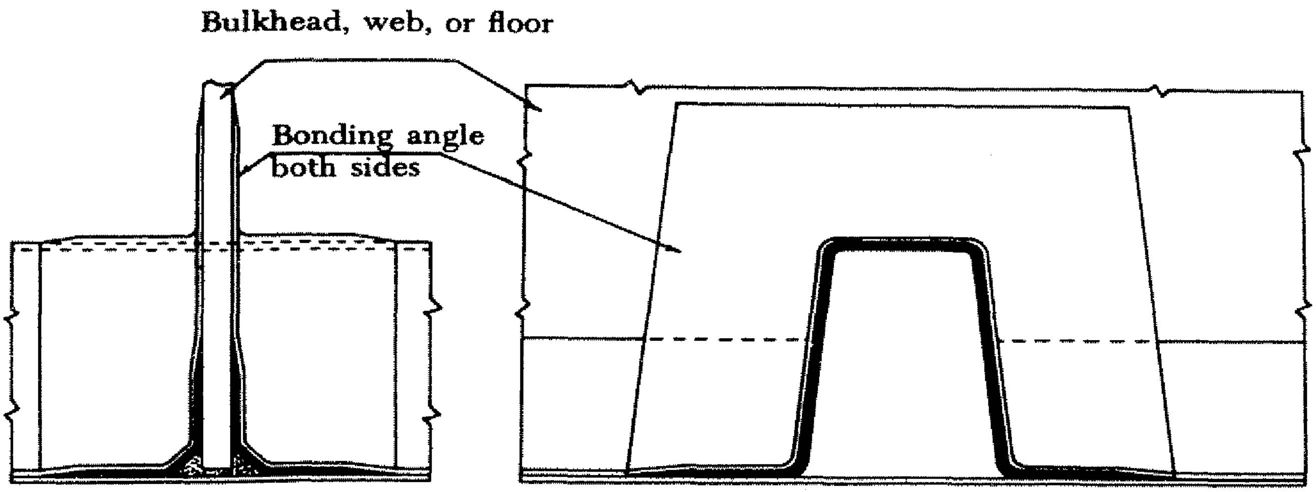


FIGURE 6.4
Bolted Scarph Joints

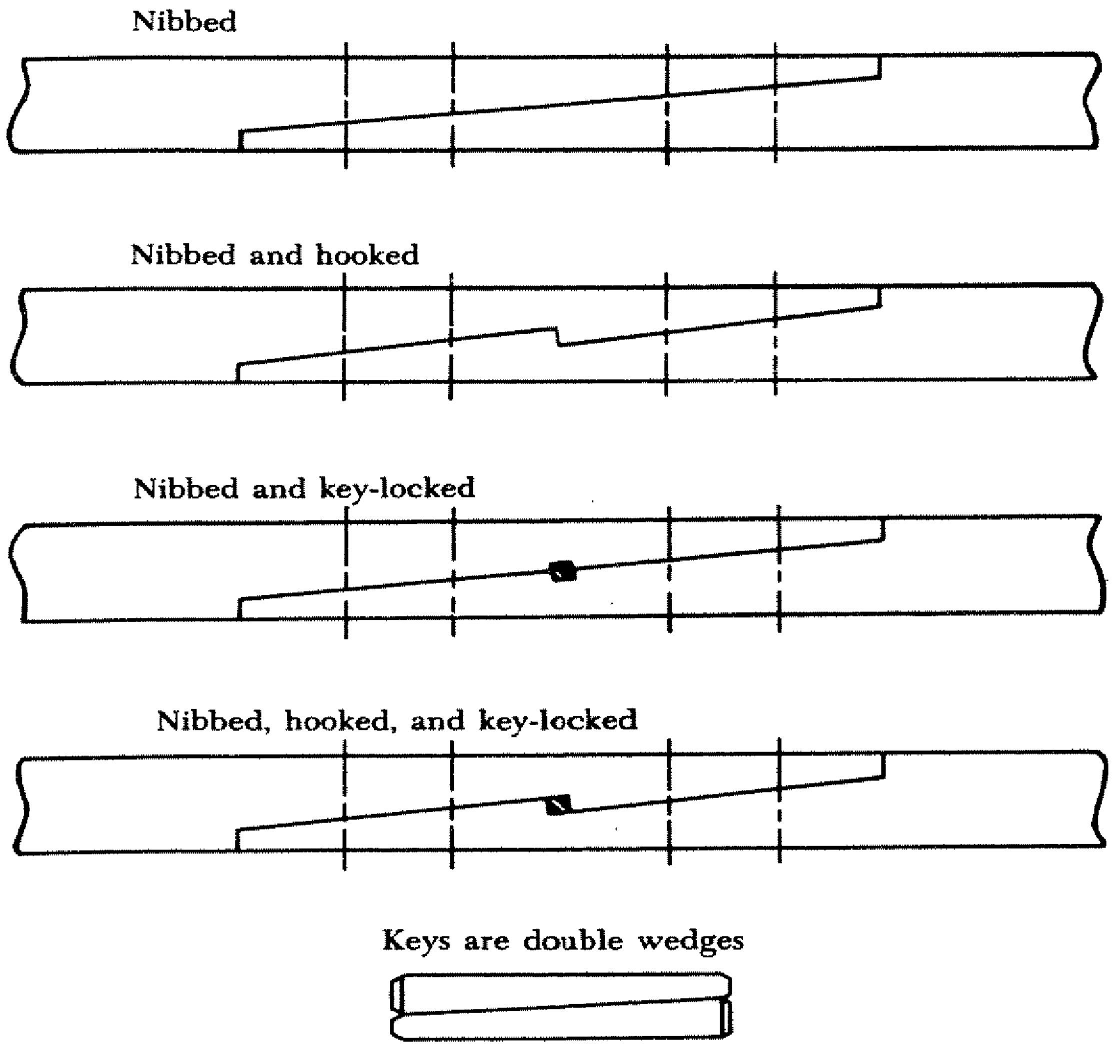


FIGURE 6.5
Engine Foundations

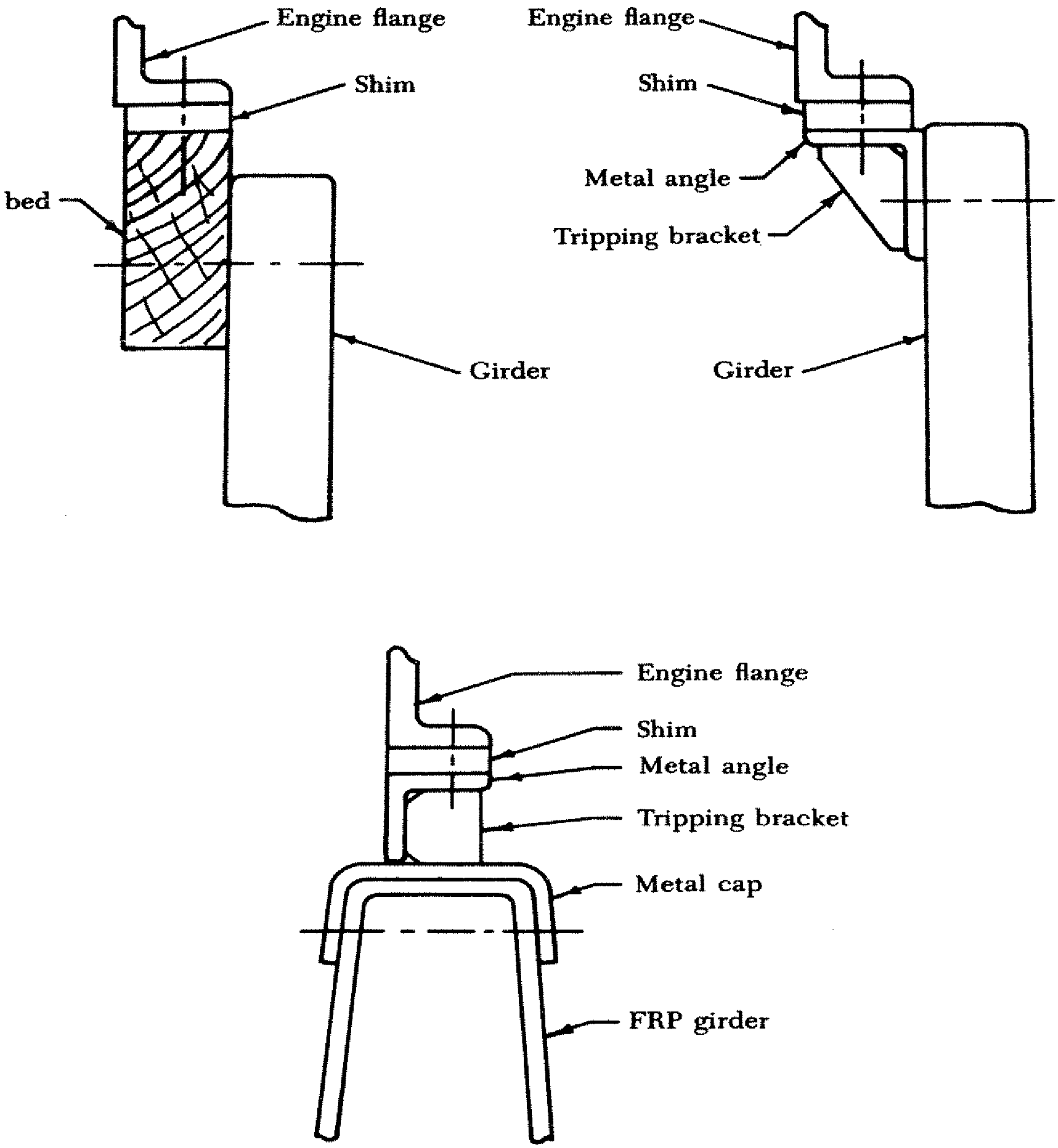


FIGURE 6.6
Boundary Angles for FRP Components

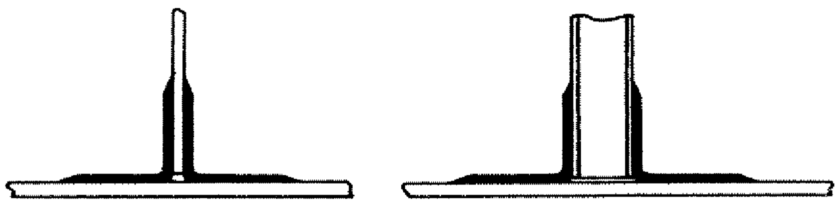
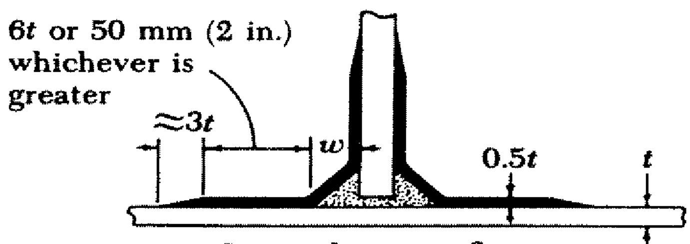
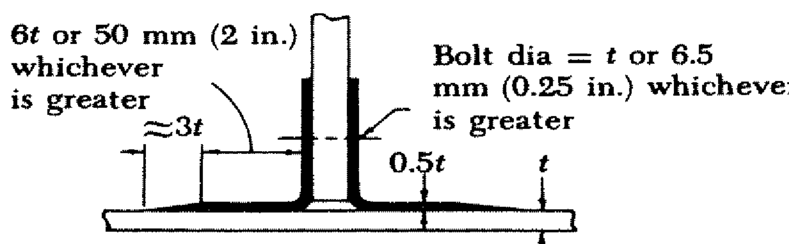


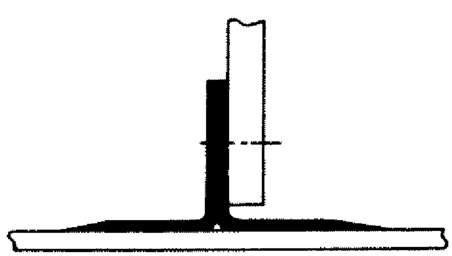
FIGURE 6.7
Boundary Angles Connecting Plywood or Wood to FRP



a Limited-service floor or bulkhead



b Unrestricted-service floor or bulkhead



c Alternative bolted boundary angles

FIGURE 6.8
Deck-to-Hull Weather Joints

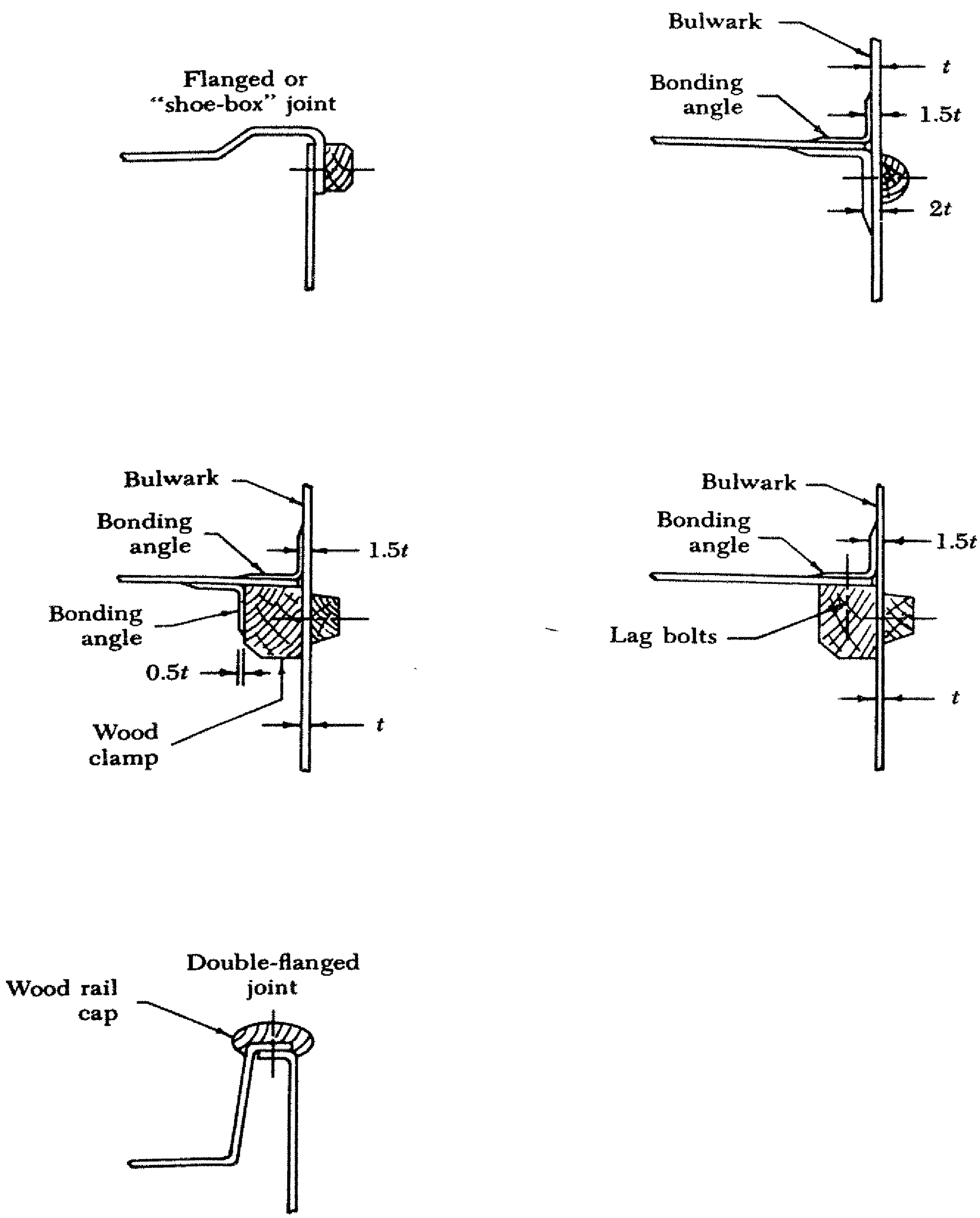


TABLE 6.1
Maximum Bolt Spacing

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

Inch Units

Length of Vessel L, ft	*Bolt Spacing, in.*	
	Unrestricted Service	*Limited Service*
30	6.0	9.0
40	6.5	9.5
50	7.0	10.0
60	7.5	10.5
70	8.0	11.0
80	8.5	11.5
90	9.0	12.0
100	9.5	12.5
110	10.0	13.0
120	10.5	13.5

TABLE 6.2
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

Inch Units

Length of Vessel L, ft	*Minimum Width of Overlap, in.*	*Minimum Bolt Diameter, in.*
30	2.5	0.25
40	3.0	0.30
50	3.5	0.35
60	4.0	0.40
70	4.5	0.45
80	5.0	0.50
90	5.5	0.55
100	6.0	0.60
110	6.5	0.65
120	7.0	0.70

SECTION 7

Bottom Structure

7.1 Bottom Shell Plating

7.1.1 General

"Bottom shell plating" refers to the single-skin FRP or sandwich laminate from the keel to 150 mm (6 in.) above the designed load waterline. Where a sea chest is installed, the thickness of the sea-chest boundary plating is to be not less than the required thickness of the bottom shell plating.

7.1.2 Single-Skin Laminates

a ***Displacement Vessels*** The thickness of the bottom shell plating in displacement vessels is to be not less than obtained from the following equation.

$$t = 0.0510s\sqrt[3]{kh} \text{ mm} \qquad t = 0.0343s\sqrt[3]{kh} \text{ in.}$$

t = thickness in mm or in.
s = span of shorter side of plating panel in mm or in.
k = coefficient that varies with bottom shell plating panel aspect ratio as shown in Table 7.1
h = distance in meters or feet from lower edge of plating to the freeboard deck at side

b ***Planing Vessels*** The thickness of the bottom shell plating in planing vessels is to be not less than either required by 7.1.2a or obtained from the following equations.

1 Where speed of vessel is less than or equal to 31 knots

$$t = 0.0384s\sqrt[3]{kV} \text{ mm or in.}$$

2 Where speed of vessel is greater than 31 knots

$$t = 0.0122s\sqrt[3]{kV^2} \text{ mm or in.}$$

t = thickness in mm or in.
s = span of shorter side of plating panel in mm or in.
k = coefficient that varies with bottom shell plating panel aspect ratio as shown in Table 7.1
V = sea speed of vessel in knots

c ***Curved Panels*** The thickness of the bottom shell plating in a curved panel (Figure 7.1) need not be greater than required by

7.1.2.a, and is to be not less than obtained from the following equation.

$$t = 0.04r\sqrt[3]{h/(k_1^2 - 1)} \text{ mm} \qquad t = 0.0269r\sqrt[3]{h/(k_1^2 - 1)} \text{ in.}$$

t = thickness in mm or in.
r = average radius of curvature in mm or in. between supports as shown in Figure 7.1
h = distance in m or ft from lower edge of plating to the freeboard deck at side
k_1 = coefficient that varies inversely to α as shown in Figure 7.2
α = one-half of angle, in degrees, between radii drawn to ends of curve as shown in Figure 7.1

d *Plate Keels in One-Piece Hulls* The thicknesses and widths of plate keels in one-piece hulls (Figure 7.3) are to be not less than obtained from the following equations.

$$t_1 = 1.5t \text{ mm or in.} \qquad w = B/10 \text{ m or ft}$$

t_1 = thickness of keel in mm or in.
t = thickness of bottom shell plating in mm or in. required by 7.1.2.a, b, and c
w = width of keel in m or ft
B = breadth of vessel as defined in Section 2

The thicknesses and widths of keels are to be maintained from stem to stern.

e *Plate Keels in Hulls Molded in Halves* The thicknesses of plate keels in hulls molded in halves (Figure 7.4) are to be not less than obtained from the following equation.

$$t_1 = 2t \text{ mm or in.}$$

t_1 = thickness of keel in mm or in.
t = thickness of bottom shell plating in mm or in. required by 7.1.2.a, b, and c

The two halves of the bottom shell plating are to be tapered to the centerline as shown by decreasing the widths of the plies at a slope of 1 : 24. The halves are to be connected with a tapered splice equal in thickness to and laminated in the same manner as the shell plating with the widths of the plies varied to butt against the widths of the plies in the shell plating. The remainder of the required thickness of the keel is to be provided by a doubler equal in thickness to and laminated in a manner equivalent to the shell plating. The width of the doubler is to be not less than obtained from the following equation.

$$w = B/10 \text{ m or ft}$$

w = width in m or ft
B = breadth of vessel as defined in Section 2

The width of the doubler plate also is to be not less than the width of the tapered splice plus 24 times the thickness of the shell plating.

f ***Vertical Keels and Skegs*** The thicknesses of vertical keels and skegs, and the distances these thicknesses are to be carried onto the bottoms of the vessels (Figure 7.5), are to be not less than obtained from the following equations.

$$t_1 = 1.5t \text{ mm or in.} \qquad w = 0.25H \text{ mm or in.}$$

t_1 = thickness of keel or skeg in mm or in.
t = thickness of bottom shell plating in mm or in. required by 7.1.2.a, b, and c
w = width in mm or in. of extension of keel or skeg thickness t_1 onto the bottom of the vessel
H = maximum depth of keel or skeg in mm or in.

