VOLUME VII

OMCS CLASS

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OMCS CLASS

Overseas Marine Certification Services

RULES FOR THE CLASSIFICATION OF FIBREGLASS REINFORCED PLASTICS SHIPS (FRP SHIPS)

Volume VII

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PART I – GENERAL REQUIREMENTS

CHAPTER 1 – GENERAL

1.1. Application

1.1.1. The Rules for the construction and classification of ships for fiberglass reinforced plastics (hereinafter referred to as the Rules) apply to the design, material, construction, and equipment for ships of fiberglass reinforced plastics (hereinafter referred to as "FRP ships") intended to be assigned and registered classification with OMCS CLASS (hereinafter referred to as the Society).

1.1.2. Unless otherwise specified, the requirements in the Rules are framed for FRP ships, with a designed speed not exceeding $3.7\nabla^{0.1667}$ (m/s) (∇ = displacement in m^3 corresponding to the load line defined in 1.3.6) other than oil tankers, of normal form and proportion, less than 35 meters in length, intended for unrestricted service. Special considerations will be given to large ships, ships for restricted service, ships of unusual form or proportion, novel design and arrangement, or ships intended for the carriage of special cargoes, the requirements for construction, equipment and scantlings may be properly modified.

1.1.3. The requirements in the Rules are applied to ships having structures of single skin laminates with stiffeners or sandwich constructions, molded by hand lay-up method or spray lay-up method, using fiberglass reinforcements and unsaturated polyester resins.

1.1.4. Reinforcement materials other than fiberglass and resins other than polyester may be accepted based upon testing and approval in each individual case. Alternative constructing method, structural arrangement, equipment, and scantlings are to be considered to the Society's satisfaction that they are equivalent to the requirements of the Rules.

1.2. Classification and Survey of FRP Ships

1.2.1. The classification and register of FRP ships are also to be in accordance with the applicable provisions in Part I of the "Rules for the Construction and Classification of Steel Ships" (hereinafter referred to as "the Steel Ship Rules ").

1.2.2. FRP ships with their class approved by the Society are to be recorded in the Register and assigned a descriptive notation (FRP Hull) affixed to the classification symbols.

1.2.3. Except specified otherwise in this Chapter, the classification surveys of FRP ships are generally to comply with the requirements in Part I of the Steel Ships Rules. Plan review and surveys during or after construction are to be conducted by the Society to verify that the construction, material, equipment, machinery, and electrical installation are in compliance with the Rules.

1.2.4. When FRP ships intended to be built under classification survey during construction, Plans or documents showing the following details are to be submitted and approved before the work is commenced.

a. General arrangement
b. List and data for raw materials

c. Midship section
d. Construction profile and deck plan
e. Scantling calculation
f. Laminating procedure and details of joint connections
g. Watertight and oiltight bulkhead
h. Superstructure and deckhouse
i. Fore and aft construction
j. Shaft strut
k. Rudder and steering gear
l. Main engine and auxiliary machinery foundations
m. Hatch and closing appliances
n. Opening construction on weather deck
o. Arrangement and details of hull port, door, and window
p. Arrangement and details of fire safety appliances and systems
q. Machinery arrangement
r. Propeller and shafting, or propulsion system
s. Piping systems
t. Electrical system
u. Automatic and remote-control systems of machinery, if CAS, CAU or CAB applied
v. Main engine, deck machinery and essential auxiliaries
w. Other plans and documents deemed necessary by the Society.

1.2.5. In addition to those required by 1.2.4, the following plans or documents are to be submitted for reference, when FRP ships are intended to be built under Classification survey during construction.

a. Designated by the Society during commencement of moulding, curing and mould releasing
b. Test of FRP materials specified in Chapter 2 of Part I
c. Connection of moulding (e.g., deck to shell)
d. Testing of hull castings and forgings
e. Hydrostatic test and watertight test
f. Test of main and auxiliary machinery
g. Sea trail

1.2.6. The stages for which the Surveyor’s inspection required may be modified according to the actual status of facilities, technical capabilities, and quality control system of the works.

1.2.7. Periodical surveys are generally to be in accordance with the provisions in 1.6 of Part I of the Steel Ships Rules. In addition, the fuel oil tanks made of FRP are to be examined internally at the bottom survey.

1.2.8. In the classification of FRP ships not built under the Society's survey, the actual scantlings of main structure of the ship are to be confirmed by suitable means in addition to the inspection of hull, equipment, machinery, electrical installations, intact safety, and fire protection as required for the special survey to the ship's age. Plans and documents required for the classification survey during construction are generally to be submitted for review and records.

1.3. Definitions

1.3.1. Length of ship (L) is the distance in meters on the designed load line defined in 1.3.6, from the fore side of stem to the axis of rudder stock. In case of a ship with a cruiser stern, L is as defined above or 96% of the total length on the load line, whichever is the greater.

1.3.2. Breath of ship (B) is the horizontal distance in meters between outsides of shell laminates measured on the upper surface of upper deck laminates at side at the broadest part of the hull.

1.3.3. Depth of ship (D) is the vertical distance in meters measured at the middle of L, from lower surface of bottom laminates or the intersection of the extension line of lower surface of bottom laminates with the center line of ship (hereinafter referred to as "the base point of D") to upper surface of upper deck laminates at side.

1.3.4. Midship part of ship is the parts for 0.4L amidships unless specified otherwise.

1.3.5. The end parts of ship are the parts for 0.1L from either end of the ship.

1.3.6. Load line is the waterline corresponding to the summer load draught in case of a ship which is required to be assigned with load lines, or the waterline corresponding to the designed maximum draught in case of a ship which is not required to be assigned with load lines.