Where a rudder shoe piece is attached to the bottom of a skeg, the scantlings of the skeg are to be suitably increased.

g ***Ballasted Vertical Keels*** The thicknesses of the bottoms of ballasted vertical keels and the distances these thicknesses are to be carried up the sides of the keels (Figure 7.6) are to be not less than obtained from the following equations.

$$t_2 = 2.0t \text{ mm or in.} \qquad H_1 = 0.5w_1 \text{ mm or in.}$$

t_2 = thickness of bottom of keel in mm or in.
t = thickness of bottom shell plating in mm or in. required by 7.1.2.a and c
H_1 = height in mm or in. of extension of thickness of bottom of keel up each side of the keel
w_1 = width of bottom of keel laminate in mm or in., or 254 mm (10 in.), whichever is greater

h ***Chines and Transoms*** In vessels of hard-chine form and in vessels having transom sterns, the thicknesses of the shells both sides of the knuckles and the distances these thicknesses are to be carried from the knuckles (Figure 7.7) are to be not less than obtained from the following equations.

$$t_1 = 1.5t \text{ mm or in.} \qquad w = B/40 \text{ m or ft}$$

t_1 = thickness of chine or transom-knuckle plating in mm or in.
t = thickness of bottom shell plating in mm or in. required by 7.1.2.a, b, and c
w = width in m or ft
B = breadth of vessel as defined in Section 2

i ***Local Strengthening and Compensation*** The bottom shell plating is to be increased in thickness in way of shaft struts, stuffing tubes, rudder posts, and other appendages and penetrations. All hull openings are to have well-rounded corners, and the exposed edges of the laminates are to be sealed with resin. All openings greater than 150 mm (6 in.) in diameter are to be compensated for by doublers.

7.1.3 Sandwich Panels

a ***Displacement Vessels*** Where sandwich construction is used for the bottom shell in a displacement vessel, the moment of inertia of both skins of a strip of the sandwich panel 25 mm (1 in.) wide is to be not less than the moment of inertia of an equal-width strip of a single-skin laminate that satisfies 7.1.2.a. The total thickness of the sandwich panel is to be not less than obtained from the following equation.

$$d = 0.0015k_2hs/u \text{ mm} \qquad d = 0.666k_2hs/u \text{ in.}$$

d = total thickness in mm or in.
k_2 = coefficient that varies inversely to the relative thickness of the core as shown in Figure 7.8, where t and t_1 are the thicknesses in mm or in. of the outer and inner skins
h = distance in m or ft from lower edge of sandwich to the freeboard deck at side
s = span of shorter side of sandwich panel in mm or in.
u = shear strength of plastic core in kg/mm^2 or psi

b ***Planing Vessels*** Where sandwich construction is used for a bottom shell in a planing vessel, the moment of inertia of both skins of a strip of the sandwich panel 25 mm (1 in.) wide is to be not less than the moment of inertia of an equal-width strip of a single-skin laminate that satisfies 7.1.2.b. The total thickness of the sandwich panel is to be not less than obtained from the following equations.

1 Where speed of vessel is less than or equal to 31 knots

$$d = 0.00041k_2Vs/u \text{ mm} \qquad d = 0.586k_2Vs/u \text{ in.}$$

2 Where speed of vessel is greater than 31 knots

$$d = 0.000013k_2V^2s/u \text{ mm} \qquad d = 0.019k_2V^2s/u \text{ in.}$$

d = total thickness in mm or in.
k_2 = coefficient that varies inversely to the relative thickness of the core as shown in Figure 7.8, where t and t_1 are the thicknesses in mm or in. of the outer and inner skins
V = sea speed of vessel in knots
s = span of shorter side of sandwich panel in mm or in.
u = shear strength of plastic core in kg/mm^2 or psi

7.2 Bottom Framing

7.2.1 General

All bottom shell plating is to be supported by girders; web frames or transverse bulkheads, or both; floors, and (where necessary) transverse or longitudinal frames, or both. In vessels equipped with sails, web frames or transverse bulkheads are to be fitted in way of the masts. Unless otherwise specifically approved, the ends of girders, web frames, and frames are to be attached to their supporting members. Limber holes are to be molded or cut in bottom stiffeners and nontight bulkheads to assure the free drainage of bilges to pump suctions. The edges of the holes are to be sealed in accordance with 6.2.

7.2.2 Girders

All single-bottom vessels having breadths between the chines or to the lower turns of the bilges equal to or exceeding 2.44 m (8.0 ft) are to have center or side girders, or both. The maximum spacing from girder to girder and from outer girder to chine or lower turn of bilge is to be 2.44 m (8.0 ft). The girders are to extend as far forward and aft as practicable. Longitudinal structural members such as wing-tank bulkheads, engine girders, vertical keels, and skegs may be considered as girders.

a *Displacement Vessels* The section modulus SM and moment of inertia I of each bottom girder in a displacement vessel, in association with the plating to which the girder is attached, are to be not less than obtained from the following equations.

FRP

$$SM = 19.38chsl^2 \text{ cm}^3 \qquad SM = 0.0102chsl^2 \text{ in.}^3$$

$$I = 34.85chsl^3 \text{ cm}^4 \qquad I = 0.0022chsl^3 \text{ in.}^4$$

Plywood or Encapsulated Plywood

$$SM = 121.41chsl^2 \text{ cm}^3 \qquad SM = 0.0639chsl^2 \text{ in.}^3$$

$$I = 47.53chsl^3 \text{ cm}^4 \qquad I = 0.0030chsl^3 \text{ in.}^4$$

Wood

$$SM = 60.80chsl^2 \text{ cm}^3 \qquad SM = 0.0320chsl^2 \text{ in.}^3$$

$$I = 47.53chsl^3 \text{ cm}^4 \qquad I = 0.0030chsl^3 \text{ in.}^4$$

c = 0.9
h = depth in m or ft from the center of area supported by the girder to the deck at side
s = girder spacing in m or ft
l = unsupported span of the girder in m or ft

b *Planing Vessels* The section modulus SM and moment of inertia I of each bottom girder in a planing vessel, in association with the plating to which the girder is attached, are to be not less than obtained from the following equations.

Where speed of vessel is less than or equal to 31 knots

FRP

$$SM = 4.17cVsl^2 \text{ cm}^3 \qquad SM = 0.0072cVsl^2 \text{ in.}^3$$

$$I = 14.97cVsl^3 \text{ cm}^4 \qquad I = 0.0031cVsl^3 \text{ in.}^4$$

Plywood or Encapsulated Plywood

$$SM = 26.0cVsl^2 \text{ cm}^3 \qquad SM = 0.0450cVsl^2 \text{ in.}^3$$

$$I = 20.28cVsl^3 \text{ cm}^4 \qquad I = 0.0042cVsl^3 \text{ in.}^4$$

Wood

$$SM = 13.0cVsl^2 \text{ cm}^3 \qquad SM = 0.0225cVsl^2 \text{ in.}^3$$

$$I = 20.28cVsl^3 \text{ cm}^4 \qquad I = 0.0042cVsl^3 \text{ in.}^4$$

Where speed of vessel is greater than 31 knots

FRP

$$SM = 0.1332cV^2sl^2 \text{ cm}^3 \qquad SM = 0.00023cV^2sl^2 \text{ in.}^3$$

$$I = 0.4828cV^2sl^3 \text{ cm}^4 \qquad I = 0.0001cV^2sl^3 \text{ in.}^4$$

Plywood or Encapsulated Plywood

$$SM = 0.8338cV^2sl^2 \text{ cm}^3 \qquad SM = 0.00144cV^2sl^2 \text{ in.}^3$$

$$I = 0.6276cV^2sl^3 \text{ cm}^4 \qquad I = 0.00013cV^2sl^3 \text{ in.}^4$$

Wood

$$SM = 0.4169cV^2sl^2 \text{ cm}^3 \qquad SM = 0.00072cV^2sl^2 \text{ in.}^3$$

$$I = 0.6276cV^2sl^3 \text{ cm}^4 \qquad I = 0.00013cV^2sl^3 \text{ in.}^4$$

c = 0.6
V = sea speed in knots
s = girder spacing in m or ft
l = unsupported span of the girder in m or ft

7.2.3 Web Frames

a ***Displacement Vessels*** In a displacement vessel the section modulus SM and moment of inertia I of each bottom web frame to the chine or upper turn of bilge, in association with the plating to which the web frame is attached, are to be not less than obtained from the following equations.

FRP

$$SM = 19.38chsl^2 \text{ cm}^3 \qquad SM = 0.0102chsl^2 \text{ in.}^3$$

$$I = 34.85chsl^3 \text{ cm}^4 \qquad I = 0.0022chsl^3 \text{ in.}^4$$

Plywood or Encapsulated Plywood

$$SM = 121.41chsl^2 \text{ cm}^3 \qquad SM = 0.0639chsl^2 \text{ in.}^3$$

$$I = 47.53chsl^3 \text{ cm}^4 \qquad I = 0.0030chsl^3 \text{ in.}^4$$

c = 0.9
s = spacing of web frames in m or ft. The maximum spacing between web frames or between web frames and transverse bulkheads is to be 2.44 in. (8.0 ft).
l = unsupported span in m or ft
h = vertical distance in meters or feet from the middle of l to the freeboard deck at side. In way of a deep tank, h is to be not less than required by Section 9.

b ***Planing Vessels*** In a planing vessel the section modulus SM and moment of inertia I of each bottom web frame, in association with the plating to which the web frame is attached, are to be not less than obtained from the following equations.

Where speed of vessel is less than or equal to 31 knots

FRP

$$SM = 4.17cVsl^2 \text{ cm}^3 \qquad SM = 0.0072cVsl^2 \text{ in.}^3$$

$$I = 14.97cVsl^3 \text{ cm}^4 \qquad I = 0.0031cVsl^3 \text{ in.}^4$$

Plywood or Encapsulated Plywood

$$SM = 26.0cVsl^2 \text{ cm}^3 \qquad SM = 0.0450cVsl^2 \text{ in.}^3$$

$$I = 20.28cVsl^3 \text{ cm}^4 \qquad I = 0.0042cVsl^3 \text{ in.}^4$$

Where speed of vessel is greater than 31 knots

FRP

$$SM = 0.1332cV^2sl^2 \text{ cm}^3 \qquad SM = 0.00023cV^2sl^2 \text{ in.}^3$$

$$I = 0.4828cV^2sl^3 \text{ cm}^4 \qquad I = 0.0001cV^2sl^3 \text{ in.}^4$$

Plywood or Encapsulated Plywood

$$SM = 0.8338cV^2sl^2 \text{ cm}^3 \qquad SM = 0.00144cV^2sl^2 \text{ in.}^3$$

$$I = 0.6276cV^2sl^3 \text{ cm}^4 \qquad I = 0.00013cV^2sl^3 \text{ in.}^4$$

c = 0.6
V = sea speed in knots
s = spacing of web frames in m or ft
l = unsupported span in m or ft

7.2.4 Floors

Floors may be required to be fitted in way of engines and the bottom forward. Additional floors may be required to be fitted to support masts, ballasted keels, shaft struts, and rudders.

7.2.5 Frames

a ***Displacement Vessels*** In a displacement vessel the section modulus SM and moment of inertia I of each FRP bottom frame, where fitted, to the chine or upper turn of bilge, in association with the plating to which the frame is attached, are to be not less than obtained from the following equations.

$$SM = 19.38chsl^2 \text{ cm}^3 \qquad SM = 0.0102chsl^2 \text{ in.}^3$$

$$I = 34.85chsl^3 \text{ cm}^4 \qquad I = 0.0022chsl^3 \text{ in.}^4$$

c = 0.85 for transverse frames
  = 1.08 for longitudinal frames
l = unsupported span in m or ft

h = vertical distance in m or ft from the middle of l to the freeboard deck at side. In way of a deep tank, h is to be not less than required by Section 9.
s = frame spacing in m or ft

b *Planing Vessels* In a planing vessel the section modulus SM and moment of inertia I of each FRP bottom frame, where fitted, to the chine or upper turn of bilge, in association with the plating to which the frame is attached, are to be not less than obtained from the following equations.

Where speed of vessel is less than or equal to 31 knots

$$SM = 4.17cVsl^2 \text{ cm}^3 \qquad SM = 0.0072cVsl^2 \text{ in.}^3$$

$$I = 14.97cVsl^3 \text{ cm}^4 \qquad I = 0.0031cVsl^3 \text{ in.}^4$$

Where speed of vessel is greater than 31 knots

$$SM = 0.1332cV^3sl^2 \text{ cm}^3 \qquad SM = 0.00023cV^2sl^2 \text{ in.}^3$$

$$I = 0.4828cV^2sl^3 \text{ cm}^4 \qquad I = 0.0001cV^2sl^3 \text{ in.}^4$$

c = 0.6
V = sea speed in knots
s = frame spacing in m or ft
l = unsupported span of the frame in m or ft

TABLE 7.1
Flat Panel Coefficients

k	*aspect ratio*
0.028	>2.0 : 1
0.028	2.0 : 1
0.027	1.9 : 1
0.027	1.8 : 1
0.026	1.7 : 1
0.025	1.6 : 1
0.024	1.5 : 1
0.023	1.4 : 1
0.021	1.3 : 1
0.019	1.2 : 1
0.016	1.1 : 1
0.014	1.0 : 1

FIGURE 7.1
Curved Panel

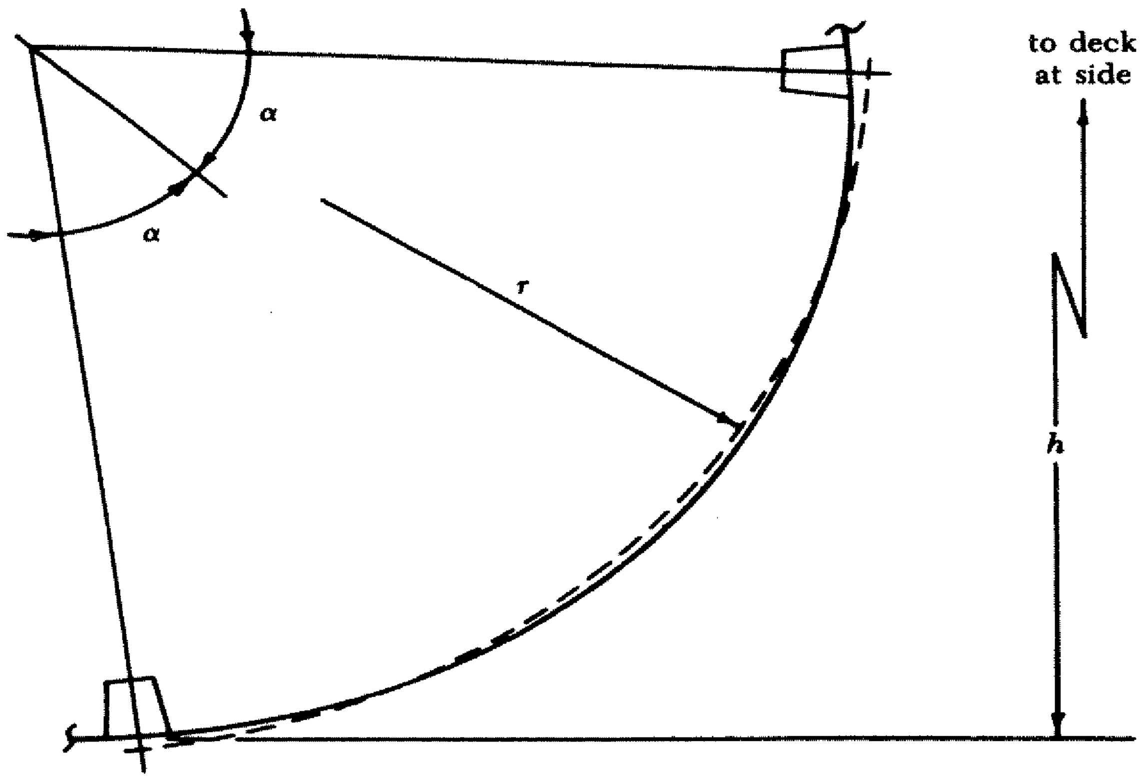
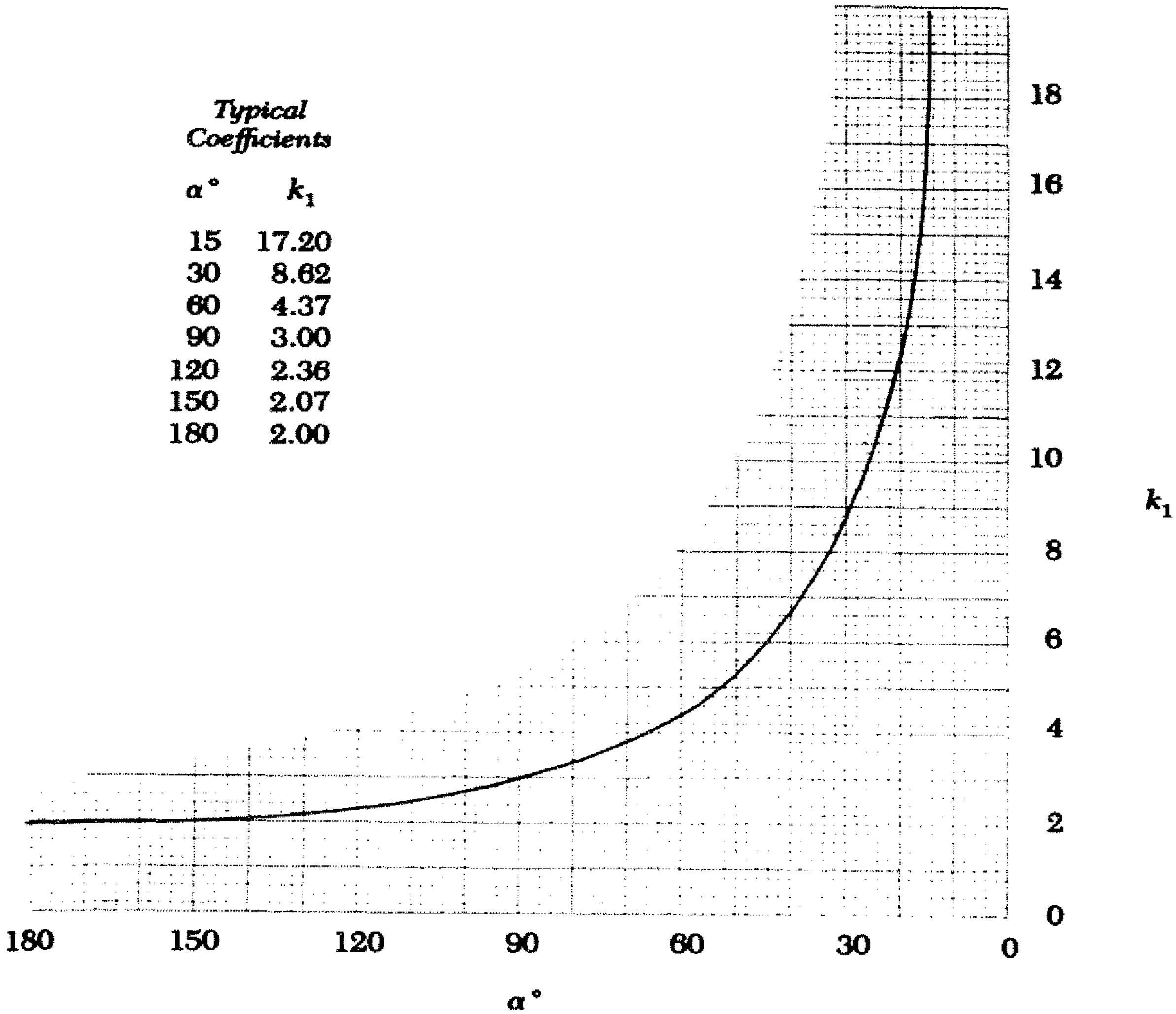