1.3.7. Load draught (d) is the vertical distance in meters from the base point of D to the load line.

1.3.8. Freeboard deck is the uppermost continuous deck which has permanent means of weathertight closing of all openings in the weather part thereof, and below which all openings in the ship side are fitted with permanent means of water tightly closing. In a ship having a discontinuous freeboard deck, the lowest line of the exposed deck and the continuation of that line parallel to the upper part of the deck is taken as freeboard deck.

1.3.9. Strength deck is the uppermost deck which forms the top of effective hull girder at any part of its length and normally to which the shell laminates extend. In case of superstructures other than a sunken superstructure, which are not considered effective to longitudinal strength, the strength deck is the deck just below the superstructure deck.

1.3.10. Superstructure is an enclosed structure on the main weather deck having side plating as an extension of the side shell, or not fitted inboard of the hull side more than 4% of the breadth.

1.4. Regulations

1.4.1. While the Rules cover the requirements for the classification of FRP ships, owner, designer, and builder are strongly recommended to deal with the regulations of governmental and other authorities in addition to the requirements of the Rules.

1.4.2. Where authorized by the Administration whose flag the ship (hereinafter refer to as the administration) is entitled to fly, and upon request of owners or builders of the ship, the Society is to review plans, survey and certify the new or existing ship for compliance with the provisions of relevant International Conventions or Codes.

CHAPTER 2 – MATERIALS

2.1. General

2.1.1. The requirements in this chapter apply to raw materials for FRP structure and FRP laminates. Materials other than plastics, such as metallic materials, are to be in accordance with requirements in the Steel Ships Rules.

2.1.2. Details of the fiberglass reinforcements, resins and sandwich core materials proposed to be used for FRP ships are to be submitted for approval before construction is commenced. The materials are to be accepted on the basis of a detailed description confirming the information given by the manufacturer with inspection and test results to the satisfaction of the surveyor.

2.1.3. At the request of manufacturers for type approval of materials, the Society is to examine the manufacturing process, inspection standards and quality control system of the works. Inspections and approval tests of materials from current production are to be carried out in the presence of the surveyor.

2.1.4. The following materials are subject to type approval:

a. Fiberglass reinforcements,
b. Polyester products,
c. Core materials for sandwich construction.

2.1.5. The type of approval for each material grade is valid for a period of 5 years and will be published in the Society's list of type approved products. The approval may be withdrawn or revoked if the manufacturing process and/or material conditions at the time of approval no longer are fulfilled. The renewal of type approval certificate is to be normally assessed by checking of production control records, random inspection, and sample testing.

2.2. Definitions

2.2.1. Resin: A reactive synthetic normally unsaturated polyester for laminating and gelcoat which is a liquid in initial stage but transformed into solid upon activation with adding substances.

a. Polyester resin is a thermosetting resin that is formed by combining saturated and unsaturated organic acids such as Orth phthalic and isophthalic acids.
b. Vinyl ester resin is a thermosetting resin that consists of a polymer chain and an acrylate or methacrylate termination.
c. Epoxy resin is a resin that contains one or more of the epoxide groups.
d. Accelerator is a material that, when mixed with resin, speed the cure time.
e. Additive is an added substance usually to improve resin properties, such as plasticizers, initiators, light stabilizers, and flame retardants.
f. Catalyst is a material that is used to activate resin, causing it to harden.
g. Cure time is the time required for resin to change from a liquid to a solid after a catalyst has been added.
h. Gel time is the time required to change a flowable, liquid resin into a non-flowing gel.

i. Exothermic heat is the heat given off as the result of the action of a catalyzed resin.
j. Inhibitor is a material that retards activation or initiation of resin, thus extending shelf life or influencing exothermic heat or gel time.
k. Pot life is the length of time that a catalyzed resin remains workable.
l. Shelf life is the length of time that an uncatalyzed resin maintains its working properties while stored in a tightly sealed opaque container.

2.2.2. Reinforcement: A material bonded into the plastic to improve its strength, stiffness, and impact resistance. Reinforcements are usually fibers of glass, or other material such as aramid or carbon fiber.

a. Chopped strand mat is fiberglass of blanket type in uniform thickness with strands of non-alkali fiberglass cut in proper length randomly oriented and held together with binder.
b. Woven roving is a coarse fabric fiberglass woven in plain with parallel strands or rovings made of non-alkali fiberglass.
c. Strand is a bundle of continuous filaments combined in a single, compact unit.
d. Roving is a band or ribbon of parallel strands grouped together.
e. Yarn is a twisted strand or strands suitable for weaving into a fabric.
f. Binder is a polyester applied in small quantities to hold fibers together in mat form.
g. Cloth is a fabric woven from yarn.

2.2.3. Laminate: A material composed of successive bonded layers, or piles, of resin and fiber or other reinforced substances.

a. Gel coat is the first resin applied to mould when fabricating a laminate to provide a smooth protective surface for laminate.
b. Lay-up is the process of applying to a mould 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.
c. Peel ply is a partially impregnated, lightly bonded layer of fiberglass used to protect a laminate in anticipation of secondary bonding providing a cleaned fresh bonding surface.
d. Primary bonding is the practice of bonding between two laminated surfaces when the resin on both surfaces has not yet cured.
e. Secondary bonding is the practice of bonding fresh materials to a cured or partially cured laminate.
f. Post cure is the act placing a laminate in higher temperature to assist in the cure cycle of the resin.

2.3. Fiberglass Reinforcement

2.3.1. Properties regarding following items are to be tested and inspected:

a. Appearance,
b. Weight per unit area and its maximum deviation
c. Ratio in weight of residual binders or knitting agents
d. Tensile strength of fiberglass, in case of woven roving’s

e. Tensile strength and modulus of tensile elasticity obtained from laminated test specimens
f. Bending strength and modulus of bending elasticity obtained from laminated test specimens

2.3.2. Test results are to meet manufacturer's specifications and to verify the properties used in design of laminates. Moisture content in reinforcement is to be observed.