FIGURE 7.2
Curved Panel Coefficients



Typical Coefficients

$\alpha°$	k_1
15	17.20
30	8.62
60	4.37
90	3.00
120	2.36
150	2.07
180	2.00

FIGURE 7.3
Plate Keel in One-Piece Hull

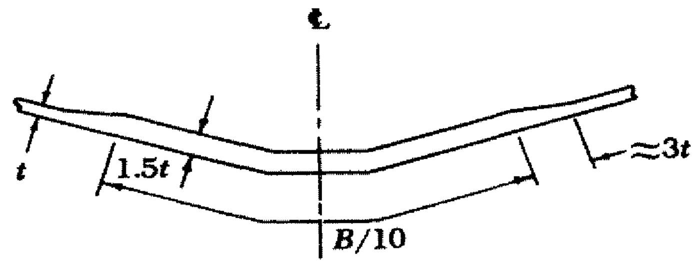


FIGURE 7.4
Plate Keel in Hull Molded in Halves

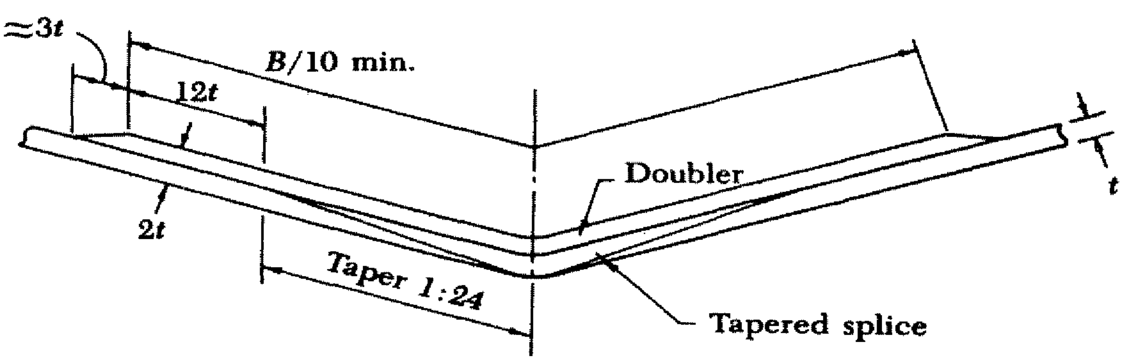


FIGURE 7.5
Vertical Keel or Skeg

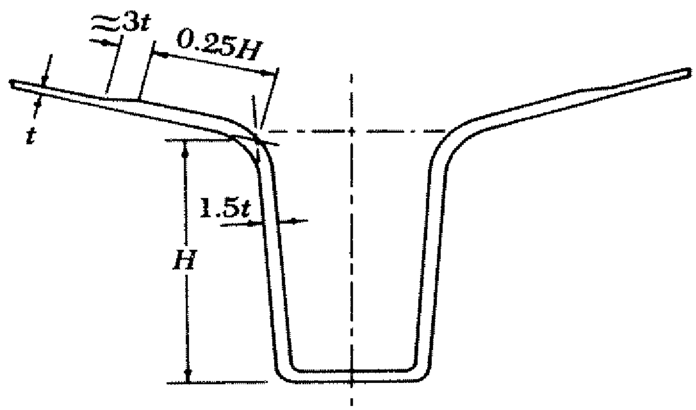


FIGURE 7.6
Ballasted Vertical Keels

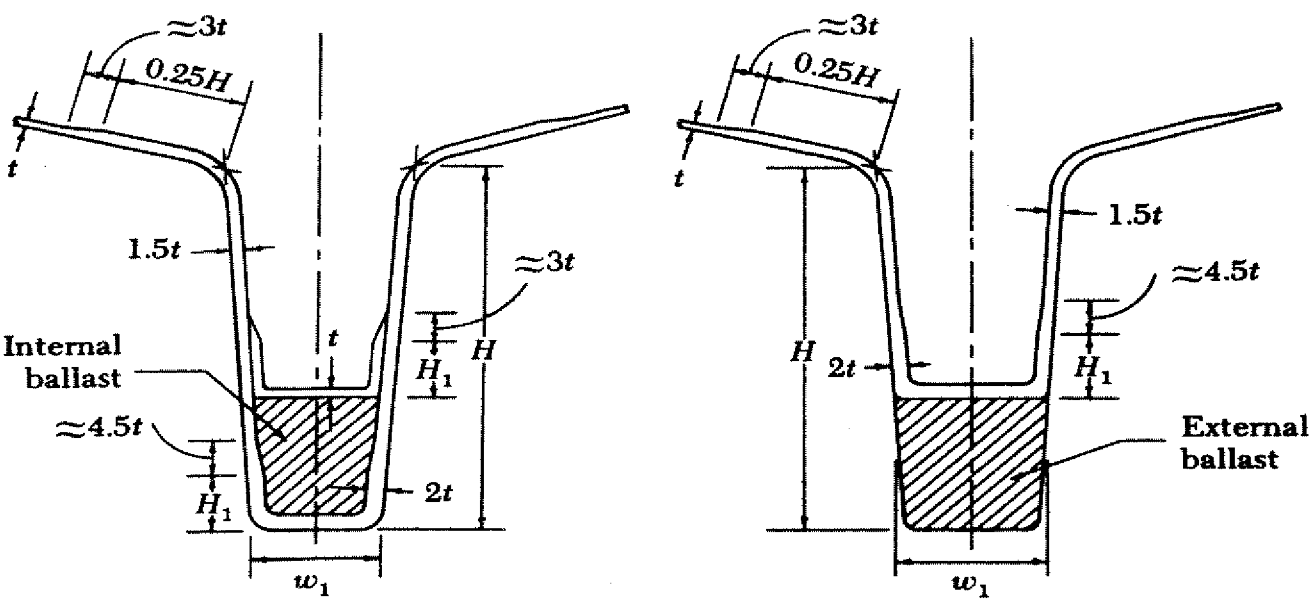


FIGURE 7.7
Chine or Transom

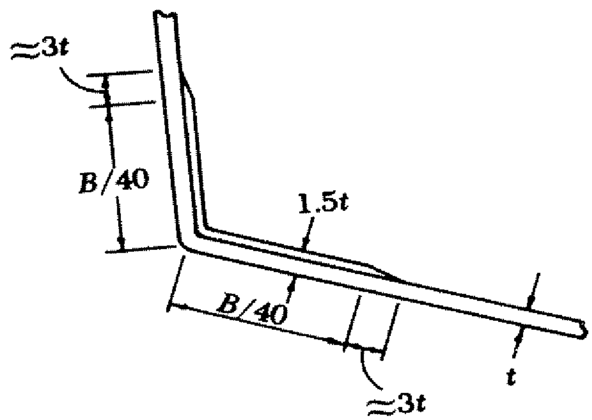
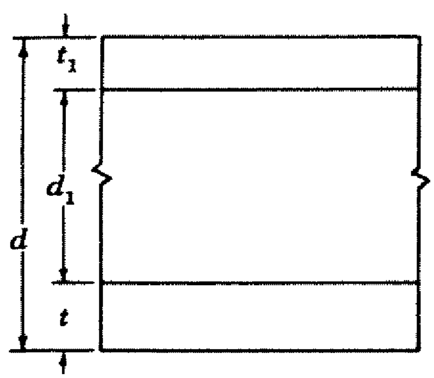


FIGURE 7.8
Sandwich Panel Coefficients



k_2	$\dfrac{d_1}{0.5(t + t_1)}$
0.86	2
0.79	4
0.76	6
0.74	8
0.72	10
0.71	12
0.71	14
0.70	16
0.70	18
0.70	20

SECTION 8

Side Structure

8.1 Side Shell Plating

8.1.1 General

"Side shell plating" refers to the single-skin FRP or sandwich laminate from 150 mm (6 in.) above the designed load waterline to the freeboard deck at side.

8.1.2 Single-Skin Laminates

a ***Flat Panels*** The thickness of the side shell plating in flat or effectively flat panels is to be not less than obtained from the following equation.

$$t = 0.0510s\sqrt[3]{kh} \text{ mm} \qquad t = 0.0343s\sqrt[3]{kh} \text{ in.}$$

t = thickness in mm or in.
s = span of shorter side of panel in mm or in.
k = coefficient that varies with panel aspect ratio as shown in Table 7.1
h = distance in m or ft from lower edge of the side plating to the freeboard deck at side

b ***Curved Panels*** The thickness of the side shell plating in curved panels (Figure 7.1) need not be greater than required by 8.1.2a, and is to be not less than obtained from the following equation.

$$t = 0.04r\sqrt[3]{h/(k_1^2 - 1)} \text{ mm} \qquad t = 0.0269r\sqrt[3]{h/(k_1^2 - 1)} \text{ in.}$$

t = thickness in mm or in.
r = average radius of curvature in mm or in. between supports as shown in Figure 7.1
h = distance in m or ft from lower edge of the side plating to the freeboard deck at side
k_1 = coefficient that varies inversely to α as shown in Figure 7.2
α = one-half of angle, in degrees, between radii drawn to ends of curve

c ***Sheer Strakes*** The thicknesses of sheer strakes in vessels having lengths L of or greater than 30 m (100 ft) are to be not less than one and one-half times the required side-shell thicknesses. The sheer-strake thicknesses are to be maintained over the amidships 0.5 L, and may be gradually reduced to the required side-shell thicknesses forward and aft of the amidships 0.5 L. The width of each sheer strake is to be not less than 0.02 L.

d ***Stems*** The keel reinforcements required by 7.1.2d, e, f, and g, are to be carried up to form stems. The thicknesses may be gradually reduced until at the freeboard deck they are midway between the required keel thicknesses and the required side-shell thicknesses. The widths may be gradually reduced until at the freeboard deck they are 60% of the required keel widths. Stems are to be supported adequately by breasthooks or webs, or both.

e ***Transoms*** In vessels having transom sterns the thicknesses of the transoms are to be not less than required by 8.1.2a and b. If the vessels are driven by inboard-outboard engines, or if necessitated by the rigs of the vessels, the transoms are to be suitably stiffened. In way of the knuckles between side shells and transoms, the laminate thicknesses are to be increased 50% (Figure 8.1). The distance these increased thicknesses are to be carried from the knuckles are to be not less than obtained from the following equation.

$$W = B/40 \text{ m or ft}$$

W = width of knuckle plating in m or ft
B = breadth of vessel as defined in Section 2

f ***Local Strengthening for Sailing Vessels*** In vessels equipped with sails the required side-shell thicknesses are to be increased 25% in way of the mast, shrouds, and chain plates. The fore-and-aft distance of the increase in shell thickness is to be not less than the beam of the vessel at the mast.

g ***Local Strengthening for Vessels Subject to Impact*** For vessels subject to impact during routine operations, side-shell thicknesses 25% greater than the required side-shell thicknesses are suggested.

h ***Local Strengthening for Fishing or Research Vessels***

1 *General* In vessels used for fishing (netting or angling) or for research, metal wear plates or rollers are suggested at all places where fishing or research methods or gear will subject the shell plating to severe wear. Special strengthening may be required in areas where small boats are regularly launched, retrieved, or stowed. Special strengthening may be required also in areas where the vessel makes contact with another vessel when pursing, hauling, brailing, pumping, loading, unloading, or running together.

2 *Vessels with Side Trawls* In way of trawl gallows the minimum thickness of the side shell plating is to be 30% greater than the thickness of the side shell plating obtained from 8.1.2a and b. In a vessel fitted with two or more gallows on each side or one side only, the minimum thickness of the side shell plating between the gallows is to be 20% greater than the thickness of the side shell plating obtained from 8.1.2a and b. Half-round metal rub bars are to be installed at the top of the bulwark, the top of the sheerstrake, and the designed load waterline. These bars are to extend from not less than $0.0225L$ forward of the forward leg of each gallow to not less than $0.045L$ aft of said gallows leg.

Additional half-round rub bars are to be installed vertically or diagonally between the longitudinal rub bars in such a manner that the shell plating cannot be subject to abrasion by the gear being handled by the gallows.

3 *Vessels with Stern Trawls* The minimum thickness of the stern trawl chute is to be 30% greater than the thickness of the side shell plating obtained from 8.1.2a, b, and c. The minimum thickness of the chute sides is to be 10% greater than the thickness of the side shell plating obtained from 8.1.2a and b. Metal wear plates are suggested at parts of the chute bottom and sides subject to severe wear.

i *Compensation* Compensation is to be made for large openings in the shell plating where required to maintain the longitudinal and transverse strength of the hull. All openings are to have well-rounded corners. Cargo and gangway openings are to be kept well clear of other discontinuities in the hull girder. Around hawse pipes, metal wear plates, of sufficient breadth to prevent damage from the flukes of stockless anchors, are to be fitted. Each portlight, where fitted, is to have its upper edge a minimum of two times its diameter, or in the case of the rectangular port, two times its height, below the edge of the deck above it. Exposed edges of laminates are to be sealed with resin.

j *Breaks* The side plating of superstructures, including forecastles and poops, is to extend beyond the ends of the superstructures in such fashion as to provide long, gradual tapers. Gangways, large freeing ports, and other sizable openings in the shell or bulwarks are to be kept clear of the breaks. Any holes that must unavoidably be cut in the shell adjacent to the breaks are to be kept as small as possible and are to be circular or oval in form.

8.1.3 Sandwich Panels

Where sandwich construction is used for a side shell, the moment of inertia of the skins of a strip of the sandwich panel 25 mm (1 in.) wide is to be not less than the moment of inertia of an equal-width strip of a single-skin laminate that satisfies 8.1.2a. The total thickness of the sandwich panel is to be not less than obtained from the following equation.

$$d = 0.0015k_2hs/u \text{ mm} \qquad d = 0.666k_2hs/u \text{ in.}$$

d = total thickness in mm or in.

k_2 = 0.89 for balsa. k_2 for other core materials listed in 4.7 varies inversely to the relative thickness of the core as shown in Figure 7.8, where t and t_1 are the thicknesses in mm or in. of the outer and inner skins

h = distance in m or ft from lower edge of side-shell sandwich panel to the freeboard deck at side

s = span of shorter side of sandwich panel in mm or in.

u = shear strength of core material in kg/mm^2 or psi

In areas where increases in thickness of single-skin laminates are required by 8.1.2, sandwich-panel moments of inertia and thicknesses are to be equivalently increased. Where the increases in 8.1.2 are for impact or wear, the thickness of the sandwich-panel external skin is to be increased by the same amount as that required for the single-skin laminate.

8.2 Side Framing

8.2.1 General

All side-shell plating is to be supported by web frames or transverse bulkheads, or both; and (where necessary) by stringers, longitudinal frames, or transverse frames, or combinations of stringers and frames. In vessels equipped with sails, web frames or transverse bulkheads are to be fitted in way of the masts. Joiner-work effectively connected to shell plating will be subject to special consideration as a possible substitute for side framing.

8.2.2 Web Frames

The section modulus SM and moment of inertia I of each FRP side web frame above the chine or upper turn of bilge, in association with the plating to which the web frame is attached, are to be not less than obtained from the following equations.

FRP

$$SM = 19.38chsl^2 \text{ cm}^3 \qquad SM = 0.0102chsl^2 \text{ in.}^3$$

$$I = 34.85chsl^3 \text{ cm}^4 \qquad I = 0.0022chsl^3 \text{ in.}^4$$

Plywood or Encapsulated Plywood

$$SM = 121.41chsl^2 \text{ cm}^3 \qquad SM = 0.0639chsl^2 \text{ in.}^3$$

$$I = 47.53chsl^3 \text{ cm}^4 \qquad I = 0.0030chsl^3 \text{ in.}^4$$

c = 0.9
s = spacing of web frames in m or ft
l = unsupported straight-line span in m or ft
h = vertical distance in m or ft from the middle of l to the freeboard deck at side. In way of a deep tank, h is to be not less than required by Section 9.

8.2.3 Stringers

All transversely framed vessels having depths above the chine or upper turn of bilge greater than 2.44 m (8.0 ft) are to have side stringers. The maximum spacing from stringer to stringer and from top stringer to freeboard deck at side is to be 2.44 m (8.0 ft). The section modulus SM and moment of inertia I of each FRP stringer in association with the plating to which the stringer is attached are to be not less than obtained from the following equations

$$SM = 19.38chsl^2 \text{ cm}^3 \qquad SM = 0.0102chsl^2 \text{ in.}^3$$

$$I = 34.85chsl^3 \text{ cm}^4 \qquad I = 0.0022chsl^3 \text{ in.}^4$$

$c = 0.9$
s = mean height of the area of the side supported by the stringer in m or ft
h = vertical distance in m or ft from the middle of s to the freeboard deck at side
l = span in m or ft between web frames or between web frame and bulkhead

8.2.4 Frames

The section modulus SM and moment of inertia I of each FRP side frame, where fitted, either longitudinal or transverse, above the chine or upper turn of bilge, in association with the plating to which the frame is attached, are to be not less than obtained from the following equations.

$$SM = 19.38chsl^2 \text{ cm}^3 \qquad SM = 0.0102chsl^2 \text{ in.}^3$$

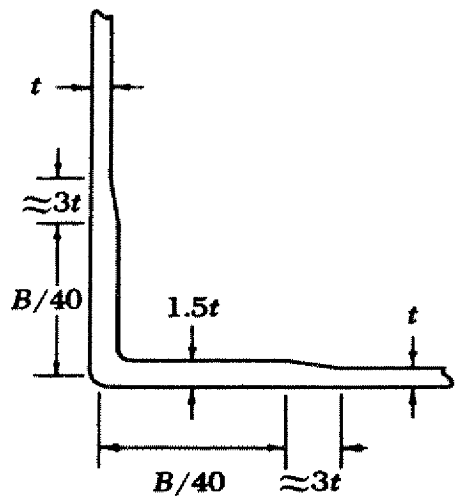
$$I = 34.85chsl^3 \text{ cm}^4 \qquad I = 0.0022chsl^3 \text{ in.}^4$$

$c = 1.0$
s = frame spacing in m or ft
h = vertical distance in m or ft from a longitudinal frame or from the midlength of a vertical frame to the freeboard deck at side
l = unsupported straight-line span in m or ft

8.2.5 Vessels Subject to Impact

For vessels subject to impact loadings during routing operation, section moduli and moments of inertia 25% greater than obtained in 8.2.2, 8.2.3, and 8.2.4 are suggested.

FIGURE 8.1
Side Plating—Transom



SECTION 9

Tanks

9.1 General

Boundary bulkheads and tight divisions of all FRP integral tanks are to be constructed in accordance with the requirements of this section. The arrangement of all integral tanks, their intended service, and the heights of the overflow pipes are to be indicated clearly on the drawings submitted for approval. No integral tanks are to be fitted in way of or are to employ sandwich construction. No stiffeners within integral tanks are to penetrate the tank boundaries. No gasoline tanks are to be fitted integrally.

All internal surfaces of FRP tanks are to be covered with fiberglass mat or chopped strand weighing at least 600 grams per square meter (2 ounces per square foot). This covering is to be in addition to the scantlings required in this section. A heavy coat of the laminating resin, or other suitable coating, is to be applied to this covering.

Where potable water tanks are fitted, water closets are not to be installed on the tank tops, soil lines are not to be run over the tank tops, and pipes containing nonpotable liquids are not to be run through the tanks.

Scantlings of pressurized tanks will be subject to special consideration.

9.2 Plating

The thickness of FRP plating in integral-tank boundary bulkheads and tight divisions is to be not less than obtained from the following equation.

$$t = 0.0510s\sqrt[3]{kh} \text{ mm} \qquad t = 0.0343s\sqrt[3]{kh} \text{ in.}$$

t = thickness in mm or in.

s = span of shorter side of plating panel in mm or in.

k = coefficient that varies with plating panel aspect ratio as shown in Table 7.1

h = greatest of the distances in m or ft from the lower edge of the plating to:

- A point located at two-thirds of the distance to the freeboard deck;
- A point located at two-thirds of the distance from the top of the tank to the top of the overflow; or
- A point located above the top of the tank not less than the greater of the following:

1 $0.01\ L + 0.15$ m (0.5 ft) where L is as defined in Section 2
2 0.46 m (1.5 ft)

In double-bottom construction where no ceiling is fitted, the thickness of the tank-top plating is to be increased 50% under cargo hatchways.

9.3 Stiffeners

The section modulus *SM* and moment of inertia *I* of each integral-tank FRP stiffener in association with the plating to which it is attached are to be not less than obtained from the following equations.

$$SM = 19.38chsl^2 \text{ cm}^3 \qquad SM = 0.0102chsl^2 \text{ in.}^3$$

$$I = 34.85chsl^3 \text{ cm}^4 \qquad I = 0.0022chsl^3 \text{ in.}^4$$

c = 1.0 for sniped stiffeners
= 0.75 for stiffeners having efficient end attachments
s = stiffener spacing in m or ft
l = unsupported straight-line span in m or ft. Where girders are fitted, l is the distance from the end attachment to the first girder or the distance between girders.
h = greatest of the distances, in m or ft, from the middle of l to:

a a point located at two-thirds of the distance from the middle of l to the freeboard deck;
b a point located at two-thirds of the distance from the top of the tank to the top of the overflow; or
c a point located above the top of the tank not less than the greater of the following:

$0.01\ L + 0.15$ m (0.5 ft) where L is as defined in Section 2
0.46 m (1.5 ft)

9.4 Girders and Webs

The section modulus *SM* and moment of inertia *I* of each girder supporting bulkhead stiffeners in FRP integral tanks, in association with the plating to which the girder is attached, are to be not less than obtained from the following equations. The section modulus *SM* and moment of inertia *I* of each girder or web supporting frames or beams in FRP integral tanks, in association with the plating to which the girder or web is attached, are to be not less than obtained from Section 8 or Section 11, or the following equations, whichever is the greater.

$$SM = 19.38chsl^2 \text{ cm}^3 \qquad SM = 0.0102chsl^2 \text{ in.}^3$$

$$I = 34.85chsl^3 \text{ cm}^4 \qquad I = 0.0022chsl^3 \text{ in.}^4$$

c = 0.9
s = sum of half lengths in m or ft (on each side of the girder or web) of the stiffeners, frames, or beams supported by the girder or web
l = unsupported length of girder or web in m or ft
h = vertical distance in m or ft from the middle of s in the case of a girder or from the middle of l in the case of a web to the same heights to which h for the stiffeners is measured (see 9.3)

9.5 Cofferdams

Cofferdams are to be fitted between all FRP integral tanks containing dissimilar liquids.

9.6 Access, Lightening, Air, and Drainage Holes

All tanks in double bottoms and all other integral tanks with depths greater than 1.0 m (3.28 ft) are to have access holes, and the nontight members in such tanks are to have lightening holes, sufficient in size and number to assure accessibility to all parts of the tanks. The proposed locations and sizes of the holes are to be indicated on the drawings submitted for approval.

Access-hole covers are to be metal or FRP, and typically are to be secured to the tanks as shown in Figure 9.1. Bolts or studs are to be not less than 6.5 mm (0.25 in.) in diameter, their spacing, center to center, is to be not more than six bolt diameters, and they are to be set in from the edges of the covers a distance not less than shown. In cargo holds where no ceiling is fitted, the covers are to be protected against damage caused by the cargo.

Air and drainage holes are to be cut in all nontight parts of integral tanks to assure the free escape of gases to the vents and the free drainage of liquids to the suctions.

Exposed edges of laminates in way of all holes are to be sealed with resin.