2.3.3. Where coupling agents are used, they are to be of the saline compound or complex chromium compound which are compatible with the laminating resins.

2.3.4. For roving which will be applied by spraying, a demonstration is to be made showing that the roving is suitable for this kind of application.

2.3.5. The glass is to be of E-quality. Fibers made of other glass qualities, S or R glass, carbon or aramid fibers may be used subject to special agreement and provided that their mechanical properties and water resistance are equal or better.

2.4. Resins

2.4.1. The properties of a resin are to be of final form actually used in laminating with all additives and fillers included. The following properties of resins in liquid condition, cured condition and curing characteristics are to be provided.

2.4.2. Liquid properties (at 25^{o}C)

a. Viscosity and thixotropic index
b. Acid value
c. Gel time, indicate initiator (catalyst) and activator (promoter) content %, the minimum cure time and Peak exothermic temperature.

2.4.3. Cured properties of resin casting

a. Load deflection temperature of resin casting
b. Water absorption of resin casting
c. Barcol hardness of resin casting
d. Tensile strength and modulus of laminated test specimens
e. Bending strength and modulus of laminated test specimens.

2.5. Core materials

2.5.1. Core materials used for sandwich construction such as honeycomb, rigid plastic foam, balsa wood, are to be of sufficient tensile, compressive and shear strength which are to be verified by test for use in the design. If the core materials are manufactured into formable sheets of small blocks, the open weave backing material and adhesive are to be compatible and soluble with the laminating resin.

2.5.2. Following properties of core materials are to be examined:

a. Specific gravity
b. Water absorption
c. Tensile strength and modulus
d. Compressive strength and modulus

e. Shear strength, modulus, and elongation

2.5.3. Rigid plastic foams are to be compatible with the resin system, have stable aging property, resistant to water and oils. The construction methods and procedures using foam cores are to be in accordance with manufacturer's recommendation.

2.5.4. Balsa woods are to be end grained, treated against fungal and insect attack and dried to have an average moisture content of 12%.

2.5.5. Plywood and timbers used in conjunction with plastic construction are to be seasoned, free from knots, shakes and other defects, of water resistance and suitably treated so as to have good adhesion to reinforced plastics.

2.6. FRP Strength Test

2.6.1. The FRP strength tests are to be carried out upon completion of laminate works of FRP Ships and in case where scantling is modified according to the requirements specified in 1.2.2 of Part II before plans being submitted for approval and construction.

2.6.2. The test specimens for FRP material tests are to be cut from the laminates and sandwich laminates taken from the actual laminates or the laminates and sandwich laminates equivalent thereto. The test specimens are to be tested and inspected as follows:

a. FRP laminates (including FRP laminates of outer skin of sandwich laminates),
   i. Thickness of moulding
   ii. Barcol hardness
   iii. Glass content
   iv. Bending strength
   v. Modulus of bending elasticity
   vi. Tensile strength
   vii. Modulus of tensile elasticity.

b. Sandwich laminates
   i. Thickness of moulding of sandwich laminates
   ii. Tensile strength of sandwich laminates, only in case where the cores are born a load in the scantling calculation. In this case, the test specimens involving joints of cores are to be included.
   iii. Shearing strength of sandwich laminates, in case where the cores are reckoned in the bending strength, the test specimens involving joints of cores are to be included.

2.6.3. The FRP strength tests are to be carried out, at least on the structural members specified as follows:

a. Bottom shell laminates
b. Side shell laminates
c. Upper deck laminates
d. Bulkhead (only of sandwich construction)

2.6.4. The results of FRP strength tests specified as follows are to be submitted to the Society.

a. Names of fiberglass reinforcements, resins for laminating and cores for sandwich construction
b. Names and amount of application of fillers
c. Names and amount of application of sclerotic and accelerators
d. Procedures and conditions of moulding
e. Direction of selection of test specimens
f. Dates of moulding and tests of test specimens
g. Place of tests and environmental condition of the site of tests
h. Types of testing machines
i. Forum and dimensions of test specimens
j. Test results.

2.6.5. The five test specimens are to be subjected to the FRP strength tests, unless specially specified, and the arithmetical mean of the smaller three values obtained from the five specimens is to be taken as the test result.

2.7. Testing Procedures for Fiberglass Reinforcements

2.7.1. Shape and selection of test specimens

a. The shape and selection of test specimens used for tests of fiberglass reinforcements are to be in accordance with Table I 2-1.
b. The manufacturing methods of laminated sheet used for tests (excluding roving's for spray-up laminating) are to be in accordance with the following:
    i. The laminated plate used for tests is to have a sufficient size to arrange all the required laminated test specimens by itself after trimming away a 30 mm breadth of its edges.
    ii. The laminate constitution and glass content are to be as the following table.

	Laminate constitution	Glass content
Chopped mat	3-ply	30 ± 3 (%)
Woven Roving	4-ply	50 ± 3 (%)

    iii. The ambient temperature while laminating is to be within the temperature range stated in the specifications.
    iv. The laminating operation is to be completed within 50% of the gel time of resins for the ambient temperature.
    v. After completion of laminating operation, the laminated plate is to be left for 24 hours at a temperature of 20 ± 5 °C, and to be subjected to curing for 16 hours in air bath at a temperature of 40 °C. The laminated plate may be cut up in proper sizes for the after cure.

c. The manufacturing method of laminated plate used for the test of rovings for spray-up are to be in accordance with the following:
    i. The size of test specimens is to be as specified in the preceding 2.7.1(b)(i)
    ii. The thickness of the test specimen is to be not less than 3mm
    iii. The glass content is to be 30 ± 3%
    iv. The after cure is to be in accordance with the preceding 2.7.1(b)(v).