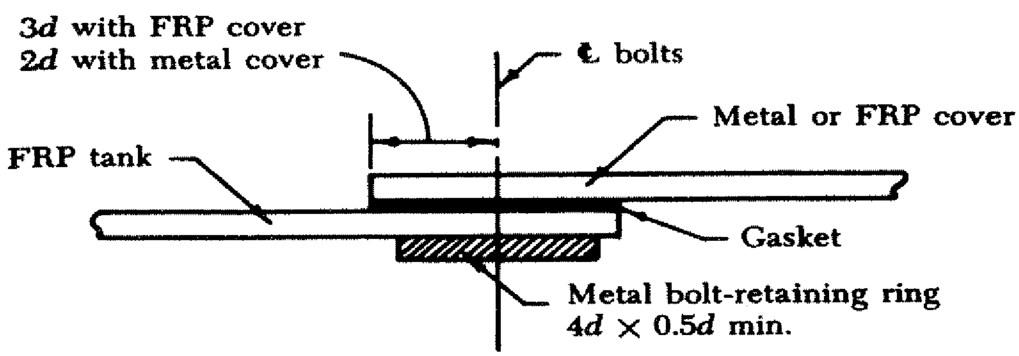
9.7 Testing

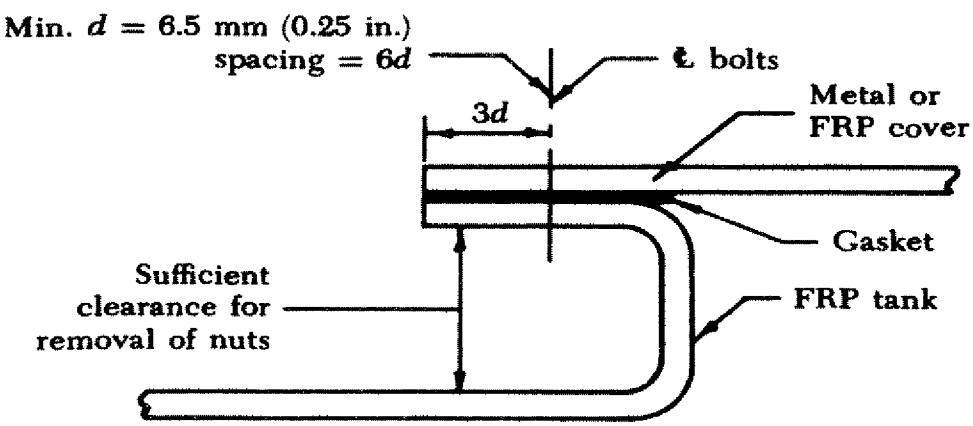
All integral tanks are to be tested hydrostatically. The test head of water is to be to the top of the overflow or to two-thirds of the distance from the top of the tank to the freeboard deck, whichever is greater.

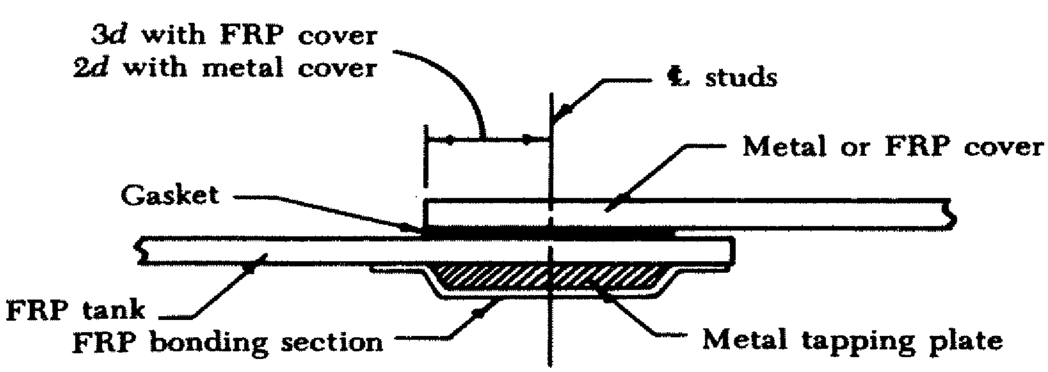
Testing is to be conducted after all work on the tanks is completed, and may be conducted after the vessel is launched.

FIGURE 9.1
Access-hole Fittings

d = diameter of fastenings







SECTION 10

Watertight Bulkheads

10.1 General

All vessels having length L, as defined in Section 2, of or exceeding 15 m (50 ft) are to be provided with watertight bulkheads in accordance with this section. The location, extent, and arrangement of each watertight bulkhead are to be indicated clearly on the plans submitted for approval.

10.2 Arrangement of Watertight Bulkheads

10.2.1 Collision Bulkheads

Collision bulkheads are to be fitted not less than $0.05L$ abaft the stem at the designed load waterline. The bulkheads are to be intact except for penetrations as permitted in 10.5, and are to extend to the freeboard deck, preferably in one plane. In vessels having long superstructures at the forward end, the bulkheads are to be extended weathertight to the superstructure deck. Provided the extensions of the bulkhead are not less than $0.05L$ abaft the stem at the designed load waterline, they need not be fitted directly over the collision bulkhead; in such cases, the part of the freeboard deck that forms the step is to be made weathertight.

10.2.2 Engine Room

The engine room is to be enclosed by watertight bulkheads extending to the freeboard deck. Where the arrangement of a vessel interferes with extending engine-room bulkheads to the freeboard deck, the bulkheads and the deck to which they are extended will be subject to special consideration.

10.2.3 Chain Lockers

Chain lockers located abaft collision bulkheads or extending into forepeak deep tanks are to be watertight.

10.3 Construction of Watertight Bulkheads

10.3.1 Plating

The thickness of plating in watertight bulkheads is to be not less than obtained from the following equations.

a ***FRP Plating***

$$t = 0.0404s\ \sqrt[3]{kh}\ \text{mm} \qquad t = 0.0272s\ \sqrt[3]{kh}\ \text{in.}$$

b ***Plywood Plating***

$$t = 0.0270s\sqrt{k_3 h}\ \text{mm} \qquad t = 0.0149s\sqrt{k_3 h}\ \text{in.}$$

t = thickness in mm or in.
s = span of shorter side of plating panel in mm or in.
h = distance from the lower edge of the plating to the bulkhead deck at center in m or ft
k = coefficient that varies with bulkhead plating panel aspect ratio as shown in Table 7.1
k_3 = coefficient that varies with bulkhead plating panel aspect ratio as shown in Table 10.1

c ***Sandwich Panels*** Where sandwich construction is used for a bulkhead, the moment of inertia of the skins of a strip of the sandwich panel 25 mm (1 in.) wide is to be not less than the moment of inertia of an equal-width strip of an FRP single-skin laminate that satisfies 10.3.1a. The total thickness of the sandwich panel is to be not less than obtained from the following equation.

$$d = 0.0015k_2hs/u\ \text{mm} \qquad d = 0.666k_2hs/u\ \text{in.}$$

d = total thickness in mm or in.
k_2 = 0.89 for balsa. k_2 for other core materials listed in 4.7 varies inversely to the relative thickness of the core as shown in Figure 7.8, where t and t_1 are the thicknesses in mm or in. of the outer and inner skins
h = distance from the lower edge of the sandwich panel to the bulkhead deck at center in m or ft
s = span of shorter side of sandwich panel in mm or in.
u = shear strength of core material in kg/mm^2 or psi

The plating of collision bulkheads is to be obtained from the above equations using a spacing 150 mm (6 in.) greater than that actually adopted.

10.3.2 Stiffeners

The section modulus SM and moment of inertia I of each bulkhead stiffener in association with the plating to which it is attached are to be not less than obtained from the following equations.

a ***FRP Stiffeners***

$$SM = 19.38chsl^2\ \text{cm}^3 \qquad SM = 0.0102chsl^2\ \text{in.}^3$$

$$I = 34.85chsl^3\ \text{cm}^4 \qquad I = 0.0022chsl^3\ \text{in.}^4$$

b ***Plywood and Encapsulated-Plywood Stiffeners***

$$SM = 121.41chsl^2\ \text{cm}^3 \qquad SM = 0.0639chsl^2\ \text{in.}^3$$

$$I = 47.53chsl^3\ \text{cm}^4 \qquad I = 0.0030chsl^3\ \text{in.}^4$$

c ***Wood Stiffeners***

$$SM = 60.80chsl^2 \text{ cm}^3 \qquad SM = 0.0320chsl^2 \text{ in.}^3$$

$$I = 47.53chsl^3 \text{ cm}^4 \qquad I = 0.0030chsl^3 \text{ in.}^4$$

c = 0.58 for sniped stiffeners
= 0.46 for stiffeners having efficient end attachments
s = spacing of stiffeners in m or ft
l = distance in m or ft between the heels of the end attachments. Where horizontal girders are fitted, l is the distance from the heel of the end attachment to the first girder, or the distance between the horizontal girders.
h = distance from the middle of l to the bulkhead deck at center in m or ft

The section moduli and moments of inertia of stiffeners on collision bulkheads are to be increased by 25% over the section moduli and moments of inertia of stiffeners on ordinary watertight bulkheads.

10.3.3 Girders and Webs

The section modulus SM and moment of inertia I of each horizontal girder or vertical web supporting bulkhead stiffeners, in association with the plating to which the girder or web is attached, are to be not less than obtained from the following equations.

a ***FRP Girders and Webs***

$$SM = 19.38chsl^2 \text{ cm}^3 \qquad SM = 0.0102chsl^2 \text{ in.}^3$$

$$I = 34.85chsl^3 \text{ cm}^4 \qquad I = 0.0022chsl^3 \text{ in.}^4$$

b ***Plywood and Encapsulated-Plywood Girders and Webs***

$$SM = 121.41chsl^2 \text{ cm}^3 \qquad SM = 0.0639chsl^2 \text{ in.}^3$$

$$I = 47.53chsl^3 \text{ cm}^4 \qquad I = 0.0030chsl^3 \text{ in.}^4$$

c ***Wood Girders and Webs***

$$SM = 60.80chsl^2 \text{ cm}^3 \qquad SM = 0.0320chsl^2 \text{ in.}^3$$

$$I = 47.53chsl^3 \text{ cm}^4 \qquad I = 0.0030chsl^3 \text{ in.}^4$$

c = 0.6
l = unsupported span of girder or web in m or ft
s = sum in m or ft of the half length on each side or the girder or web of the stiffeners supported by the girder or web
h = vertical distance in m or ft to the bulkhead deck at center from the midlength of s in the case of a horizontal girder or from the middle of l in the case of a vertical web

The section moduli and moments of inertia of girders or webs on collision bulkheads are to be increased by 25% over the section moduli and moments of inertia of girders or webs on ordinary bulkheads.

10.4 Watertight Doors

Watertight doors may be installed in all watertight bulkheads except collision bulkheads. The doors are to be of ample strength for the water pressure to which they may be subjected. Where stiffeners are cut in way of a watertight door, the opening is to be framed to maintain the full strength of the bulkhead.

10.5 Bulkhead Penetrations

The number of penetrations in watertight bulkheads is to be kept to a minimum, and all penetrations are to be watertight. The penetrations are to be kept as high and as far inboard as practicable.

10.6 Testing

Collision bulkheads are to be tested with a head of water in the forepeak tank equal to draft d as defined in Section 2. Engine-room bulkheads are to be hose-tested with a water pressure at the nozzle of not less than 2.11 kg/cm^2 (30 psi). Chain lockers abaft collision bulkheads are to be tested by filling with water. Bulkheads forming boundaries of integral tanks are to be tested in accordance with the requirements in Section 9. Testing is to be carried out after all work on the bulkheads is completed, and may be conducted after the vessel is launched.

TABLE 10.1
Plywood Panel Coefficients

k_3	*aspect ratio*
0.500	>2.0:1
0.497	2.0:1
0.493	1.9:1
0.487	1.8:1
0.479	1.7:1
0.468	1.6:1
0.454	1.5:1
0.436	1.4:1
0.412	1.3:1
0.383	1.2:1
0.349	1.1:1
0.308	1.0:1

SECTION 11

Decks and Deck Openings

11.1 General

Where a deck is molded integrally with cabin sides, joinerwork, or other components, the requirements of this section apply to the deck portion only.

11.2 Decking

The thickness of each deck is to be not less than obtained from the following equations.

11.2.1 Single-Skin Laminates

$$t = 0.0642s\sqrt[3]{kch}\ \text{mm} \qquad t = 0.0432s\sqrt[3]{kch}\ \text{in.}$$

11.2.2 Plywood Decking

$$t = 0.0232s\sqrt{h} + 14.73\ \text{mm} \qquad t = 0.0128s\sqrt{h} + 0.58\ \text{in.}$$

11.2.3 Wood Decking

$$t = 0.0308s\sqrt{h} + 19.56\ \text{mm} \qquad t = 0.0170s\sqrt{h} + 0.77\ \text{in.}$$

t = thickness in mm or in.
s = beam spacing in mm or in.
k = coefficient that varies with deck plating aspect ratio as shown in Table 7.1
c = 1.0 for decking at tops of tanks
= 0.7 for decking elsewhere
h = height in m or ft as follows

h for a deck or portion of deck forming a tank top is the greater of the following distances

two-thirds of the distance from the tank top to the top of the overflow
two-thirds of the distance from the tank top to the bulkhead deck or freeboard deck

h for a deck on which cargo or stores are carried is the 'tween-deck height at side; where the cargo weights are greater than normal [717.7 kg/m^3 (44.8 pounds/ft^3)], h is to be suitably adjusted *h* for an exposed deck on which cargo is carried is 3.66 m (12 ft). Where it is intended to carry deck cargoes in excess of 2636 kg/m^2 (540 psf) this head is to be increased in proportion to the added loads which will be imposed on the structure.

h for elsewhere not to be less than obtained from the appropriate following equation (where L = length of vessel in m or ft as defined in Section 2):

a ***Unrestricted-Service Vessels***

1 *Exposed freeboard deck:*

$$h = 0.02L + 0.76 \text{ m} \qquad h = 0.02L + 2.5 \text{ ft}$$

2 *Forecastle deck, superstructure deck, forward of amidships 0.5L:*

$$h = 0.02L + 0.46 \text{ m} \qquad h = 0.02L + 1.5 \text{ ft}$$

$$h = 0.70 \text{ m min.} \qquad h = 2.3 \text{ ft min.}$$

3 *Freeboard deck within superstructure, any deck below freeboard deck, superstructure deck between 0.25L forward of and 0.20L aft of amidships:*

$$h = 0.01L + 0.61 \text{ m} \qquad h = 0.01L + 2.00 \text{ ft}$$

4 *All other locations:*

$$h = 0.01L + 0.30 \text{ m} \qquad h = 0.01L + 1.0 \text{ ft}$$

b ***Limited-Service Vessels***

1 *Exposed freeboard deck and cockpit:*

$$h = 0.02L + 0.46 \text{ m} \qquad h = 0.02L + 1.5 \text{ ft}$$

2 *First deck above freeboard deck:*

$$h = 0.01L + 0.46 \text{ m} \qquad h = 0.01L + 1.5 \text{ ft}$$

3 *All other locations:*

$$h = 0.01L + 0.30 \text{ m} \qquad h = 0.01L + 1.0 \text{ ft}$$

The material for wood decks is to be quartersawed. The thickness of wood decks subject to severe wear (such as freeboard decks in fishing and research vessels) is to be not less than 50 mm (2 in.).

11.2.4 Stringer Plates

FRP freeboard decks of vessels having lengths L, as defined in Section 2, equal to or greater than 30 m (100 ft) are to be increased in thickness along their edges and in way of large openings to form stringer plates. The thicknesses of these stringer plates are to be not less than one and one-half times the thickness obtained from 11.2.1, are to be maintained over the amidships 0.5L, and may be gradually reduced to the thicknesses obtained from 11.2.1 forward and aft of the amidships 0.5L. The width of each stringer plate is to be not less than 0.02L.

11.2.5 Sandwich Panels

Where sandwich construction is used for a deck, the moment of inertia of the skins of a strip of the sandwich panel 25 mm (1 in.) wide is to be not less than the moment of inertia of an equal-width strip of an FRP single-skin laminate that satisfies 11.2.1. The total thickness of the sandwich panel is to be not less than obtained from the following equation.

$$d = 0.0015k_2hs/u \text{ mm} \qquad d = 0.666k_2hs/u \text{ in.}$$

d = total thickness in mm or in.
k_2 = 0.89 for balsa
k_2 = Other core materials listed in 4.7 varies inversely to the relative thickness of the core as shown in Figure 7.8, where t and t_1 are the thicknesses in mm or in. of the outer and inner skins
h = height in m or ft as determined above
s = span of shorter side of sandwich panel in mm or in.
u = shear strength of core material in kg/mm^2 or psi

11.2.6 Wood Decking in Combination with Other Materials

Where plywood is laid under a wood deck, the combined thickness is to be not less than 70% of the thickness obtained from 11.2.3, the thickness of the plywood is to be not less than 30% of the combined thickness, and the minimum thickness of plywood to be used is 6.5 mm (0.25 in.). Where a wood deck is covered with canvas, fiberglass, or other approved fabric or cloth, the thickness of the wood may be reduced by 1.5 mm (0.0625 in.).

11.3 Deck Beams

11.3.1 Spacing

Beams may be fitted either transversely or longitudinally. Transverse beams, where fitted, are to be fitted on all frames at tank tops, tunnel tops, and bulkhead recesses; elsewhere these beams are to be not more than two frame spaces apart except where sandwich construction is used for the deck supported by the beams. Beams in different tiers are to be fitted on the same frames.

11.3.2 Scantlings

The section modulus SM and moment of inertia I of each transverse or longitudinal beam in association with the plating to which it is attached are to be not less than obtained from the following equations.

a ***FRP Beams***

$$SM = 19.38chsl^2 \text{ cm}^3 \qquad SM = 0.0102chsl^2 \text{ in.}^3$$

$$I = 34.85chsl^3 \text{ cm}^4 \qquad I = 0.0022chsl^3 \text{ in.}^4$$

b ***Plywood and Encapsulated-Plywood Beams***

$$SM = 121.41chsl^2 \text{ cm}^3 \qquad SM = 0.0639chsl^2 \text{ in.}^3$$

$$I = 47.53chsl^3 \text{ cm}^4 \qquad I = 0.0030chsl^3 \text{ in.}^4$$

c ***Wood and Encapsulated-Wood Beams***

$$SM = 60.80chsl^2 \text{ cm}^3 \qquad SM = 0.0320chsl^2 \text{ in.}^3$$

$$I = 47.53chsl^3 \text{ cm}^4 \qquad I = 0.0030chsl^3 \text{ in.}^4$$

c = 1.00 for beams at tops of tanks
= 0.70 for beams elsewhere
s = spacing of beams in m or ft
l = unsupported length of beam in m or ft
h = height in m or ft. as determined in 11.2

11.3.3 Heavy Beams

Heavy beams are to be fitted at web frames, at the ends of deck openings where two or more beams are cut, and under concentrated loads such as the ends of deckhouses, masts, winches, auxiliary machinery, etc.

11.4 Deck Girders and Transverses

11.4.1 General

Girders or transverses are to be fitted as required to support transverse or longitudinal deck beams, including those ending at the perimeters of trunk cabins or deckhouses. Additional girders or transverses are to be fitted as required to support concentrated loads.

11.4.2 Scantlings

The section modulus *SM* and moment of inertia *I* of each deck girder or transverse in association with the plating to which it is attached are to be not less than obtained from the following equations:

a ***FRP Girders and Transverses***

$$SM = 19.38chsl^2 \text{ cm}^3 \qquad SM = 0.0102chsl^2 \text{ in.}^3$$

$$I = 34.85chsl^3 \text{ cm}^4 \qquad I = 0.0022chsl^3 \text{ in.}^4$$

b ***Plywood and Encapsulated-Plywood Girders and Transverses***

$$SM = 121.41chsl^2 \text{ cm}^3 \qquad SM = 0.0639chsl^2 \text{ in.}^3$$

$$I = 47.53chsl^3 \text{ cm}^4 \qquad I = 0.0030chsl^3 \text{ in.}^4$$

c ***Wood and Encapsulated-Wood Girders and Transverses***

$$SM = 60.80chsl^2 \text{ cm}^3 \qquad SM = 0.0320chsl^2 \text{ in.}^3$$

$$I = 47.53chsl^3 \text{ cm}^4 \qquad I = 0.0030chsl^3 \text{ in.}^4$$

c = 0.90 for girders and transverses at tops of tanks
= 0.60 for girders and transverses elsewhere

s = mean breadth (in the case of a girder) or mean length (in the case of a transverse) in m or ft of the area of the deck supported
l = unsupported length of girder or transverse in m or ft
h = height in m or ft as determined in 11.2

Ends of wood beams are to be dovetailed, slotted, or suitably housed and bolted to wood girders and transverses.

11.5 Stanchions

11.5.1 General

Supports under stanchions are to be of sufficient strength to distribute the loads effectively. Stanchions between decks are to be arranged directly above stanchions below wherever possible; where this is not possible, effective means are to be provided for transmitting the loads to supports below. Stanchions in double bottoms and under the tops of deep tanks are to be metal and solid in cross section.

11.5.2 Stanchion Load

The load on a stanchion is to be obtained from the following equation.

$$W = 0.715bhs \text{ metric tons} \qquad W = 0.02bhs \text{ long tons}$$

W = load in metric or long tons
b = mean breadth in m or ft of area supported
s = mean length in m or ft of area supported
h = height in m or ft as determined in 11.2. Where a stanchion supports two or more decks, h is to be the height for the deck at the top of the stanchion plus the sum of the heights for all complete decks and one-half the heights for all decks in deckhouses above the deck being directly supported. All of these heights are to be as determined in 11.2.

11.5.3 Permissible Load

The load a stanchion may carry is to be equal to or greater than the load on the stanchion obtained in 11.5.2. This permissible load is to be obtained from the following equations.

a ***Mild-Steel Stanchions***

$$W_a = (1.232 - 0.00452l/r)A \text{ metric tons}$$
$$W_a = (7.83 - 0.345l/r)A \text{ long tons}$$

b ***Aluminum-Alloy Stanchions***

$$W_a = (1.02 - 0.00593l/r)AY/17 \text{ metric tons}$$
$$W_a = (6.49 - 0.452l/r)AY/24000 \text{ long tons}$$

c ***Wood Stanchions***

$$W_a = (1 - 0.0167l/d)0.103A \text{ metric tons}$$
$$W_a = (1 - 0.2l/d)0.654A \text{ long tons}$$

W_a = load in metric or long tons

r = least radius of gyration of stanchion in cm or in.
A = area of stanchion in cm^2 or in.^{2}
l = unsupported length of stanchion in cm or ft
d = diameter of circular stanchion or shorter side of rectangular stanchion in cm or in.
Y = minimum yield strength of the welded aluminum alloy under consideration
= 14.80 kg/mm^2 (21000 psi) for 5083 alloy
= 12.60 kg/mm^2 (18000 psi) for 5086 alloy
= 8.45 kg/mm^2 (12000 psi) for 5454 alloy
= 13.40 kg/mm^2 (19000 psi) for 5456 alloy
= 10.60 kg/mm^2 (15000 psi) for 6061 alloy

The adoption of aluminum-alloy test values higher than given above will be subject to special consideration.

11.5.4 FRP Stanchions

Normally FRP is not considered to be a material suitable for stanchions. If for special reasons FRP stanchions are contemplated, they will be subject to special consideration.

11.5.5 Bulkheads

Bulkheads supporting girders or bulkheads fitted in lieu of girders are to be stiffened to provide supports not less effective than required for stanchions.

11.6 Protection of Deck Openings

11.6.1 General

All openings in decks are to be framed as necessary to provide efficient support and attachment to the ends of the deck beams. The proposed arrangements and details for all cargo hatchways are to be submitted for approval.

11.6.2 Positions of Deck Openings

For the purpose of these Rules, the two positions of deck openings are defined as follows:

Position 1—Upon exposed freeboard decks; upon exposed first decks above freeboard decks forward of 0.25L and aft of 0.75L, where L is as defined in Section 2.
Position 2—Upon exposed first decks above freeboard decks between 0.25L and 0.75L.

11.6.3 Coaming and Sill Heights

The heights above deck of coamings of hatchways secured weathertight by tarpaulins and battening devices, and sills of companionways and access openings, are to be not less than given in Table 11.1. Where hatch covers are made tight by means of gaskets and clamping devices, these heights may be reduced, or the coamings omitted entirely, provided that the safety of the vessel is not thereby impaired. Coaming and sill heights in limited-service vessels will be subject to special consideration.

11.6.4 Cargo Hatchway Covers

a ***River Vessels*** For vessels in service on the rivers of the United States and on connecting intracoastal waterways, cargo hatchway covers are to be raintight. Where no cargo is intended to be carried on the covers, they are to be designed to withstand a load of 170 kg/m^2 (35 psf) exclusive of the weights of the covers themselves with a factor of safety of not less than 3.25 on the minimum ultimate tensile strength of the material being used for the covers. Where cargo is intended to be carried on the covers, the design load is to be suitably increased.

Although specifically intended for vessels in service on the rivers and intracoastal waterways of the United States, this section may be used also in the development of designs for vessels intended for service on other bodies of comparatively smooth water.

b ***Unrestricted Service***

1 *Wood Hatchway Covers* The finished thickness of wood covers on exposed hatchways is to be not less than 60 mm (2.375 in.) where the span is not more than 1.5 m (4.9 ft). The wood is to be of good quality, straight-grained, and reasonably free from knots, sap, and shakes.

2 *Hatchway Covers Other than Wood* The loads to be used when calculating the strengths of hatchway covers other than wood are to be not less than obtained from the following equations.

Position 1

$w = 0.01L + 0.766$ metric tons per m^2

$w = 0.61L + 157.0$ psf

Position 2

$w = 0.00725L + 0.576$ metric tons per m^2

$w = 0.455L + 118.0$ psf

w = design load in metric tons per square meter or psf
L = length of vessel in m or ft as defined in Section 2

The product of the stresses obtained with these design loads and the factor 4.25 is not to exceed the minimum ultimate strength of the material used. The covers are to be designed to limit deflection under these loads to not more than 0.0028 times the spans.

3 *Weathertightness* All hatchway covers are to be secured weathertight.

11.6.5 Machinery Casings

Machinery-space openings in exposed decks in unrestricted-service and fishing-service vessels are to be framed and efficiently enclosed by casings. Access openings in exposed casings are to be fitted with permanently attached doors that are capable of being closed and maintained weathertight. Each door is to be so arranged that it can be operated from either side. Door sills are to be in accordance with 11.6.3 for companionways. Other openings in casings are to be fitted with equivalent, permanently attached covers. All openings in casings are to be framed and stiffened in such a manner that the structure when closed is equivalent in strength to the unpierced casing.

11.6.6 Miscellaneous Openings in Exposed Decks

a ***Manholes and Scuttles*** Manholes and flush scuttles in Position 1 or 2 are to be closed by substantial covers capable of being made watertight. Unless secured by closely spaced bolts, the covers are to be permanently attached.

b ***Other Openings*** Openings in freeboard decks and first decks above freeboard decks in unrestricted-service and fishing-service vessels, other than cargo hatchways, machinery-space openings, manholes, and flush scuttles, are to be protected by superstructures, deckhouses, trunk cabins, or weathertight companionways fitted with doors that are in accordance with 11.6.5.

11.6.7 Mast Openings

Openings penetrating decks and other structures to accommodate masts and similar members are to be reinforced by fitting doublers or plating of increased thickness.

Table 11.1
Coaming and Sill Heights

L equal to or over 24 meters (79 feet) in length

Unrestricted Service	*Position 1*	*Position 2*
Hatch coamings	600 mm (23.5 in.)	450 mm (17.5 in.)
Companionway sills	600 mm (23.5 in.)	380 mm (15 in.)
Access sills	380 mm (15 in.)	380 mm (15 in.)
Fishing Service		
Hatch coamings	600 mm (23.5 in.)	300 mm (12 in.)
Companionway sills	600 mm (23.5 in.)	300 mm (12 in.)
Access sills	380 mm (15 in.)	150 mm (6 in.)

L under 24 meters (79 feet) in length

Unrestricted Service	*Position 1*	*Position 2*
Hatch coamings and companionways	450 mm (17.5 in.)	300 mm (12 in.)
Access sills	380 mm (15 in.)	300 mm (12 in.)
Fishing Service		
Hatch coamings	300 mm (12 in.)	300 mm (12 in.)
Companionway sills	450 mm (17.5 in.)	300 mm (12 in.)
Access sills	300 mm (12 in.)	150 mm (6 in.)

SECTION 12

Superstructures and Deckhouses

12.1 General

For purposes of these Rules, a superstructure is an enclosed structure on the freeboard deck having side plating that is not set inboard of the hull's side-shell plating more than 4% of the breadth B of the vessel as defined in Section 2. A deckhouse is an enclosed structure on the freeboard deck having side plating set inboard of the hull's side-shell plating more than 4% of the breadth B of the vessel.

Bulkheads, partial bulkheads, or web frames are to be fitted over main hull bulkheads and web frames, and elsewhere as may be required to give effective transverse rigidity to the structure.

Scantlings in trunk-cabin sides and ends are to be equivalent to scantlings in deckhouse sides and ends. Where trunk-cabin sides or ends are molded integrally with decks, joinerwork, or other components, the requirements of this section apply to the cabin side or end portions of the laminate only.

12.2 Design Loads

The design loads to be used when calculating superstructure and deckhouse scantlings are to be not less than obtained from the following equations.

12.2.1 Front Ends

a ***Unrestricted-Service Vessels***

$h = 0.0199L + 0.51$ m $\quad$ $h = 0.0199L + 1.66$ ft

b ***Limited-Service Vessels***

$h = 0.0119L + 0.30$ m $\quad$ $h = 0.0119L + 0.99$ ft

12.2.2 Sides and After Ends

a ***Unrestricted-Service Vessels***

$h = 0.0159L + 0.27$ m $\quad$ $h = 0.0159L + 0.87$ ft

b ***Limited-Service Vessels***

$h = 0.0093L + 0.19$ m $\quad$ $h = 0.0093L + 0.62$ ft

h = design head in m or ft
L = length of vessel as defined in Section 2

12.3 Plating

12.3.1 Superstructure Side Plating

The thickness of superstructure side plating is to be not less than obtained from 8.1; the thickness also is to be not less than required by 12.3.2, 12.3.3, or 12.3.4 when using the pertinent design load obtained from 12.2.

12.3.2 Single-Skin Laminates

a ***Flat Panels*** The thickness of single-skin FRP plating in flat or effectively flat panels in superstructure and deckhouse sides and end bulkheads is to be not less than obtained from the following equation.

$$t = 0.0510s\sqrt[3]{kh} \text{ mm} \qquad t = 0.0343s\sqrt[3]{kh} \text{ in.}$$

t = thickness in mm or in.
s = span of shorter side of plating panel in mm or in.
k = coefficient that varies with plating panel aspect ratio as shown in Table 7.1
h = design head obtained from 12.2

b ***Curved Panels*** The thickness of single-skin FRP plating in curved panels in superstructure and deckhouse end bulkheads need not be greater than the thickness required by 12.3.2.a, and is to be not less than obtained from the following equation.

$$t = 0.04r\sqrt[3]{h/(k_1^2 - 1)} \text{ mm} \qquad t = 0.0269r\sqrt[3]{h/(k_1^2 - 1)} \text{ in.}$$

t = thickness in mm or in.
r = average radius of curvature in mm or in.
h = design head obtained from 12.2
k_1 = coefficient that varies inversely to α as shown in Figure 7.2
α = one-half of angle between radii drawn to ends of curve

12.3.3 Sandwich Panels

Where sandwich construction is used for superstructure or deckhouse sides or end bulkheads, the moment of inertia of the skins of a strip of the sandwich panel 25 mm (1 in.) wide is to be not less than the moment of inertia of an equal-width strip of an FRP single-skin laminate that satisfies 12.3.2. The total thickness of the sandwich panel is to be not less than obtained from the following equation.

$$d = 0.0015k_2hs/u \text{ mm} \qquad d = 0.666k_2hs/u \text{ in.}$$

d = total thickness in mm or in.
k_2 = 0.89 for balsa. k_2 for other core materials listed in 4.7 varies inversely to the relative thickness of the core as shown in Figure 7.8, where t and t_1 are the thicknesses in mm or in. of the outer and inner skins
h = design head obtained from 12.2
s = span of shorter side of sandwich panel in mm or in.
u = shear strength of core material in kg/mm^2 or psi

12.3.4 Plywood Panels

The thickness of plywood panels in superstructure and deckhouse sides and end bulkheads is to be not less than obtained from the following equation.

$$t = 0.0382s\sqrt{k_3 h} \text{ mm} \qquad t = 0.0211s\sqrt{k_3 h} \text{ in.}$$

t = thickness in mm or in.
s = spacing of stiffeners in mm or in.
h = design head obtained from 12.2
k_3 = coefficient that varies with panel aspect ratio as shown in Table 10.1

12.4 Stiffeners

The section modulus SM and moment of inertia I of each side or end-bulkhead stiffener in association with the plating to which it is attached are to be not less than obtained from the following equations.

12.4.1 FRP Stiffeners

$$SM = 19.38chsl^2 \text{ cm}^3 \qquad SM = 0.0102chsl^2 \text{ in.}^3$$

$$I = 34.85chsl^3 \text{ cm}^4 \qquad I = 0.0022chsl^3 \text{ in.}^4$$

12.4.2 Plywood and Encapsulated-Plywood Stiffeners

$$SM = 121.41chsl^2 \text{ cm}^3 \qquad SM = 0.0639chsl^2 \text{ in.}^3$$

$$I = 47.53chsl^3 \text{ cm}^4 \qquad I = 0.0030chsl^3 \text{ in.}^4$$

12.4.3 Wood and Encapsulated-Wood Stiffeners

$$SM = 60.80chsl^2 \text{ cm}^3 \qquad SM = 0.0320chsl^2 \text{ in.}^3$$

$$I = 47.53chsl^3 \text{ cm}^4 \qquad I = 0.0030chsl^3 \text{ in.}^4$$

c = 1.0
h = design head obtained from 12.2
s = spacing of stiffeners in m or ft
l = molded height of superstructure or deckhouse in m or ft or, in case of horizontal stiffeners, spacing between bulkheads, partial bulkheads, or web frames in m or ft

12.5 Openings

All openings are to be framed and stiffened so that the whole structure when closed is equivalent to the unpierced structure. All openings are to be provided with efficient means for closing and maintaining weathertight. Doors are to be in accordance with 11.6.5. Door sills are to be in accordance with 11.6.3 for companionways or access sills as applicable. Portlights are to be of substantial construction; portlights in superstructure side plating and exposed front ends are to be provided with efficient inside deadlights.

SECTION 13

Bulwarks, Rails, Ports, Portlights, and Ventilators

13.1 Bulwarks and Guard Rails

13.1.1 Height

The height of bulwarks and guard rails on exposed freeboard and superstructure decks is to be at least one meter (39.5 in.). Where this height would interfere with the normal service or operation of a vessel, a less height may be approved if adequate protection is provided. Where approval of a less height is requested, justifying information is to be submitted.

13.1.2 Bulwarks

Bulwarks may be continuations of hull laminates, integral parts of deck moldings, or separate assemblies. Bulwarks are to be of ample strength in proportion to their heights, efficiently stiffened top and bottom, and supported by efficient stays. Stays on freeboard decks are to be spaced not more than 1.83 m (6.0 ft) apart, and efficiently attached to the bulwarks and hulls or decks. Cuts in bulwarks for freeing ports, gangway ports, mooring pipes, and similar openings are to have well-rounded corners. Exposed edges of laminates are to be sealed with resin.

13.1.3 Guard Rails

Where guard rails are installed, the opening below the lowest course is not to exceed 230 mm (9 in.). The other courses are to be spaced not more than 380 mm (15 in.) apart. In the case of vessels with rounded gunwales, the guard-rail stanchions or supports are to be placed on the flat of the deck.

13.2 Freeing Ports

13.2.1 Basic Area

Where bulwarks on freeboard decks form wells, the minimum freeing-port area on each side of the vessel for each well is to be obtained from the following equation.

$$A = 0.7 + 0.035l \text{ m}^2 \qquad A = 7.6 + 0.115l \text{ ft}^2$$

Where the bulwark length exceeds 20 m (66 ft):

$$A = 0.07l \text{ m}^2 \qquad A = 0.23l \text{ ft}^2$$

A = freeing-port area in m^2 or ft^2
l = bulwark length in m or ft, but need not exceed $0.7L$

If a bulwark is more than 1.2 m (47 in.) in height, the freeing-port area is to be increased by 0.004 square meter per meter (0.04 square foot per foot) of length of well for each 0.1 meter (12 in.) difference in height. If a bulwark is less than 0.9 meter (36 in.) in height, the freeing-port area may be decreased by the same ratio. Vessels being assigned load lines are required to comply with the International Convention on Load Lines, 1966.

13.2.2 Trunks, Deckhouses, and Hatchway Coamings

Where a vessel is fitted with a trunk or deckhouse on the freeboard deck, and open rails are not fitted in way of the trunk or deckhouse for at least one-half its length, or where continuous or substantially continuous hatchway side coamings are fitted between superstructures, the minimum area of freeing-port openings is to be obtained from the following table.

Breadth of trunk deckhouse or hatchway in relation to breadth of vessel	*Area of freeing ports in relation to area of bulwarks*
40% or less	20%
75% or more	10%

The area of freeing ports at intermediate breadths is to be obtained by interpolation.

13.2.3 Superstructure Decks

Where bulwarks on superstructure decks form wells, the minimum freeing-port area on each side of the vessel for each well is to be one-half of the area obtained in 13.2.1 and 13.2.2.

13.2.4 Limited-service Vessels

In limited-service vessels, freeing ports are to be fitted in bulwarks in sufficient number to relieve decks rapidly of water.

13.2.5 Details of Freeing Ports

Freeing area may be provided either by continuous openings between bulwarks and decks or by rounded freeing-port openings in the bulwarks. The lower edges of freeing ports are to be as near the deck as practicable. Two-thirds of the required freeing-port area is to be provided in the half of the well nearest the lowest point of the sheer curve. Freeing-port openings are to be protected by rails or bars in such a manner that the maximum clear vertical or horizontal space is 230 mm (9 in.). Where shutters are fitted, ample clearance is to be provided to prevent them from jamming. If the shutters are equipped with securing appliances, the appliances are to be of approved construction.

13.3 Cargo, Gangway, or Fueling Ports

13.3.1 Construction

Cargo, gangway, or fueling ports in the sides of vessels are to be strongly constructed and capable of being made thoroughly watertight. Where frames are cut in way of such ports, web frames are to be fitted on the sides of the openings, and suitable arrangements are to be provided for the support of the beams over the openings. Thick shell plates or doublers are to be fitted as required to compensate for the openings. The corners of the openings are to be well rounded. Waterway angles and scuppers are to be provided on the decks in way of ports in cargo spaces below the freeboard deck or in cargo spaces within enclosed superstructures to prevent the spread of any leakage water over the decks.

13.3.2 Location

The lower edges of cargo, gangway, or fueling-port openings are not to be below a line parallel to the freeboard deck at side having as its lowest point the designed load waterline or upper edge of the uppermost load line.

13.4 Portlights

13.4.1 Construction

Portlights to spaces below the freeboard deck or in superstructure side plating and exposed front ends are to be fitted with efficient inside deadlights arranged in such manner that they can be closed and secured watertight. The portlights are to have strong frames (other than cast iron), and if of the opening type are to have noncorrosive hinge pins.

13.4.2 Location

The lower edges of portlight sills are not to be below a line parallel to the freeboard deck at side having as its lowest point either 2.5% of the breadth of the vessel or 500 mm (19.5 in.) above the designed load waterline, whichever is the greater distance. See also 8.1.2.i.

13.5 Ventilators

13.5.1 General

Ventilators on exposed freeboard decks, superstructure decks, and deckhouses are to be substantially constructed and effectively secured to the deck. Ventilators in Position 1 are to have coamings at least 900 mm (35.5 in.) high. Ventilators in Position 2 are to have coamings at least 760 mm (30 in.) high. For definitions of Position 1 and Position 2, see 11.6.2. Except as provided below, ventilator openings are to be provided with efficient, permanently attached closing appliances.

In vessels measuring 24 m (79 ft) or more in length (as defined in the International Convention on Load Lines, 1966) ventilators in Position 1, the coamings of which extend to more than 4.5 m (14.8 ft) above the deck, and in Position 2, the coamings of which extend to more than 2.3 m (7.5 ft) above the deck, need not be fitted with closing arrangements.

The coaming height requirements for ventilators with no closing arrangements may be modified in vessels measuring less than 24 m (79 ft) in length. The minimum coaming heights in vessels measuring 9 m (30 ft) in length are to be 2 m (6.6 ft) in Position 1 and 1 m (3.3 ft) in Position 2. Minimum coaming heights in vessels measuring between 24 m (79 ft) and 9 m (30 ft) in length may be found by straight-line interpolation.

13.5.2 Limited-service Vessels

In limited-service vessels measuring 20 m (65 ft) in length or less, ventilation openings are to be located to prevent entrance of significant amounts of water considering maximum conditions of heel, trim, reverse operation, eccentric loading, and wave action.

SECTION 14

Ceiling and Sparring

14.1 Ceiling

In cargo holds of vessels with single bottoms, close ceiling is to be fitted on the floors and up to the chines or upper turns of the bilges. The ceiling on the floors is to be laid in portable sections or other convenient arrangements are to be made for removal for cleaning, painting, or inspection.

In cargo holds of vessels with double bottoms, close ceiling is to be fitted from the outboard edges of the double bottoms up to the chines or upper turns of the bilges. Under all cargo hatches, either ceiling is to be fitted or the thickness of the FRP inner bottom is to be increased by 5 mm (0.20 in.). Ceiling fitted at the bilges is to be removable for cleaning and inspection. Ceiling fitted on the inner-bottom plating either is to be laid on battens for drainage or is to be bedded in a suitable composition.

The thickness of wood ceiling is not to be less than 50 mm (2 in.) in vessels over 20 m (65 ft) in length nor less than 25 mm (1 in.) in vessels 9 m (30 ft) in length; between 9 m (30 ft) and 20 m (65 ft) in length, the thicknesses may be proportioned.

14.2 Sparring

In spaces intended to carry general cargo, sparring, where fitted, is to be arranged between the bilge ceiling and the deck beams. In vessels over 20 m (65 ft) in length, sparring is not to provide less protection to the framing than would be obtained from wood battens 40 mm ($1\frac{5}{8}$ in.) thick, 140 mm ($5\frac{1}{2}$ in.) wide, and spaced 380 mm (15 in.) center to center. In vessels 9 m (30 ft) in length, the thickness of wood battens may be 20 mm ($\frac{13}{16}$ in.). Between 9 m (30 ft) and 20 m (65 ft) in length, the thicknesses may be proportioned. Sparring is to be portable and fitted in cleats or in portable frames.

SECTION 15

Rudders

15.1 General

All vessels are to have suitable steering apparatus except where steering action is obtained by changes of setting of the propelling units. The surfaces of rudder stocks in way of exposed bearings are to be of noncorrosive material.