2.7.2. Test procedures

The procedure of the tests given in 2.3.1 is to be in accordance with the following:

a. Design weight per unit area or unit length and the maximum deviation.
    i. The test samples are to be in accordance with Table I 2-1
    ii. The weight of the test sample is to be measured to the accuracy of 0.1g.
    iii. The deviation is to be of the value obtained from the following formulae.
        1. Chopped mats and woven roving
            - For test sample of $1m^2$

$$\frac{|M_1 - W|}{W} \times 100\%$$

            - For test sample of $300 \times 300\ m^2$

$$\frac{|M_2 / 0.09 - W|}{W} \times 100\%$$

Where:

M_1 = Weight of test sample of $1\ m^2$, in g
M_2 = Weight of test sample of $300 \times 300\ mm^2$, in g
W = Weight of test sample per $1\ m^2$ intended to be stated in the specification, in g

        2. Rovings

$$\frac{|1000M/ l - W|}{W} \times 100\%$$

Where:
l = Length of test sample, in m
W = Weight per 1,000 m to be stated in specification, in g
M = Weight of test sample, in g

b. Ratio in weight of binder (including sheafing agents)
    i. The test specimen is to be in accordance with Table I 2-1
    ii. Each test specimen is to be heated in a heating furnace (625 ± 25°C) for about 10 minutes to burn out the binder or sheafing agent, then to be taken out from the furnace and left it to cool down to the room temperature.

iii. The test sample in (ii) above is to be weighed to the accuracy of 0.1 g.

iv. The ratio in weight of binders (including sheafing agent) is to be of the value obtained from the following formula:

$$\frac{W_0 - W_1}{W_0} \times 100(\%)$$

where:

W_0 = Weight before heating, in g

W_1 = Weight after cooling, in g

c. Tensile strength of fiberglass in woven roving

i. The test specimen is to be in accordance with the Table I 2–1

ii. The standard tensile speed is to be 200 mm/min

iii. When the test specimen failed or slipped at the grip of the testing machine, the measured value of this test sample is to be judged unacceptable. In such a case, an additional test specimen is to be taken for test.

iv. The breaking load is to be taken as the tensile strength of fiberglass.

d. Bending strength and modulus of bending elasticity obtained from laminates

i. The test specimen is to be in accordance with Table I 2-1.

ii. The test is to be carried out after keeping the test specimen in the standard condition for 20 hours or more.

iii. The testing arrangement of three-point bending is to be in accordance with Fig. I 2-5.

iv. The standard loading rate during test is to t/2 mm/min. (t = thickness of the test specimen in mm).

v. The bending strength is to be of the value obtained from the following formula:

$$\frac{3}{2} \cdot \frac{Pl}{bt^2} \text{ N/mm}^2$$

where:

P = Breaking load, in N

l = Gauge length, in mm

b = Breadth of test specimen, in mm

t = Thickness of test specimen, in mm

vi. The modulus of bending elasticity is to be of the value obtained from the following formula

$$\frac{l^3}{} \cdot \frac{dP}{} \text{ N/mm}^2$$

$4bt^3$ dy

where:

(dP/dy) = Gradient of the straight portion of load-deflection curve, in N/mm

y = Deflection at mid-point of gauge length, in mm

l, b, and t = As specified in (v) above

e. Tensile strength and modulus of tensile elasticity obtained from laminates

i. The test specimens are to be in accordance with Table I 2-1.

ii. The tests are to be carried out after keeping the test specimen in the standard condition for 20 hours or more.

iii. The standard tensile speed is to be 5 mm/min

iv. When the test specimen failed outside the gauge length, the measured values of the test specimen are to be judged unacceptable. In such a case, an additional test specimen is to be taken for test.

v. The tensile strength is to be of the value obtained from the following formula

$$\frac{P}{A} \text{ N/mm}^2$$

where:

P = Breaking load, in N

A = Sectional area of test specimen at its mid-point, in mm^2

vi. The modulus of tensile elasticity is to be of the value obtained from the following formula:

$$\frac{l}{A}\frac{(dP)}{(dl)} \quad \text{N/mm}^2$$

where:

l = Original gauge length, in mm

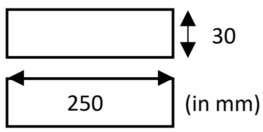
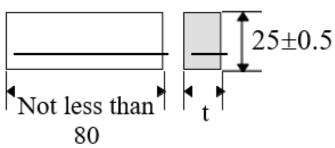
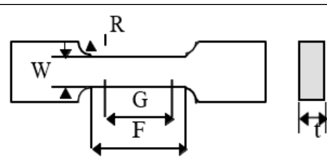
A = Sectional area at mid-point of test specimen, in mm^2

(dP/dl) = Gradient of the straight portion of load-deflection curve, in N/mm

dl = Elongation of the distance between gauge marks

TABLE I 2-1
FIBREGLASS REINFORCEMENTS

Paragraph 2.7.2		Shape and size of test specimen	Quantity	Sampling procedure, etc.
(a)	Deviation	Type [1] A = $1m^2$	type 1……………..5pcs type 2………….10 pcs	Discard 30 mm from one longitudinal end and 30 mm from both transverse ends,