15.2 Steel Unbalanced Rudders

15.2.1 Upper Rudder Stocks

Rudder stocks above the top pintle are to have diameters not less than obtained from the following equation.

$$S = 21.66c\sqrt[3]{RAV^2}\ \text{mm} \qquad S = 0.26c\sqrt[3]{RAV^2}\ \text{in.}$$

S = diameter of upper stock in mm or in.
c = 1.0 for unrestricted-service vessels
= 0.85 for limited-service vessels where V is less than 20 knots
= 0.73 for limited-service vessels where V is greater than 31 knots. Where V is between 20 and 31 knots, c may be found by interpolation.
R = distance in m or ft from the centerline of pintles to the center of gravity of A
A = projected rudder area below the design load waterline in m^2 or ft^2 measured between the centerline of the pintles and the trailing edge of the rudder
V = sea speed of vessel in knots

In the case of unrestricted vessels, the least speed V to be used with the equation is 8 knots for vessels of 30 m (100 ft) length or less, 9 knots for 45 m (150 ft), and 10 knots for 61 m (200 ft). The coefficient c may be reduced from 1.0 to 0.885 where the sea speeds are 6 or more knots greater than the above minimums; intermediate coefficients may be used for smaller additions to the minimums. Where rudders are of efficient streamlined shape, the coefficient c may be taken as 0.885, but the minimum sea speeds to be used are to be increased 20% over those given above.

In all cases the stock diameter is to be adequate for the maximum astern speed.

15.2.2 Lower Rudder Stocks

Lower stocks are to be of the required diameter for upper stocks at the top arm of a single-plate rudder or the top of a built-up rudder, but the diameter may be gradually reduced until it is 0.75S at the bottom. Where the ratio of the unsupported length of the stock to its diameter exceeds 15 to 1, the diameter may be required to be reduced by fitting an additional rudder arm and pintle. Lower stocks for built-up rudders may be omitted provided the strength of the rudder in torsion and bending is equivalent to that required for the lower stock of a single-plate rudder.

15.2.3 Rudder Couplings

a ***General*** Rudder couplings, where provided, are to be supported by ample metal worked out from the stocks with no narrowing or necking of the material permitted. If the center of the lower part of the stock is abaft that of the upper part of the stock, the latter is to be suitably increased in area where it makes the transition between centers.

b ***Fastenings*** Where S is equal to 150 mm (6 in.) or more, at least six bolts are to be used in each coupling; where S is less than 150 mm (6 in.) at least four bolts are to be used. Coupling nuts and bolts are to be locked in position after tightening. The total area of the bolts is not to be less than obtained from the following equation.

Horizontal Couplings	*Vertical Couplings*
$a = 0.3S^3/r$	$a = 0.33S^2$

a = total bolt root area in mm² or in.²
r = mean distance in mm or in. of the bolt centers from the center of the system of bolts
S = diameter of upper stock in mm or in.

The minimum distance between the bolt holes and the edges of the coupling flanges is to be two-thirds the diameter of the bolts.

c ***Flanges*** Where flanges are employed as couplings, the minimum thickness of each flange is to be 0.25S. If keyways are cut in the flanges, the thickness of each flange is to be increased by an amount equal to the keyway depth.

d ***Vertical Couplings*** Where a vertical scarphed coupling is used, the minimum length of scarph and width of scarph at bottom is to be 2.5S, the minimum width of scarph at top is to be 2.5S, and the minimum thickness of scarph is to be 0.13S.

15.2.4 Pintles

A pintle is to be fitted at each rudder arm. The pintles are to be of diameters not less than obtained from Table 15.1.

Where d is diameter of pintles in mm or in., the depths of the pintle bosses are not to be less than $1.2d$. Pintles are to extend for the full depth of the gudgeons. The top pintle is to be placed as high as practicable. In general, pintles are to be fitted as taper bolts, there are to be no shoulders on the pins, and the nuts are to be fitted with efficient locking devices.

15.2.5 Gudgeons

Rudder gudgeons are to be integral parts of or bolted to stern posts or transoms. Gudgeon depths are to be not less than 1.2 times the diameters of the pintles required in 15.2.4. The thicknesses of unbushed gudgeons are to be not less than 55%, and those of bushed gudgeons not less than 50%, of the diameters of the pintles.

15.3 Steel Balanced Rudders

15.3.1 Rudder Stocks above Neck Bearings

Rudder stocks above neck bearings are to have diameters not less than obtained from the following equation.

$$S = 21.66c\sqrt[3]{RAV^2}\ \text{mm} \qquad S = 0.26c\sqrt[3]{RAV^2}\ \text{in.}$$

S = diameter of upper stock in mm or in.
c = 1.0 for unrestricted-service vessels
  = 0.85 for limited-service vessels where V is less than 20 knots
  = 0.73 for limited-service vessels where V is greater than 31 knots. Where V is between 20 and 31 knots, c may be found by interpolation.
R = horizontal distance in m or ft from the centerline of the upper stock to the center of gravity of A
A = total projected area of rudder below the design load waterline in m^2 or ft^2
V = sea speed of vessel in knots

In the case of unrestricted vessels, the least speed V to be used with the equation is 8 knots for vessels of 30 m (100 ft) length or less, 9 knots for 45 m (150 ft), and 10 knots for 61 m (200 ft). The coefficient c may be reduced from 1.0 to 0.885 where the sea speeds are 6 or more knots greater than the above minimums; intermediate coefficients may be used for smaller additions to the minimums. Where rudders are of efficient streamlined shape, the coefficient c may be taken as 0.885, but the minimum sea speeds to be used are to be increased 20% over those given above.

In addition, the upper stock is not to be less in diameter than obtained from the equation where R and A are for the rudder area between the centerline of the upper stock and the back edge of the rudder, V is equal to the minimum speed appropriate to the vessel's length, and c is adjusted as permitted above.

In all cases, the stock diameter is to be adequate for the maximum astern speed.

15.3.2 Rudder Stocks in way of and below Neck Bearings

Rudder stocks in way of and below neck bearings are to have diameters not less than obtained from the following equation.

$$S_1 = 21.66c\sqrt[3]{RAV^2}\ \text{mm} \qquad S_1 = 0.26c\sqrt[3]{RAV^2}\ \text{in.}$$

S_1 = diameter of lower stock in mm or in.
c = 1.0 for unrestricted-service vessels, adjusted as permitted in 15.3.1

= 0.85 for limited-service vessels, where V is less than 20 knots
= 0.73 for limited-service vessels where V is greater than 31 knots. Where V is between 20 and 31 knots, c may be found by interpolation.

R = $0.25\,(a + \sqrt{a^2 + 16b^2})$ for balanced rudders which have efficient neck and bottom bearings
= $a + \sqrt{a^2 + b^2}$ for balanced rudders which have no bottom bearings

A = projected area in m^2 or ft^2 of the immersed rudder surface

a = vertical distance in m or ft from the bottom of the neck bearing to the center of gravity of A

b = horizontal distance in m or ft from the center of the lower stock to the center of gravity of A

V = sea speed of the vessel in knots or the minimum speed appropriate to the vessel's length as given in 15.3.1, whichever is greater

The stock of a balanced rudder having efficient neck and bottom bearings is to be full diameter for at least two-thirds of the distance from the neck to the bottom bearing. The diameter may be gradually reduced below this point until it is $0.75S_1$ in the bottom bearing. The stock is to extend into the bottom bearing for a distance not less than $0.7S_1$. Both bearings are to be bushed.

The stock of a balanced rudder having no bottom bearing is to be full diameter to the underside of the top rudder arm if a single-plate rudder, or to the top of the rudder if a built-up rudder. The diameter may be gradually reduced below this until it is $0.33S_1$ at the bottom. The length of the neck bearing generally need not be greater than $1.5S_1$, and the bearing is to be bushed. Lower stocks for built-up rudders may be omitted provided the strength of the rudder in torsion and bending is equivalent to that required for the lower stock.

15.3.3 Rudder Couplings

Couplings on balanced rudders are not to be less effective than couplings on unbalanced rudders as required by 15.2.3. Where the couplings are so located as to be subject to bending as well as torsion, the arrangements will be specially considered.

15.4 Steel Single-plate Rudders

15.4.1 Thickness of Plate

Single-plate rudders with upper stock diameters S measuring 76 mm (3 in.) or less are to have plating thicknesses not less than obtained from the following equation.

$$t = 0.15S + 6 \text{ mm} \qquad t = 0.15S + 0.23 \text{ in.}$$

Single-plate rudders with upper stock diameters S measuring more than 76 mm (3 in.) are to have plating thickness not less than obtained from the following equation.

$$t = 0.04S + 14 \text{ mm} \qquad t = 0.04S + 0.56 \text{ in.}$$

t = thickness of rudder plate in mm or in.
S = diameter of upper stock in mm or in.

Where the speed of the vessel exceeds 15 knots, the required thickness of the rudder is to be increased at the rate of 1 mm (0.04 in.) per knot of excess speed.

15.4.2 Rudder Arms

a *Distance between Centers* The distance between centers of rudder arms is not to be greater than obtained from the following equation.

$$h = 2.5S + 952.5 \text{ mm} \qquad h = 2.5S + 37.5 \text{ in.}$$

h = vertical distance between centers of arms in mm or in.
S = diameter of upper stock in mm or in.

Where the distances between centers of rudder arms are less than obtained from the foregoing equation, the thicknesses of the rudder plating t will be subject to special consideration.

b *Section Modulus* The section modulus SM of each arm in way of the forward and after edges of the stock is not to be less than obtained from the following equation, where S is defined in 15.4.2a.

$$SM = 0.8(S - 51) \text{ cm}^3 \qquad SM = 1.24(S - 2) \text{ in.}^3$$

c *Breadth* The breadths b of the arms may be tapered forward and aft of the maximum breadths required to satisfy the above section modulus; however, the breadths at the leading and trailing edges of the rudder are not to be less than obtained from the following equation, where S is as defined in 15.4.2a.

$$b = 0.1S + 8 \text{ mm} \qquad b = 0.1S + 0.315 \text{ in.}$$

15.5 Steel Double-plate Rudders

Double-plate rudders are to have horizontal internal diaphragms. The thickness of the rudder side plating and diaphragms is not to be less than obtained from the following equation.

$$t = 0.117V\sqrt{A} + 6.5 \text{ mm} \qquad t = 0.00142V\sqrt{A} + 0.25 \text{ in.}$$

t = thickness in mm or in.
V = sea speed of vessel in knots or the minimum speed appropriate to the vessel's length as given in 15.2.1, whichever is greater
A = total area of rudder in m^2 or ft^2

The distance between centers of the diaphragms is not to be greater than obtained from the following equation.

$$S_p = 2.41V\sqrt{A} + 585 \text{ mm} \qquad S_p = 0.029V\sqrt{A} + 23 \text{ in.}$$

S_p = distance between centers in mm or in.
V and A are as defined above

The thickness of the plating is to be increased at the rate of 0.015 mm for each millimeter (0.015 in. for each inch) of spacing greater than given by the equation, and may be reduced at the same rate for lesser spacing.

Diaphragms are to be attached to the plating by fillet welds consisting of 75 mm (3 in.) increments spaced 150 mm (6 in.) between their centers. Where the interior of a rudder is inaccessible for welding, it is recommended that the diaphragms be fitted with flat bars and the plating be connected to these flat bars by continuous or slot welds.

Double-plate rudders are to be watertight. Means for draining them are to be provided.

15.6 Alternative Materials

15.6.1 Rudder Stocks or Pintles

Where metals other than ordinary-strength steel are used for rudder stocks or pintles, the diameters are to be not less than obtained from the following equation.

$$d_2 = d_1 \sqrt[3]{41/u} \text{ mm} \qquad d_2 = d_1 \sqrt[3]{58000/u} \text{ in.}$$

d_2 = diameter of alternative-metal rudder stock or pintle in mm or in.
d_1 = diameter of ordinary-strength steel in mm or in., as required by these Rules
u = minimum ultimate tensile strength of the alternative metal in kg/mm^2 or psi

u for welded aluminum alloy rudders is to be the minimum ultimate tensile strength of the alloy after welding

15.6.2 Single or Double-Plate Rudders

Where metals other than ordinary-strength steel are used for single or double-plate rudders, plating thicknesses are to be not less than obtained from the following equation.

$$t_2 = t_1 \sqrt{41/u} \text{ mm} \qquad t_2 = t_1 \sqrt{58000/u} \text{ in.}$$

t_2 = thickness of alternative-metal plating in mm or in.
t_1 = thickness of ordinary-strength steel in mm or in., as required by these Rules
u = minimum ultimate tensile strength of the alternative metal in kg/mm^2 or psi

u for welded aluminum alloy rudders is to be the minimum ultimate tensile strength of the alloy after welding

15.6.3 Single-Plate Rudder Arms

Where metals other than ordinary-strength steel are used for single-plate rudder arms, the section moduli of the arms are to be not less than obtained from the following equation.

$$SM_2 = 41 SM_1/u \text{ cm}^3 \qquad SM_2 = 58000 SM_1/u \text{ in.}^3$$

SM_2 = section modulus of alternative-metal arm in cm^3 or in.^3

SM_1 = section modulus of ordinary-strength steel arm in cm^3 or in.^3, as required by these Rules

u = minimum ultimate tensile strength of the alternative metal in kg/mm^2 or psi

u for welded aluminum alloy rudders is to be the minimum ultimate tensile strength of the alloy after welding

15.6.4 FRP or Wood Rudders

The scantlings and arrangements of FRP or wood rudders will be subject to special consideration.

15.7 Steering Gear

Effective means for steering are to be provided in accordance with the applicable requirements of the "Rules for Building and Classing Steel Vessels". No auxiliary gear will be required where steering is done by positioning the propulsion unit.

TABLE 15.1
Pintle Diameters

Where rudder stocks are greater than 125 mm (5 in.) in diameter, the minimum pintle diameters are to be 50% of the rudder-stock diameters.

Rudder Stock *mm*	*Pintle* *mm*	*Rudder Stock* *in.*	*Pintle* *in.*
25	19	1	3/4
30	22	1 1/8	13/16
35	25	1 1/4	7/8
40	28	1 3/8	1
45	31	1 1/2	1 1/16
50	34	1 5/8	1 1/8
55	37	1 3/4	1 1/4
60	40	2	1 3/8
65	43	2 1/4	1 1/2
70	45	2 1/2	1 5/8
75	47	2 3/4	1 3/4
80	49	3	1 7/8
85	51	3 1/4	2
90	53	3 1/2	2 1/8
95	55	3 3/4	2 1/4
100	57	4	2 1/4
105	59	4 1/4	2 3/8
110	60	4 1/2	2 3/8
115	61	4 3/4	2 1/2
120	62	5	2 1/2
125	63		

SECTION 16

Equipment

16.1 General

All vessels are to be equipped with anchors and cable. The symbol Ⓔ placed after the symbols of classification in the Record, thus: ✠ **A1** Ⓔ, will signify that the equipment is in compliance with the requirements of 16.4. The weight per anchor of anchors given in Tables 16.1 and 16.2 is for anchors of equal weight. The weight of individual anchors may vary 7% from the tabular weight provided that the combined weight of anchors is not less than the total weight required. The total length of cable required to be carried on board, as given in Tables 16.1 and 16.2, is to be reasonably divided between the two anchors.

Cables intended for equipment are not to be used as check cables when the vessel is launched. The inboard ends of the cables are to be secured by efficient means. The anchors and their cables are to be connected and positioned, ready for use. Means are to be provided for stopping each cable as it is paid out, and the windlass, where fitted, should be capable of heaving in either cable. Suitable arrangements are to be provided for securing the anchors and stowing the cables.

16.2 Unrestricted-Service Equipment Weight and Size

Anchors and chains for unrestricted-service vessels are to be in accordance with Table 16.1, and the weights and sizes of these are to be regulated by the equipment number obtained from the following equation.

Metric Units

$$\text{Equipment Number} = \Delta^{2/3} + 2(Ba + \Sigma bh) + 0.1A$$

Inch/Pound Units

$$\text{Equipment Number} = 1.012\Delta^{2/3} + 0.186(Ba + \Sigma bh) + 0.00929A$$

Δ = molded displacement in metric or long tons to the summer load waterline

B = breadth of vessel as defined in Section 2

a = the freeboard in m or ft amidships from the summer load waterline plus the height (at side) of any shelter deck

b = breadth in m or ft of the widest superstructure or deckhouse on each tier

h = the height in m or ft of each tier of deckhouse or superstructure having a width of $B/4$ or greater. In the calculation of h, sheer, camber, and trim may be neglected.

A = the profile area in m^2 or ft^2 of the hull, superstructure, and houses above the design load waterline, which are within the Rule length and have a breadth of $B/4$ or greater. Screens and bulwarks less than 1.5 m (5 ft) in height need not be regarded as parts of houses when calculating h and A.

16.3 Limited-Service Equipment Weight and Size

Anchors and cables for limited-service vessels need not be larger than obtained from 16.2 and are to be not less than obtained from Table 16.2 and the following equation.

Metric Units

$$\text{Y Equipment Number} = 0.269LBD + 0.179lbh + \Sigma 0.135 l_1 b_1 h_1$$

Inch/Pound Units

$$\text{Y Equipment Number} = 0.0075LBD + 0.0050lbh + \Sigma 0.00375 l_1 b_1 h_1$$

L = length of vessel as defined in Section 2
B = breadth of vessel as defined in Section 2
D = depth of vessel as defined in Section 2
l = total length of superstructure erections in m or ft
b = maximum breadth of superstructure erections in m or ft
h = mean height of superstructure erections in m or ft
l_1 = length of each deckhouse in m or ft
b_1 = breadth of each deckhouse in m or ft
h_1 = height of each deckhouse in m or ft

Where the equipment number is Y60 or less, the weight of the second anchor may be reduced 30%. Where the equipment number is between Y60 and Y170, the weight of the second anchor may be reduced 15%. Where the cable is chain, it is to be unstudded short-link chain or stronger.

16.4 Equipment with the Symbol Ⓔ

The equipment weights and sizes for all vessels with the symbol Ⓔ are to be in accordance with Table 16.1 and Table 16.2 as regulated by 16.2 and 16.3.

16.5 Equipment without the Symbol Ⓔ

16.5.1 Unrestricted Service

The equipment weights and sizes for all unrestricted-service vessels for which the symbol Ⓔ is not desired are to be in accordance with 16.4, but need not be tested in accordance with the Rules.

16.5.2 Limited Service

A limited-service vessel for which the symbol Ⓔ is not desired is to have one anchor of the tabular weight and one-half the tabulated length of anchor cable in Table 16.2. Alternatively, two anchors of one-half the tabular weight with the total length of anchor cable listed in Table 16.2 may be fitted provided both anchors are positioned and ready for use and the windlass is capable of heaving in either cable. This equipment need not be tested in accordance with the Rules.

16.5.3 Tugs

A tug is to have at least one anchor of one-half the tabular weight listed in Table 16.1.

16.6 Wire Rope

16.6.1 Unrestricted Service

On unrestricted-service vessels less than 30 m (98.4 ft) in length, anchor chains may be replaced with wire rope of equal strength. On unrestricted-service vessels between 30 m (98.4 ft) and 40 m (131.2 ft) in length, one anchor chain only may be replaced with wire rope of equal strength. In general, wire ropes of trawl winches may be used to comply with the cable requirements permitted in this paragraph. Where wire ropes are substituted for anchor chain, the following additional requirements apply:

- **a** Chain is to be provided between the anchor and the wire rope. The length of this chain is to be either 12.5 m (41 ft) or the distance between the anchor in stowed position and the windlass, whichever is less.
- **b** The length of wire rope is to be 1.5 times that required for the chain it is replacing.

16.6.2 Limited Service

On limited-service vessels where equipment is in accordance with Table 16.2 and the cable is wire rope, the wire rope is to be 6 × 19 standard steel or of equivalent strength.

16.7 Nylon Rope

On limited-service vessels less than 19.8 m (65 ft) in length where equipment is in accordance with Table 16.2, the cable may be nylon rope. Where nylon rope is used, a length of chain is to be installed between the rope and each anchor. The length and diameter of chain to be used with each diameter of nylon rope follow.

Nylon	*Chain*		*Nylon*	*Chain*	
Diameter mm	*Length m*	*Diameter mm*	*Diameter in.*	*Length ft*	*Diameter in.*
9.5	1.2	6.5	3/8	4	1/4
11.0	1.5	8.0	7/16	5	5/16
12.5	1.8	9.5	1/2	6	3/8
16.0	2.4	11.0	5/8	8	7/16
19.0	2.4	12.5	3/4	8	1/2

Where cordage with natural or manmade fibers other than nylon is proposed, the diameter of the cordage will be subject to special consideration.

16.8 Materials and Tests

Materials and tests for anchors and chains are to be in accordance with the applicable requirements of "Rules for Building and Classing Steel Vessels".

16.9 Anchor Types

16.9.1 Unrestricted Service

On unrestricted-service vessels, anchors are to be of the stockless type. The weight of the head of a stockless anchor, including pins and fittings, is to be not less than three-fifths of the total weight of the anchor.

16.9.2 Limited Service

On limited-service vessels, anchors may be of either the stockless type or the ordinary (common, old-style, kedge, mariner's, yachtsman) type. If of the latter type, the weight per anchor given in Table 16.2 is the weight with stock, and the weight of the stock is to be one-fifth of the total weight of the anchor, including stock.

16.9.3 Special Anchor Types

Where specifically requested, the Bureau is prepared to give consideration to the use of special types of anchors, and where these are of proven superior holding ability, consideration may also be given to some reduction in the weight, up to a maximum of 25% from the weights specified in Tables 16.1 and 16.2. In such cases an appropriate notation will be made in the Record.