		Type 2 300 × 300 (in mm)		and take a test sample of 1 m2 continuously in the longitudinal direction (See Fig. I 2-1) After measuring weight of test sample (type 1), take a square (300 × 300) test specimen therefrom. (See Fig. I 2-2)
		Rovings for spray-up are to have a length equivalent to approximately 15 g.	5 pcs	
(b)	Ratio in weight of binders	Same as type 2 in (a)	5 pcs	
(c)	Tensile strength of fiberglass		warp direction... 5 pcs weft direction ... 5 pcs	Test specimens are to be taken in warp and weft direction, respectively. (See Fig. I 2-3) Finish it in the shape as shown in Fig. I 2-4
(d) & (e)	Bending strength obtained from laminates	 t = original thickness. (in mm)	5 pcs	In woven roving, 5 pieces of test specimens are to be taken in warp and weft direction, respectively. Finish the cutout section smoothly.
(f)	Tensile strength obtained from laminates	 t = original thickness F = 60 ± 0.5 (mm) G = 50 ± 0.5 (mm) W = 25 (mm) or more R = 60 (mm) or more	Standard condition ……………………..5 pcs	In woven roving, 5 pieces of test specimens are to be taken from warp and weft direction respectively. Finish the cutout section smoothly

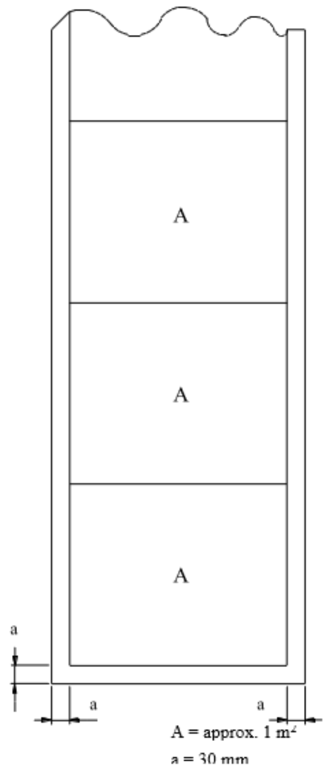


Fig. I 2–1
Selection of Test Specimens from Fiberglass Reinforcements

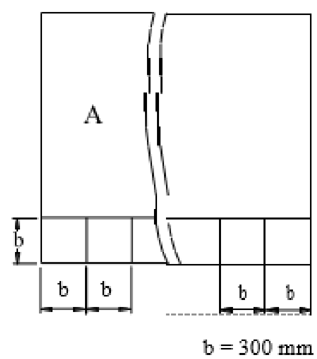
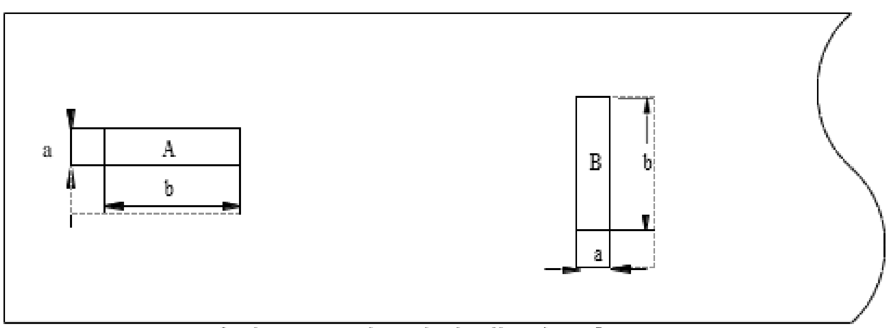


Fig. I 2–2
Selection of Test Specimens from Fiberglass Reinforcements



A: the test specimen in the direction of warp
B: the test specimen in the direction of weft
a = approx. 30 mm
b = approx. 250 mm