16.10 Anchor Handling

The arrangements for handling the anchors and cables are to be submitted for approval in accordance with 1.5.1. The windlass or other approved device for paying out and heaving in the cables is to be of good and substantial make, and suitable for the size and type of cable to be used. Care is to be taken to insure fair leads to and from this device. It is to be well bolted down to a substantial bed, and deck beams below it are to be of extra strength and properly supported.

16.11 Hawse Pipes

Hawse pipes, where fitted, are to be of ample size and strength; they are to have full, rounded flanges and the least possible lead in order to minimize nip on the cables; they are to be securely attached to thick doubling or insert plates. When in position they are to be hose-tested with a water pressure at the nozzle of not less than 2.1 kg/cm^2 (30 psi). Hawse pipes for stockless anchors are to provide ample clearances; the anchors are to be shipped and unshipped so the Surveyor may be satisfied that there is no risk of an anchor jamming in its hawse pipe.

16.12 Masts, Spars, and Rigging

All masts, spars, and rigging, where fitted, are to be in good condition, their scantlings and arrangements are to be in accordance with best practice, and they are to be installed to the satisfaction of the Surveyor in attendance.

16.13 Sails

In vessels equipped with sails, they are to be made of suitable materials, sufficient in number, and in good condition.

TABLE 16.1

Equipment for Unrestricted-Service Vessels

For intermediate values of the equipment number use equipment complement in sizes and weights given for the lower equipment number in the table.

Metric Units

		Stockless Bower Anchors		*Stud Link Bower Chain*					*Mooring Lines*		
					Normal Strength Steel (Grade 1)		*High Strength Steel (Grade 2)*				
Equipment Numeral	*Equipment No.*	*Number*	*Weight per Anchor kg*	*Total Length m*	*Diameter mm*	*Breaking Strength kg*	*Diameter mm*	*Breaking Strength kg*	*Number*	*Length of Each m*	*Breaking Strength kg*
UA1	30	2	75	192.5	12.5	6700	—	—	—	—	—
UA2	40	2	100	192.5	12.5	6700	—	—	—	—	—
UA3	50	2	120	192.5	12.5	6700	—	—	2	60	3000
UA4	60	2	140	192.5	12.5	6700	—	—	2	80	3000
UA5	70	2	160	220.0	14.0	8400	12.5	9400	2	100	3500
UA6	80	2	180	220.0	14.0	8400	12.5	9400	2	100	3750
UA7	90	2	210	220.0	16.0	10900	14.0	11800	2	110	3750
UA8	100	2	240	220.0	16.0	10900	14.0	11800	2	110	4000
UA9	110	2	270	247.5	17.5	13000	16.0	15300	2	110	4000
UA10	120	2	300	247.5	17.5	13000	16.0	15300	2	110	4500
UA11	130	2	340	275.0	19.0	15300	16.0	15300	2	120	4500
UA12	140	2	390	275.0	20.5	17800	17.5	18300	2	120	5000
U6	150	2	480	275.0	22.0	20400	19.0	21500	2	120	5550
U7	175	2	570	302.5	24.0	24200	20.5	24900	2	120	6000
U8	205	2	660	302.5	26.0	28300	22.0	28600	2	120	6550

U9	240	2	780	330.0	28.0	32700	24.0	33900	3	120	7250
U10	280	2	900	357.5	30.0	37500	26.0	39700	3	140	8000
U11	320	2	1020	357.5	32.0	42500	28.0	45800	3	140	8750
U12	360	2	1140	385.0	34.0	47700	30.0	52400	3	140	9500
U13	400	2	1290	385.0	36.0	53300	32.0	59400	3	140	10250
U14	450	2	1440	412.5	38.0	59200	34.0	66800	3	140	11000
U15	500	2	1590	412.5	40.0	65300	34.0	66800	4	160	11500
U16	550	2	1740	440.0	42.0	71700	36.0	74600	4	160	12000
U17	600	2	1920	440.0	44.0	78400	38.0	82800	4	160	12500
U18	660	2	2100	440.0	46.0	85300	40.0	91400	4	160	13000

TABLE 16.1
Equipment for Unrestricted-service Vessels

For intermediate values of the equipment number use equipment complement in sizes and weights given for the lower equipment number in the table.

Inch/Pound Units

		Stockless Bower Anchors		*Stud Link Bower Chain*					*Mooring Lines*		
					Normal Strength Steel (Grade 1)		*High Strength Steel (Grade 2)*				
Equipment Numeral	*Equipment No.*	*Number*	*Weight per Anchor pounds*	*Total Length fathoms*	*Diameter inches*	*Breaking Strength pounds*	*Diameter inches*	*Breaking Strength pounds*	*Number*	*Length of Each fathoms*	*Breaking Strength pounds*
UA1	30	2	165	105	1/2	15300	—	—	—	—	—
UA2	40	2	220	105	1/2	15300	—	—	—	—	—
UA3	50	2	265	105	1/2	15300	—	—	2	33	6600
UA4	60	2	310	105	1/2	15300	—	—	2	44	6600
UA5	70	2	350	120	9/16	19300	1/2	21400	2	55	7700
UA6	80	2	400	120	9/16	19300	1/2	21400	2	55	8250
UA7	90	2	460	120	5/8	23700	9/16	27000	2	60	8250
UA8	100	2	530	120	5/8	23700	9/16	27000	2	60	8800
UA9	110	2	595	135	11/16	28600	5/8	33200	2	60	8800
UA10	120	2	670	135	11/16	28600	5/8	33200	2	60	9900
UA11	130	2	750	150	3/4	34000	11/16	40100	2	66	9900
UA12	140	2	860	150	13/16	39800	11/16	40100	2	66	11000
U6	150	2	1060	150	7/8	46000	3/4	47600	2	66	12200
U7	175	2	1255	165	15/16	52600	13/16	55700	2	66	13200
U8	205	2	1455	165	1	59700	7/8	64400	2	66	14400

U9	240	2	1720	180	1 1/8	75000	15/16	73700	3	66	16000
U10	280	2	1985	195	1 3/16	83400	1	83600	3	77	17600
U11	320	2	2250	195	1 1/4	92200	1 1/8	105000	3	77	19300
U12	360	2	2510	210	1 5/16	101500	1 3/16	116500	3	77	20900
U13	400	2	2840	210	1 7/16	120500	1 1/4	129000	3	77	22600
U14	450	2	3170	225	1 1/2	131000	1 5/16	142000	3	77	24200
U15	500	2	3500	225	1 9/16	142000	1 5/16	142000	4	88	25300
U16	550	2	3830	240	1 5/8	153000	1 7/16	169000	4	88	26400
U17	600	2	4230	240	1 3/4	176000	1 1/2	183500	4	88	27600
U18	660	2	4630	240	1 13/16	188500	1 9/16	198500	4	88	28700

TABLE 16.2
Equipment for Limited-Service Vessels

For intermediate values of the equipment number use equipment complement in sizes and weights given for the lower equipment number in the table.

Metric Units

	Anchors		*Cable*			
				Diameter mm		
Equipment Number	*Number*	*Weight per Anchor kg*	*Total Length m*	*Chain*	*Wire Rope*	*Nylon Rope*
Y5	2	18	55.0	6.5	6.5	9.5
Y10	2	22.5	55.0	6.5	6.5	9.5
Y15	2	27	55.0	8.0	8.0	11.0
Y20	2	32	73.0	8.0	8.0	11.0
Y30	2	38	91.5	9.5	9.5	12.5
Y40	2	46	110.0	9.5	9.5	12.5
Y50	2	55	119.0	11.0	11.0	16.0
Y60	2	64	128.0	11.0	11.0	16.0
Y70	2	73	137.0	11.0	11.0	16.0
Y80	2	82	146.0	12.5	12.5	19.0
Y90	2	91	155.5	12.5	12.5	19.0
Y100	2	102	164.5	12.5	12.5	19.0
Y120	2	116	183.0	12.5	12.5	19.0
Y140	2	134	192.0	12.5	12.5	19.0
Y160	2	152	192.0	14.0	14.0	—
Y180	2	170	210.5	14.0	14.0	—
Y200	2	188	219.5	16.0	16.0	—
Y220	2	206	219.5	16.0	16.0	—
Y240	2	224	219.5	16.0	16.0	—
Y260	2	242	219.5	16.0	16.0	—
Y280	2	260	247.0	16.0	16.0	—
Y300	2	278	247.0	16.0	16.0	—

TABLE 16.2
Equipment for Limited-service Vessels

For intermediate values of the equipment number use equipment complement in sizes and weights given for the lower equipment number in the table.

Inch/Pound Units

	Anchors		*Cable*			
				Diameter in.		
Equipment Number	*Number*	*Weight per Anchor lb*	*Total Length fathoms*	*Chain*	*Wire Rope*	*Nylon Rope*
Y5	2	40	30	1/4	1/4	3/8
Y10	2	50	30	1/4	1/4	3/8
Y15	2	60	30	5/16	5/16	7/16
Y20	2	70	40	5/16	5/16	7/16
Y30	2	85	50	3/8	3/8	1/2
Y40	2	100	60	3/8	3/8	1/2
Y50	2	120	65	7/16	7/16	5/8
Y60	2	140	70	7/16	7/16	5/8
Y70	2	160	75	7/16	7/16	5/8
Y80	2	180	80	1/2	1/2	3/4
Y90	2	200	85	1/2	1/2	3/4
Y100	2	225	90	1/2	1/2	3/4
Y120	2	255	100	1/2	1/2	3/4
Y140	2	295	105	1/2	1/2	3/4
Y160	2	335	105	9/16	9/16	—
Y180	2	375	115	9/16	9/16	—
Y200	2	415	120	5/8	5/8	—
Y220	2	455	120	5/8	5/8	—
Y240	2	495	120	5/8	5/8	—
Y260	2	535	120	5/8	5/8	—
Y280	2	575	135	5/8	5/8	—
Y300	2	615	135	5/8	5/8	—

SECTION 17

Propulsion and Auxiliary Machinery

17.1 General

All propulsion machinery and all auxiliary machinery of 135 horsepower and over are to be in accordance with the applicable requirements of the "Rules for Building and Classing Steel Vessels," or, for noncommercial vessels, may be of an alternative design which has demonstrated satisfactory service experience for the intended application. Smaller auxiliaries are to be designed, constructed, and equipped in accordance with good commercial practice, but need not be inspected at the plant of the manufacturer, whose guarantee will be accepted subject to satisfactory performance witnessed by the Surveyor after installation.

17.2 Pressure Vessels

Starting-air tanks and other pressure vessels essential for the safe operation of the vessel are to be designed and constructed in accordance with the applicable requirements of the "Rules for Building and Classing Steel Vessels" or other recognized standards. Arrangements are to be made to have plans giving complete details of design as well as material specifications submitted for approval before proceeding with the construction.

17.3 Torsional Vibrations

A torsional-vibration analysis of the propulsion system is to be submitted in accordance with the "Rules for Building and Classing Steel Vessels." This is not required where the installation is essentially the same as previous designs that have been proven satisfactory.

17.4 Engine Exhaust Systems

Engine exhaust systems are to be so installed that the vessel's structure cannot be damaged by heat from the systems. Exhaust piping is to be arranged to prevent backflow of water from reaching the engine.

17.5 Trial

Before final acceptance, the entire installation is to be operated in the presence of the Surveyor to demonstrate its reliability and sufficiency to function satisfactorily under operating conditions and its freedom from dangerous vibration at speeds within the operating range.

SECTION 18

Shafting and Propellers

18.1 General

Propulsion shafting and propellers are to be in accordance with the applicable requirements of the "Rules for Building and Classing Steel Vessels" except that for vessels below 30.5 m (100 ft) in length, the following alternative requirements may be applied.

18.2 Tail-shaft, Tube-shaft, and Lineshaft Diameters

The least diameter of shafting is to be obtained from the following equation.

$$d = c\sqrt[3]{KH/R}$$

d = diameter of shaft in mm or in.
K = service factor from Table 18.1
H = brake horsepower at rated speed
R = shaft revolutions per minute at rated speed
c = a constant from the following table

Metric (Inch/Pound) Units

Shaft Type	$K < 84$	$K \geq 84$
Lineshaft	24.13 (0.95)	20.32 (0.80)
Tube shaft	25.40 (1.00)	24.13 (0.95)
Tail shaft	25.40 (1.00)	25.40 (1.00)

As an alternative, shafting designed with a factor of safety of at least 2.0, based on a detailed fatigue analysis, will be specially considered.

18.3 Coupling Bolts

The minimum diameter of the shaft coupling bolts is to be obtained from the following equation.

$$d_b = 0.54\sqrt{d^3/Nr}$$

d_b = diameter of bolts at joint in mm or in.
d = required diameter of lineshaft in mm or in. as determined in 18.2 using mechanical properties of coupling-bolt material
N = number of bolts fitted in one coupling
r = radius of bolt pitch circle in mm or in.

Where couplings are separate from the shaft, provision is to be made to resist the astern thrust.

18.4 Tail Shafts and Tube Shafts

18.4.1 Propeller-End Design

Tail shafts are to be provided with an accurate taper fit in the propeller hub, particular attention being given to the fit at the large end of the taper. Where exposed to seawater the propeller assembly is to be sealed at the forward end with a well-fitted soft-rubber packing ring. The key is to fit tightly in the keyway and be of sufficient size to transmit the full torque applied to the shaft at rated speed. The forward end of the keyway is to be so cut in the shaft as to give a gradual rise from the bottom of the keyway to the surface of the shaft. Ample fillets are to be provided in the corners of the keyway and in general, stress concentrations are to be reduced as far as practicable. Suitable means are to be provided for sealing the after end of the shaft against seawater.

18.4.2 Propeller-End Bearings

a ***Water-Lubricated Bearings*** The length of the bearing next to and supporting the propeller is to be not less than four times the required tail-shaft diameter except that the length of metal bearings will be subject to special consideration.

b ***Oil-Lubricated Bearings*** The length of white-metal-lined, oil-lubricated propeller-end bearings fitted with an approved oil seal gland is to be on the order of two times the required tail-shaft diameter. Oil-lubricated unlined cast-iron and bronze bearings will be subject to special consideration.

18.4.3 Protection of Shafting

Tail shafts and tube shafts exposed to seawater are to be protected against galvanic corrosion. The use of graphite-impregnated packing in stuffing boxes is to be avoided because of the possibility of such corrosion. Stainless-steel, nickel-copper alloys, or other shafting materials adversely affected by stagnant water are to be provided with a positive means of water circulation in stern tubes or similar enclosures that tend to trap water next to the shafting.

18.5 Tail-shaft Journals

18.5.1 Fitted Bronze Liners

The thickness of bronze liners fitted to tail shafts or tube shafts in way of bearings is to be not less than obtained from the following equation.

$$t = d/25 + 5.1 \text{ mm} \qquad t = d/25 + 0.2 \text{ in.}$$

t = thickness of liner in mm or in.
d = required diameter of tail shaft in mm or in.

The thickness of fitted liners of other materials will be specially considered.

18.5.2 Welded Overlays

Journal buildup with a welded overlay of stainless steel or other alloy will be specially considered.

18.6 Propeller-Blade Design

Where the propeller blades are of conventional design the thickness of the blades is to be not less than determined by the following equation.

$$t = 915\sqrt{AH/CRN} \pm 1.72BK/C \text{ mm}$$

$$t = 41\sqrt{AH/CRN} \pm 1.72BK/C \text{ in.}$$

t = required thickness at the one-quarter radius in mm or in.
A = $1.0 + 6.0/P_{0.70} + 4.3P_{0.25}$
H = shaft horsepower at the maximum continuous rating
C = $(1 + 1.5P_{0.25})(Wf - B)$
R = shaft revolutions/minute at the maximum continuous rating
N = number of blades
B = $(4300wa/N)(R/100)^2(D/20)^3$
K = rake of propeller blade in mm/m or in./ft multiplied by $D/2$ (with forward rake, use minus sign in equations; with aft rake, use plus sign)
$P_{0.25}$ = pitch at one-quarter radius divided by propeller diameter
$P_{0.70}$ = pitch at seven-tenths radius divided by propeller diameter
W = expanded width of a cylindrical section at the one-quarter radius in mm or in.
a = expanded blade area divided by disc area
D = propeller diameter in m or ft
f, w = material constants from the following table

Representative Propeller Materials	*Metric Units*		*Inch/Pound Units*	
	f	w	f	w
Austentitic Stainless Steel	2.10	7.75	68	0.28
Cast Steel	2.10	8.30	68	0.30
Manganese Bronze	2.10	8.30	68	0.30
Nickel-manganese Bronze	2.25	8.00	73	0.29
Nickel-aluminum Bronze	2.62	7.50	85	0.27
Mn-Ni-Al Bronze	2.37	7.50	77	0.27

Notes

1 For propellers of unusual design, material, or application, the blade thicknesses will be specially considered.

2 For launches, vessels with multiple shafts, and all vessels below 20 m (65 ft) in length, consideration will be given to the acceptance of propeller designs on the basis of a review of the manufacturer's design parameters and guarantee of physical properties and suitability for the intended service.

TABLE 18.1
Service Factor K

Shaft Material	*Minimum Yield Strength at 0.2% offset kg/mm² (psi)*	*Minimum Elongation in 50 mm (2 in.) %*	*Yachting Service*	*Commercial Vessels up to 20 m (65 ft)*	*Commercial Vessels 20 m (65 ft) to 30.5 m (100 ft)*
Carbon and Alloy Steels (unprotected)	21 (30,000)	20	49	61	90
Carbon and Alloy Steels (protected)	21 (30,000)	20	43	50	84
Austenitic Stainless Steels	24.6 (35,000)	40	43	50	84
Age Hardened Martensitic Stainless Steels	73.8 (105,000)	16	23	35	45
Nickel Copper Alloys	73.8 (105,000)	20	23	35	45

Notes

1. Increased dimensions may be required where critical-speed or vibratory torque arrangements are not favorable.
2. The shaft material specification together with physical properties is to be indicated on the submitted shafting drawings and the material specification is to be stamped on the forward end of the shaft. When alloys not represented in Table 18.1 are proposed as shafting material, both the material and shaft size will be subject to special consideration.
3. The thickness of shaft coupling flanges is not to be less than the minimum required diameter of the coupling bolts, and the fillet radius at the base of the flange is not to be less than one-eighth of the shaft diameter.
4. Carbon and alloy steel shafts are considered to be protected when fitted with continuous liners or equivalent such as an oil-lubricated bearing arrangement or when fiberglass reinforced plastic is applied by approved means between non-continuous liners.
5. The service factors for protected carbon and alloy steel shafts are to be used in the calculation of lineshafting.

SECTION 19

Pumps and Piping Systems

19.1 General

Pumps and piping systems are to be in accordance with the applicable requirements of the "Rules for Building and Classing Steel Vessels" except where vessels are below 30.5 m (100 ft) in length, or as provided in 19.2 the following alternative requirements may be applied.

19.2 Plastic Pipe

In general, rigid plastic pipe may be used except in fuel-oil, lubricating-oil and other combustible-liquid systems. The maximum working pressure is to be not greater than one-fifth the hydrostatic bursting pressure indicated in the material specifications, which are to be submitted. The wall thickness for plain-end pipe is to be not less than Schedule 40 I.P.S. The wall thickness for threaded pipe is to be not less than Schedule 80 I.P.S.

19.3 Bilge System

All self-propelled vessels 20 m (65 ft) in length or greater are to be provided with two power-driven bilge pumps, one of which may be attached to the propulsion unit. Vessels below 20 m (65 ft) are to be provided with one power-driven bilge pump, which may be an attached unit, and one suitable hand pump. Power-driven bilge-pump capacity and bilge-pipe size are to be in accordance with the following.

Vessel Length	*Minimum Capacity*	*Minimum Pipe Size*
Below 20 m (65 ft)	5.5 m^3/hr (25 gpm)	25 mm (1 in.) i.d.
20 m (65 ft) or greater but below 30.5 m (100 ft)	11.0 m^3/hr (50 gpm)	38 mm (1.5 in.) i.d.

19.4 Vent, Sounding, and Overflow Pipes

19.4.1 Vent Pipes

In all vessels the structural arrangement in double-bottom and other tanks is to be such as to permit the free passage of air and gases from all parts of the tanks to the vent pipes. Each tank is to be fitted with at least one vent pipe, which is to be located at the highest part of the tank. Vent pipes are to be arranged to provide adequate drainage under normal conditions. Vent pipes are to have a minimum internal diameter not less than 38 mm (1.5 in.) and not less than the internal diameter of the fill line. All vent and overflow pipes on the open deck are to terminate by way of return bends. Vent pipes on fuel-oil tanks are to be fitted with metallic corrosion-resistant flame screens. Satisfactory means, permanently attached, are to be provided for closing the openings of the vent pipes.

19.4.2 Vent Heights

Where vent pipes from tanks are exposed to the weather, their height is to be at least 760 mm (30 in.) above the freeboard deck or 450 mm (17.5 in.) above the superstructure deck except that where these heights may interfere with the working of the vessel a lower height may be approved. The height of vents on vessels under 20 m (65 ft) and on pleasure yachts and fishing vessels will be specially considered.

19.4.3 Sounding Arrangements

Sounding pipes or other suitable means are to be provided to determine the level in all permanently installed tanks. Consideration as to the type and location is to be given in each case depending on the hazard of the liquid involved. Sounding pipes are to be provided with a means for closing.

19.4.4 Overflow Pipes

Where overflow pipes are fitted in tanks, the effective area of the overflow is not to be less than that of the inlet pipe and the vents need not exceed the minimum size in 19.4.1.

19.5 Fuel-oil Piping Systems

Flexible hose of appropriate material may be used for short runs provided it is visible at all times, easily accessible, and confined to one watertight compartment. A duplex strainer or a strainer with a suitable bypass arrangement is to be installed in the fuel supply to each engine.

19.6 Shell Connections

Fluid lines penetrating the hull near or below the maximum load waterline are to be fitted with positive-closing valves. The valves are to be as close to the shell as practicable and either readily accessible or capable of being manually operated from a readily accessible location.

SECTION 20

Electrical Installations

20.1 General

Electrical installations are to be in accordance with the applicable requirements of the "Rules for Building and Classing Steel Vessels" and 20.2 except that where vessels have an aggregate generator capacity not exceeding 50 kw the following alternative requirements may be applied. Electrical installations in machinery spaces with gasoline engines will be specially considered.

20.2 Grounding and Lightning Protection

20.2.1 Equipment Grounding

All electrical enclosures, fittings, and similar equipment are to be permanently grounded to the generator frame and engine bedplate with equipment grounding conductors that are at least as large as the conductors supplying the equipment. All generator frames are to be connected with equipment grounding conductors at least as large as the generator conductors. On systems using grounded neutrals, the neutral is not to be used as an equipment ground.

20.2.2 Lightning Protection

A lightning-protection system consisting of a copper spike, a copper conductor of at least 8 mm^2 (No. 8 AWG), and a grounding plate of not less than 450 cm^2 (1 ft^2) is to be installed. The spike is to project at least 150 mm (6 in.) above the uppermost part of the vessel, the conductor is to run clear of metal objects and as straight as practicable, and the grounding plate is to be located so that it is immersed under all conditions of heel. Metallic rudders may be used as grounding plates.

20.3 Temperature Ratings

In the following requirements an ambient temperature of 40C has been assumed for all locations. Where the ambient temperature is in excess of this value, the total temperature specified is not to be exceeded. Where equipment has been rated on ambient temperature less than that contemplated, consideration will be given to the use of such equipment provided the total temperature for which the equipment is rated will not be exceeded.

20.4 Generators

Vessels using electricity for propulsion auxiliaries or preservation of cargo are to be provided with at least two generators. These generators are not to be driven by the same engine. The capacity of the generating sets is to be sufficient to carry the necessary load essential for the propulsion and safety of the vessel and preservation of the cargo with any one generator set in reserve. Vessels having only one generator are to be provided with a battery source to supply sufficient lighting for safety.

20.5 Location

Generators, motors, and other electrical equipment are to be so arranged that they cannot be damaged by bilge water, and are to be protected from openings to the weather.

20.6 Storage Batteries

20.6.1 Location

Storage batteries are to be located in well-ventilated areas as high above the bilges as possible and as far away as practicable from potential sources of ignition.

20.6.2 Installation

Lead-acid storage batteries are to be installed in liquid-tight trays lined with lead or other suitable material. Alkaline storage batteries are to be installed on suitable insulating supports, and where metal cell containers are used these are to be protected against conducting materials that can cause short-circuiting between the containers and between the containers and metal structure. Batteries are to have not less than 250 mm (10 in.) vertical clearance and are to be chocked all around to prevent their movement due to the motion of the vessel.

20.6.3 Charging

Means are to be provided for determining the charged condition of storage batteries and charging them when necessary. Where voltage-dropping resistors are utilized, they are to be mounted in a well-ventilated noncombustible enclosure situated away from other combustible material. Battery-charging circuits are to have overcurrent and reverse-current protection, and a disconnect switch is to be provided before the battery charger.

20.6.4 Connections

Connections to storage batteries are to be made with fitted connectors providing good mechanical and electrical unions. Spring clips or other temporary clamps are not to be used.

20.7 Cables

20.7.1 Construction

Cables are to have copper conductors constructed in accordance with a recognized standard and are to be of the stranded type, except sizes not exceeding 1.5 mm^2 (16 AWG) may have solid conductors.

20.7.2 Installation

All wiring is to be run as high as possible above the bilges, and cable runs are to be made without splices and be as straight and accessible as practicable. Cables installed in machinery spaces are to have an insulation with a temperature rating of not less than 75C. They are to be effectively supported and secured, and protected against mechanical damage where liable to such damage. Cables exposed to moisture are to be moisture-resisting jacketed (impervious-sheathed). All cable entrances in exposed locations and all penetrations through watertight decks and bulkheads are to be made watertight.

20.8 Distribution Boxes and Panels

20.8.1 Construction

Distribution boxes and panels are to be of noncombustible material and are to be preferably of the dead-front type. They may be of metal or of nonconductive material. If of metal they are to be grounded in accordance with 20.2. All terminal strips, fuse blocks, switches, and similar equipment are to be of noncombustible high-dielectric-strength insulating material.

20.8.2 Installation

Distribution boxes and panels are to be installed in dry, accessible, and well-ventilated areas. Not less than 610 mm (24 in.) clearance is to be provided in front of distribution boxes and panels. When located at the helm or other area adjacent to or part of an open cockpit or weather deck, they are to be protected by a watertight enclosure.

20.8.3 Instrumentation

A voltmeter, ammeter, frequency meter, and voltage regulator are to be provided for each generator installed. Control equipment and measuring instruments are to be provided as necessary to insure satisfactory operation of the generator or generators.

SECTION 21

Fire Extinguishing Systems

21.1 Fire Pumps

21.1.1 Number of Pumps

Two power-driven fire pumps are to be installed, one of which may be attached to the propulsion unit. Where vessels are less than 20 m (65 ft) in length, one power-driven pump, which may be an attached unit, and one hand-operated fire pump are to be provided. Sanitary, bilge, and general-service pumps may be accepted as fire pumps.

21.1.2 Capacity

Fire-pump capacity is to be in accordance with the following.

Vessel Length	*Minimum Capacity*
Below 20 m (65 ft)	5.5 m^3/hr (25 gpm)
20 m (65 ft) or greater but below 30.5 m (100 ft)	11.0 m^3/hr (50 gpm)
30.5 m (100 ft) or greater	14.3 m^3/hr (66.6 gpm)

Power-driven fire pumps are to have sufficient pressure to supply the effective stream required by 21.3. Hand-operated fire pumps are to have a minimum capacity of 1.1 m^3/hr (5 gpm).

21.2 Hoses, Nozzles, and Hydrants

Hoses are not to have a diameter greater than 38 mm (1.5 in.). Hoses for vessels under 20 m (65 ft) in length may be garden type of good commercial grade having a diameter of not less than 16 mm ($\frac{5}{8}$ in.). Nozzle sizes are to be in accordance with the "Rules for Building and Classing Steel Vessels." Fire hydrants are to be of sufficient number and so located that any part of the vessel may be reached with an effective stream of water from a single length of hose not exceeding 15 m (50 ft). All hoses attached to hydrants serving machinery spaces of vessels over 20 m (65 ft) are in addition to be fitted with nozzles suitable for spraying water on oil or, alternatively, dual-purpose nozzles.

21.3 Fixed Systems

A fixed fire-extinguishing system is to be provided for the machinery space of vessels over 1000 horsepower.

21.4 Axe

One fire axe is to be provided on each vessel 20 m (65 ft) and over.

21.5 Portable Extinguishers

Portable extinguishers are to be provided in the quantities and locations indicated in Tables 21.1 and 21.2.

TABLE 21.1
Classification of Portable and Semiportable Extinguishers

Classification Type	*Size*	*Soda-Acid and Water, liters (U.S. gallons)*	*Foam, liters (U.S. gallons)*	*Carbon Dioxide, kg (lb)*	*Dry Chemical, kg (lb)*
A	II	9 (2.5)	9 (2.5)	—	—
B	II	—	9 (2.5)	6.8 (15)	4.5 (10)
C	II	—	—	6.8 (15)	4.5 (10)

TABLE 21.2
Portable and Semiportable Extinguishers

Space	*Classification*	*Quantity and location*
Safety Areas		
Communicating corridors	A-II	1 in each main corridor not more than 46 m (150 ft) apart. (May be located in stairways.)
Radio room	C-II	1 in vicinity of exit.
Accommodations		
Sleeping accommodations	A-II	1 in each sleeping accommodation space. (Where occupied by more than 4 persons.)
Service Spaces		
Galleys	B-II or C-II	1 for each 230 m² (2500 ft²) or fraction thereof for hazards involved.
Storerooms	A-II	1 for each 230 m² (2500 ft²) or fraction thereof located in vicinity of exits, either inside or outside of spaces.
Machinery Spaces		
Internal combustion or gas turbine-engines	B-II	1 for each engine. See *Note* 1.
Electric motors or generators of open type	C-II	1 for each 2 motors or generators. See *Note* 2.

Notes
1 When installation is on weather deck or open to atmosphere at all times 1 B-II for each three engines is allowable.
2 Small electrical appliances, such as fans, etc., are not to be counted or used as basis for determining number of extinguishers required.

SECTION 22

Surveys after Construction

22.1 Conditions for Surveys after Construction

22.1. Annual Surveys
Annual Surveys are to be made during each year of service.

22.1.2 Special Periodical Surveys
The first Special Periodical Survey becomes due four years after the date of build. Subsequent Special Periodical Surveys are due four years after the crediting date of the previous Special Survey. The interval between Special Surveys may be reduced by the Committee. If a Special Survey is not completed at one time, it will be credited as of the end of that period during which the greatest part of the survey has been carried out. Special consideration may be given to Special Periodical Survey requirements in the case of vessels of unusual design.

22.1.3 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 Survey requirements are carried out in regular rotation to complete all the requirements of the particular Special Survey within a five-year period. 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 examined and dealt with to the satisfaction of the Surveyor.

22.1.4 Year of Grace
To be eligible for the year of grace to complete the Special Survey within one year after the due date, the vessel is to be presented for survey at about the due date of the Special Survey. The requirements for surveys to qualify for a period of grace are to be specially considered in each case and may include drydocking. If the survey is satisfactory, the completion of the Special Survey may be deferred for a period not exceeding twelve months, provided the whole Special Survey is satisfactorily completed within five years from date of build or from the date recorded for the previous Special Survey.

22.1.5 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.

22.1.6 Premature Commencement—Special Survey

When circumstances cause a Special Survey to be commenced before it is due, the entire survey is to be completed within a period of twelve months if such work is to be credited to the Special Survey.

22.1.7 Load Line Surveys

In addition to Annual and Special Surveys, vessels to which Load Lines have been assigned are subject to the inspection and survey requirements of the International Convention on Load Lines.

22.1.8 Alterations

No structural alterations which affect or may affect seaworthiness, classification, or the assignment of load lines are to be made to the hull or machinery of a classed vessel unless plans of the proposed alterations are submitted and approved by the Committee before the work of alterations is commenced and such work, when approved, is carried out under the supervision of the Surveyor.

22.1.9 Drydocking Survey

a ***Interval*** An examination of each classed vessel is to be made in drydock at intervals not exceeding two years. Consideration may be given to any special circumstances justifying an extension of the interval.

b ***Parts to Be Examined*** The vessel is to be placed in drydock or upon a slipway and the keel, stem, stern frame or stern post, rudder, and outside of plating are to be cleaned and examined together with appendages. The propeller, exposed parts of the stern-bearing assembly, rudder pintle and gudgeon securing arrangements, sea chests, strainers, and their fastenings are to be examined. The stern-bearing clearance and rudder-bearing clearances are to be ascertained and reported upon.

22.2 Annual Surveys—Hull

An examination of each classed vessel is to be made once a year when in service, and may be made afloat. At each annual survey the following parts are to be examined, placed in satisfactory condition, and reported upon.

- a All accessible parts of the steering arrangements, including the steering machinery if fitted, quadrants, tillers, blocks, rods, chains, telemotor or other control transmission gear, and brakes.
- b Doors in watertight bulkheads and vessel's sides, closing appliances in enclosed superstructure bulkheads and for air vent and sounding pipes.
- c Coamings and closing arrangements of ventilators to spaces below the freeboard deck and into enclosed superstructures, hatchway coamings, and hatch covers.
- d All accessible parts particularly liable to rapid deterioration.

- e Exposed machinery casings, guard rails and all other means of protection provided for openings and for access to crew's quarters.
- f Freeing ports in bulwarks.
- g The deck-to-hull connection, and superstructure and deckhouse connections to the deck.

22.3 Special Periodical Surveys—Hull

22.3.1 All Vessels

In addition to compliance with the Annual Survey requirements, the following are to be examined, placed in satisfactory condition, and reported upon.

- a The vessel is to be placed in drydock or upon a slipway and all items of 22.1.9b are to be examined.
- b In the case of vessels which have been surveyed in drydock approximately one year before the commencement of Special Survey, no further drydocking will be required, provided all requirements incidental to the drydocking survey are completed satisfactorily.
- c 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.
- d Where there is evidence of cracking, distortion, wetness, or delamination, destructive or nondestructive testing and removal and repair of the defect is subject to the discretion of the attending Surveyor.
- e All watertight bulkheads are to be examined.
- f Engine foundations and their attachment to the hull are to be examined.
- g The Surveyor is to see that a pad is securely fixed below each sounding pipe for the rod to strike upon.
- h Integral tanks are to be tested with a head of liquid to the highest point that liquid will rise under service conditions. The testing of double bottoms and other spaces not designed for the carriage of liquids may be omitted provided an internal examination is carried out.
- i Independent oil tanks in machinery spaces are to be externally examined, and if considered necessary tested under liquid head.
- j The decks are to be examined and deck compositions are to be examined and sounded, but need not be disturbed if found to be adhering satisfactorily.
- k Hatch covers in weather decks, not fitted with tarpaulins, are to be hose tested or otherwise proven tight.
- l 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.

m The rudder is to be examined and lifted when required, and the gudgeons rebushed. The conditions of carrier and steadiment bearings and the effectiveness of stuffing boxes are to be ascertained when the rudder is lifted.

n The efficiency of hand pumps or other drainage arrangements for end spaces is to be tested.

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

22.3.2 Sailing and Unpowered Vessels

In addition to the items in 22.3.1 where applicable, ballast-keel fastenings and all openings to the sea, including sanitary and other overboard discharges, together with the cocks and valves connected therewith, are to be examined while the vessel is in drydock. Masts, spars, sails, and standing and running rigging also are to be examined.

22.4 Annual Surveys—Machinery

A general inspection of engines, steering machinery, windlass, and fire-extinguishing apparatus required for Classification is to be made during each year of service.

22.5 Special Periodical Surveys—Machinery

22.5.1 Correlation with Hull Special Surveys

Main and auxiliary engines of all types are to undergo Special Periodical Survey at intervals similar to those for Special Surveys on the hull, in order that both may be recorded at approximately the same time. In cases where damage has involved extensive repairs and examination, the survey thereon may, where approved by the Committee, be accepted as equivalent to a Special Periodical Survey.

22.5.2 Parts to Be Examined

At each Special Periodical Survey effect is to be given to the following requirements.

a All openings in the shell, including sanitary and other overboard discharges, together with the cocks and valves connected therewith, are to be examined while the vessel is in drydock; and the fastenings to the shell are to be renewed when considered necessary by the Surveyor.

b Pumps and pumping arrangements, including valves, cocks, pipes, and strainers, are to be examined. Nonmetallic flexible expansion pieces in the main circulating system are to be examined. The Surveyor is to be satisfied with the operation of the bilge system. Other systems are to be tested as considered necessary.

- **c** Shafts (except the propeller shaft), shaft bearings, and thrust bearings are to be opened for examination.
- **d** Unfired pressure vessels necessary to the vessel's operation are to be opened for examination, gauged if considered necessary, and associated relief valves intended for working pressure above 3.5 kg/cm^2 (50 psi) are to be proven operable.
- **e** Examination of the steering machinery is to be carried out, including an operational test and checking of relief-valve settings, and the machinery may be required to be opened for further examination as considered necessary by the Surveyor.
- **f** Reduction gears are to be opened as considered necessary by the Surveyor in order to permit the examination of the gears, gear teeth spiders, pinions, shafts, and bearings.
- **g** An examination of the fire-extinguishing apparatus required for Classification as outlined in Section 21 is to be made in order that the Surveyor may satisfy himself as to its efficient state.

22.5.3 Internal-Combustion Engines

- **a** In addition to the foregoing applicable requirements, cylinders, cylinder heads, valves and valve gear, fuel pumps, scavenging pumps, and superchargers, pistons, crossheads, connecting rods, crankshafts, clutch, reversing gear, air compressors, intercoolers, and such other parts of the main and auxiliary machinery as are considered necessary are to be opened out for examination. Parts which have been examined within twelve months need not be examined again except in special circumstances.
- **b** If fitted, air reservoirs are to be examined and their relief valves proven operable. If air reservoirs cannot be examined internally they are to be gauged by nondestructive means or hydrostatically tested to one and one-half times the working pressure.
- **c** Special consideration will be given to modification of examination required under 22.5.3a if satisfactory alternate overhaul procedure suggested by engine builder or special operating service is proposed and approved by the Bureau.

22.5.4 Examination during Overhaul

On all occasions of overhaul or adjustment, facilities are to be provided for the Surveyor to examine the parts opened; in the event of defects being discovered, such other parts as may be considered necessary are to be opened and examined.

22.6 Propeller Shaft Surveys

Propeller-shaft surveys and intervals between surveys will be specially considered, dependent on type of installation and operational service.

22.7 Special Periodical Surveys—Electrical Equipment

The entire installation, including auxiliary and emergency equipment, is to undergo Special Periodical Survey every four years at the same time as the Special Survey on the machinery. The following are to be carried out at each Special Periodical Survey.

- **a** Fittings and connections on main switchboards and distribution panels are to be examined, and care is to be taken to see that no circuits are overfused.
- **b** Cables are to be examined as far as practicable without undue disturbance of fixtures.
- **c** All generators are to be run under load, either separately or in parallel; switches and circuit breakers are to be tested.
- **d** All equipment and circuits are to be inspected for possible development of physical changes or deterioration. The insulation resistance of the circuits is to be measured between conductors, and between conductors and ground, and these values compared with those previously measured. Any large and abrupt decrease in insulation resistance is to be further investigated and either restored to normal or renewed as indicated by the conditions found.
- **e** Where electrical auxiliaries are used for vital purposes, the generators and motors are to be examined and their prime movers opened for inspection. The insulation resistance of each generator and motor is to be measured with all circuits of different voltages above ground being tested separately.

Appendices

APPENDIX A

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APPENDIX **B**

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Record of the American Bureau of Shipping
Annual subscription with Supplements
USA $235 Other countries $275

Rules for Building and Classing Steel Vessels
English Language Edition (Annual)
$20.00

French Language Edition (1976)
$20.00

Greek Language Edition (1973)
$16.00

German Language Edition (1973)
$16.00

Spanish Language Edition (1972)
$16.00

Portuguese Language Edition (1973)
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Japanese Language Edition (1975)
$22.00

Rules for Building and Classing Aluminum Vessels (1975)
$10.00

Rules for Building and Classing Steel Vessels for Service on Rivers and Intracoastal Waterways
English Language Edition (1971)
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Spanish Language Edition (1975)
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Rules for Building and Classing Steel Vessels under 61 Meters (200 Feet) in Length (1973)
$10.00

Rules for Building and Classing Offshore Mobile Drilling Units (1973)
$7.50

Rules for Building and Classing Single Point Moorings (1975)
$7.50

Rules for Building and Classing Steel Barges for Offshore Service (1973)
$5.00

Rules for Building and Classing Steel Floating Dry Docks (1977)
$5.00

Rules for Building and Classing Bulk Carriers for Service on the Great lakes (1978)
$10.00

Rules for Building and Classing Reinforced Plastic Vessels (1978)
$10.00

Rules for Certification of Cargo Containers (1974)
$5.00

Rules for Nondestructive Inspection of Hull Welds (1975)
$5.00

Guide for the Classification of Manned Submersibles (1968)
$5.00

Guide for Construction of Shipboard Elevators (1975)
$3.00

Guide for Repair, Welding, Cladding and Straightening of Tail Shafts (1975)
$3.00

Guide for the Classification of Nuclear Ships (1962)
$1.00

Guide for Inert Gas Installations on Vessels Carrying Oil in Bulk (1973)
$.50

Guide for Underwater Inspection in lieu of Drydocking Survey (1975)
Free

Guide for Burning Crude Oil and Slops in Main and Auxiliary Boilers (1978)
$3.00

Guide for Building and Classing Fixed Offshore Structures (1978)
Free

Guidance Manual for Making Bronze Propeller Repair (1972)
$3.00

Requirements for Certification of Self-Unloading Cargo Gear on Great Lakes Vessels (1974)
$1.50

Requirements for Certification of the Construction and Survey of Cargo Gear on Merchant Vessels (1975)
$2.00

Approved Welding Electrodes, Wire-Flux and Wire-Gas Combinations (Annual)
$10.00

IMCO Publications

For the convenience of the user of the *Rules for Building and Classing Steel Vessels*, the Bureau has a supply of the Codes published by the Inter-Governmental Maritime Consultative Organization that are referenced in these Rules. The publications listed below can be purchased from the Book Order Section, American Bureau of Shipping, 65 Broadway, New York, NY 10006, U.S.A. or from the IMCO Secretariat, Publications Section, 101–104 Piccadilly, London W1VOAE, England.

Code for the Construction and Equipment of Ships Carrying Dangerous Chemicals in Bulk
$2.60

Code for Existing Ships Carrying Liquefied Gases in Bulk
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Code for the Construction and Equipment for Ships Carrying Liquefied Gases in Bulk
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