Fig. I 2–3
Selection of Tensile Test Specimen from Woven Roving Reinforcements

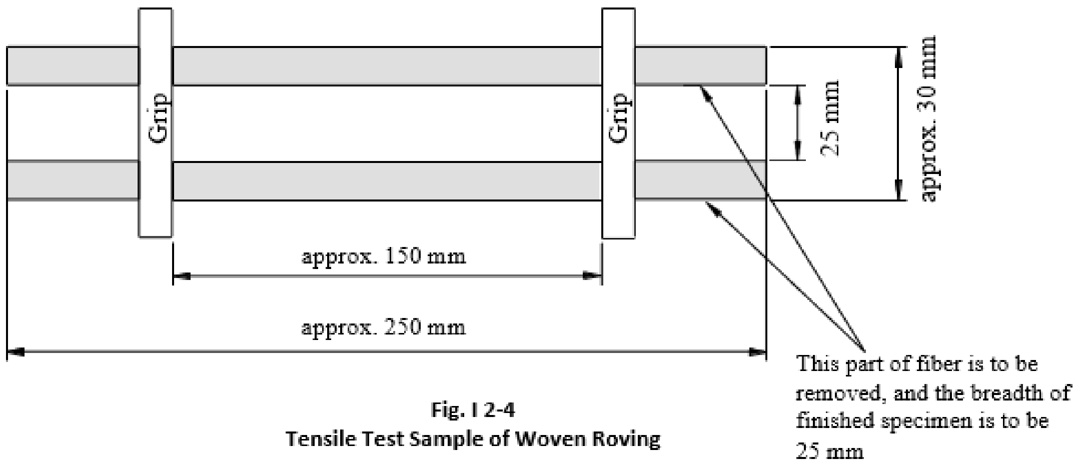


Fig. I 2-4
Tensile Test Sample of Woven Roving

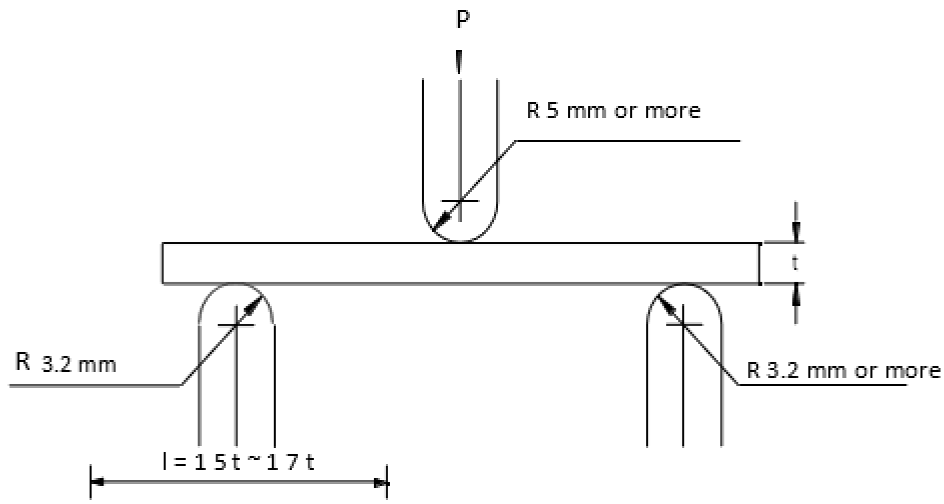


Fig. I 2-5
Testing Arrangement of Three Point Bending

TABLE I 2–2
ACCEPTANCE CRITERIA FOR FIBERGLASS REINFORCEMENTS

Test item		Acceptance criteria
Deviation	Chopped mat	1m².........................Not greater than 10% for each specimen 300×300mm............Not greater than 20% for each specimen
	Woven Roving	1 m².........................Not greater than 3% for each specimen 300×300mm............ Not greater than 5% for each specimen
	Rovings	15g.......................... Not greater than 10% for each specimen
Ratio in weight of residual binders	Chopped mat	Mean value............ Not greater than 10% Test results of at least 4 test specimens are not to be greater than 10%
	Woven roving	Mean value............ Not greater than 1% Test results of at least 4 test specimens are not to be greater than 1%
	Rovings	Mean value............ Not greater than 3% Test results of at least 4 test specimens are not to be greater than 3%
Tensile strength of fiberglass of glass woven roving		Mean value............ Not less than 0.35W (kg) W: the stated weight (g) Test results of at least 4 test specimens in 5 test specimens of respective warpand weft directions are not to be less than 0.35W (kg)
Chopped mat Roving	Bending strength	Mean value............................... Not less than 160 N/mm² Test results of at least 4 test specimens are not to be less than 157 N/mm²
	Modulus of bending elasticity	Mean value............................... Not less than 7000 N/mm² Test results of at least 4 test specimens are not to be less than 7000 N/mm²
Woven Roving	Bending strength	Mean value............................... Not less than 280 N/mm² Test results of at least 4 test specimens are not to be less than 280 N/mm²
	Modulus of bending elasticity	Mean value............................... Not less than 12900 N/mm² Test results of at least 4 test specimens are not to be less than 12900 N/mm²
Chopped mat Roving	Tensile strength	Mean value............................... Not less than 85 N/mm² Test results of at least 4 test specimens are not to be less than 85 N/mm²
	Modulus of tensileelasticity	Mean value............................... Not less than 7500 N/mm² Test results of at least 4 test specimens are not to be less than 7500 N/mm²

Woven Roving	Tensile strength	Mean value .... Not less than 190 N/mm^2 Test results of at least 4 test specimens are not to be less than 190 N/mm^2
	Modulus of tensileelasticity	Mean value................................ Not less than 1600 N/mm^2 Test results of at least 4 test specimens are not to be less than 1600 N/mm^2

2.8. Test Procedures

2.8.1. Shapes and selection of Test Specimens

a. The shape and selection of test specimens used for the tests of resins for laminating are to be in accordance with the Table I 2-3

b. The manufacturing methods of resin casting test specimens are to be in accordance with the following:

i. The sclerotics and accelerators are to be as specified by the manufacturer of the resins.

ii. The size of cast sheet is to be such that all test specimens required in Table I 2 -3 for the resin casting test specimen can be cut out of the sheet.

iii. The cure time, temperature and after cure are to be as specified by the manufacturer of resins.

c. The manufacturing procedures of laminates used for tests are to be in accordance with the following:

i. The laminating arrangements is to be of chopped mat with weight per unit area of 450 g/m2 in 3-ply and the glass content is to be 30 ± 3% in weight.

ii. For other procedures, apply to the requirements in 2.7.1(b) correspondingly.

2.8.2. Test procedures: The procedures for the tests given in 2.4 are to be in accordance with the following:

a. Viscosity and thixotropy:

i. The test resins are to be as given in Table I 2-3.

ii. Brookfield viscometer is to be used.

iii. The rotor and guard (or sleeve guard) chosen according to the predicted viscosity of the liquid sample are to be mounted on the viscometer.

iv. The test liquid resins (25 ± 0.5 °C) after being stirred well are to be filled into the beaker to a depth so that the reference mark on the rotor may be equal to the liquid level.

v. After leaving still for approximately 5 minutes and then turning the rotor at a rotational speed of 60 rpm for 3 minutes, the reading of the scale is to be taken. The viscosity is to be obtained by multiplying the reading by a coefficient determined according to the type of rotor used and rotational speed.

vi. After keeping still for another 5 minutes and then turning the rotor at a rotational speed of 6 rpm for 3 minutes, the reading is to be taken for obtaining the viscosity.

vii. The thixotropy index is to be obtained by dividing the viscosity determined at the rotor run of 6 rpm by the viscosity at 60 rpm.

viii. The operations shown in (v) and (vi) above are to be repeated for two times or more and the respective mean values are to be regarded as the "viscosity" and "thixotropy index".

b. Gel time, minimum cure time and peak exothermic temperature.

i. The test resins are to be given in Table I 2-3.

ii. The testing apparatus for hardening characteristics at room temperature is to be fixed in a thermostatic water bath (25 ± 0.5 °C). (See Fig. I 2-6)

iii. The test resins are to be dipped in the thermostatic water bath and then the specified amount of sclerotic is to be added thereto when the temperature of the test resins reached 25 ± 0.5 °C, and the mixture is to be stirred evenly.

iv. The test resins added with sclerotic are to be filled into a test tube of 18 mm in diameter to a depth of 100 mm.

v. The 18mm dia. test tube is to be fixed in a test tube of 30 mm in diameter so that the top surface of the test resins assumes approximately 10 mm below the liquid surface of the thermostatic water bath.

vi. The welded junction of thermocouple is to be placed at half the depth of the test resins and to be fixed at the center of the test tube. However, a thermocouple ensleeved in a protection tube or a thermistor may be used in place of the above thermocouple.

vii. The time in minutes required for the test resins to reach a temperature of 30 °C from the time when the sclerotic are mixed is to be taken as the gel time, and the time in minutes required to reach the highest temperature after adding the sclerotic is to be taken as the minimum cure time, and the temperature indicated as the maximum temperature of the test resin is to be taken as the peak exothermic temperature (°C).

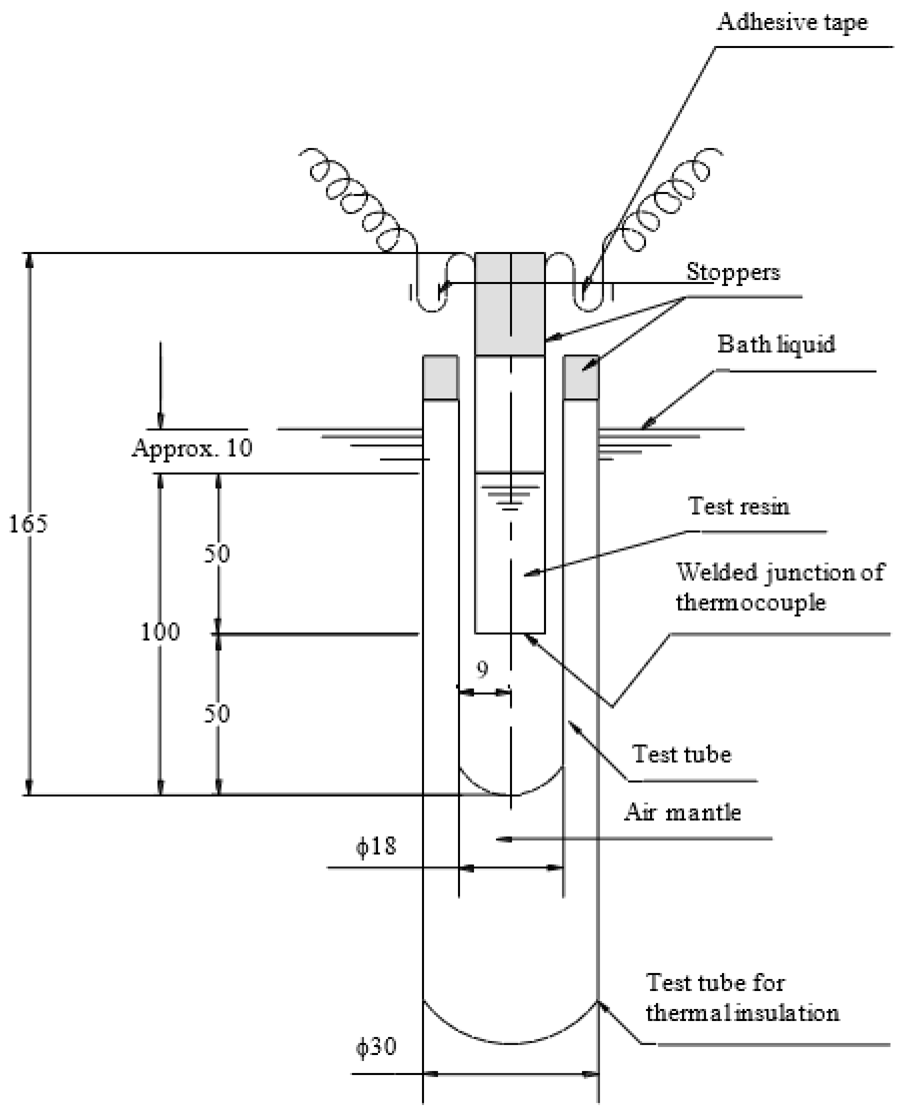


Fig. I 2-6
Testing Apparatus for Hardening Characteristics at Room Temperature

viii. Measurements are to be taken for two or more times, and the respective mean values are to be regarded as the "gel time", "minimum cure time" and "peak exothermic temperature".

ix. The types and amounts of the sclerotic and accelerators are to be recorded.

c. Acid value

i. Take Take 1 g of the test resins, add it to about 10 ml of mixed solvent ［mixture of 7 parts by mass of toluene (reagent) and 3 parts by mass of methyl alcohol (reagent)］, and stir the mixture well.
ii. Add the mixed indicator and titrate the solution with 0.1 mole/l ethyl alcoholic potassium hydroxide solution.
iii. When the color of the solution turns from green into pale violet, take it as a point of termination.
iv. The acid value is to be of the value obtained from the following formula:

$$\frac{5.61\,\upsilon f}{S}$$

where:

υ = Consumption of 0.1 mole/*l* ethyl alcoholic potassium hydroxide, in ml

f = Factor of 0.1 mole/*l* ethyl alcoholic potassium hydroxide

S = Mass of test resins, in g

The mixed indicator is the reagent obtained by adding 20 m*l* of distilled water to 0.1 g of finely ground bromthymol blue and 0.1 g of phenol red, and adding further 0.1 mole/*l* ethyl alcoholic potassium hydroxide solution thereto to the discolouring range while stirring it well, and by diluting it further with distilled water to a volume of 200 m*l*.

d. Water absorption rate of cast test specimens.
i. The test specimens are to be in accordance with Table I 2-3.
ii. Put a filter paper on an asbestos board (thickness: approximately 10 mm), place the test specimen thereon, and heat the test specimen in a thermostatic air oven (50 ± 2 °C) for 24 ± 1 hours.
iii. Cool the test specimen subjected to heating process in (2) above in a desiccator and measure the weight.
iv. Immerse the test specimen in a container with a lid filled with sufficient volume of distilled water, leave the container in a thermostatic water bath (25 ± 1 °C) for 24 hours, and then take the test specimen out, wipe the surface water and measure the weight. During immersion in distilled water, the test specimens are to be hold not to be brought in contact with each other.
v. The water absorption rate is to be of the value obtained from the following formula:

$$\frac{W_1 - W_0}{W_0} \times 100\ (\%)$$

where:

W_0 = Weight of test specimen after heating, in g
W_1 = Weight of test specimen after immersion in water, in g

e. Barcol hardness of cast test specimens
   i. Use the Barcol hardness tester.
   ii. Hold the hardness tester in such a manner that the point contacts at right angles with the testing surface of the test specimen which is placed on a hard base.
   iii. Apply 4.5 kg to 6.8 kg of an impact pressure and read out the maximum indication on the hardness tester.
   iv. Ensure that the measuring point is 3 mm or more apart from the periphery of test specimen and other measuring points, and that those measuring points clear the areas from which other test specimens are taken.
   v. Take measurements at least 10 points.

f. Tensile elongation and tensile strength of the cast test specimens:
   i. The test specimens are to be in accordance with Table I 2-3.
   ii. The standard tensile speed is to be 5 mm/min.
   iii. When the test specimen failed outside the place between gauge points, the measured value of such a test specimen is to be judged unacceptable, and a new test specimen is to be taken for additional test.
   iv. The tensile elongation is to be obtained from the following formula:

$$\frac{\text{Elongation of the gauge length at failure}}{\text{Initial gauge length}} \times 100\ (\%)$$

   v. The tensile strength is to be obtained from the following formula.

$$\frac{P}{A}\ \text{N/mm}^2$$

where:

P = Breaking load, in N
A = Sectional area of test specimen at mid-point, in mm^2

g. Load deflection temperature of cast test specimens
   i. The test specimens are to be in accordance with Table I 2-3.
   ii. The testing apparatus is to be as shown in Fig. I 2-7.
   iii. The weight of balance weight is to be of the value obtained from the following formula:

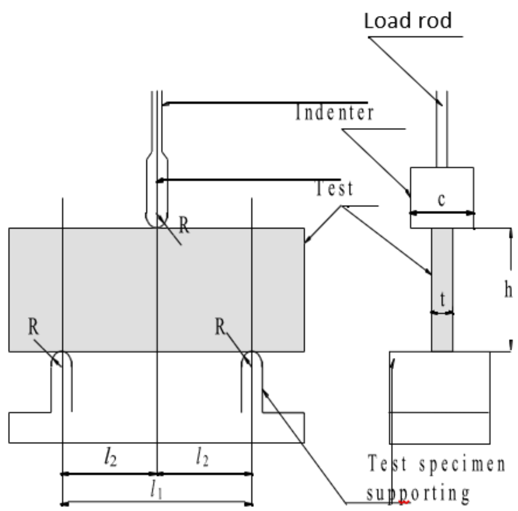
$$0.123 \cdot \frac{th^2}{l} - Q \qquad \text{kg}$$

where:

t = Thickness of test specimen, in mm
h = Height of test specimen, in mm
l = Distance between supports, in mm
Q = Weight, in kg, obtained by adding the load reading on a dial gauge to the weight of loading rod including the weight pan.

iv. Fix the testing apparatus with the test specimen in an oil bath, apply load and leave it from the initial temperature of 25 ± 1 °C for 5 minutes.
v. Raise the temperature of the oil bath at a rate of 2.0 ± 0.2 °C /min.
vi. The temperature when the deflection reaches 0.26 mm is to be taken as the load deflection temperature.

h. Barcol hardness of the laminate test specimens: The requirements in (e) above are to apply correspondingly.
i. Bending strength and modulus of bending elasticity obtained by laminate test specimens.
    i. The test specimens are to be in accordance with Table I 2-3.
    ii. The testing procedures are to be in accordance with 2.7.2(d).
j. Tensile strength and modulus of tensile elasticity obtained by laminate test specimens.
    i. The test specimens are to be in accordance with Table I 2-3.
    ii. The testing procedures are to be in accordance with 2.7.2(f).
k. High temperature characteristics obtained by laminate test specimens.
    i. Barcol hardness
    Leave the test specimen at 60 ± 1 °C for 24 hours and carry out the test specified in (e) above within one minute.
    ii. Bending strength and modulus of bending elasticity
    Leave the test specimen at a temperature of 60 ± 1 °C for 24 hours and then carry out the test specified in (i) above at a temperature of 60 ± 2 °C.



l_1 = 100 ± 2.0 (mm)
l_2 = 50 ± 1.0 (mm)
R = 3.0 ± 0.2 (mm)
t = thickness of test specimen (mm)
h = height of test specimen (mm)
c = to be 13 mm or more

Unit: mm

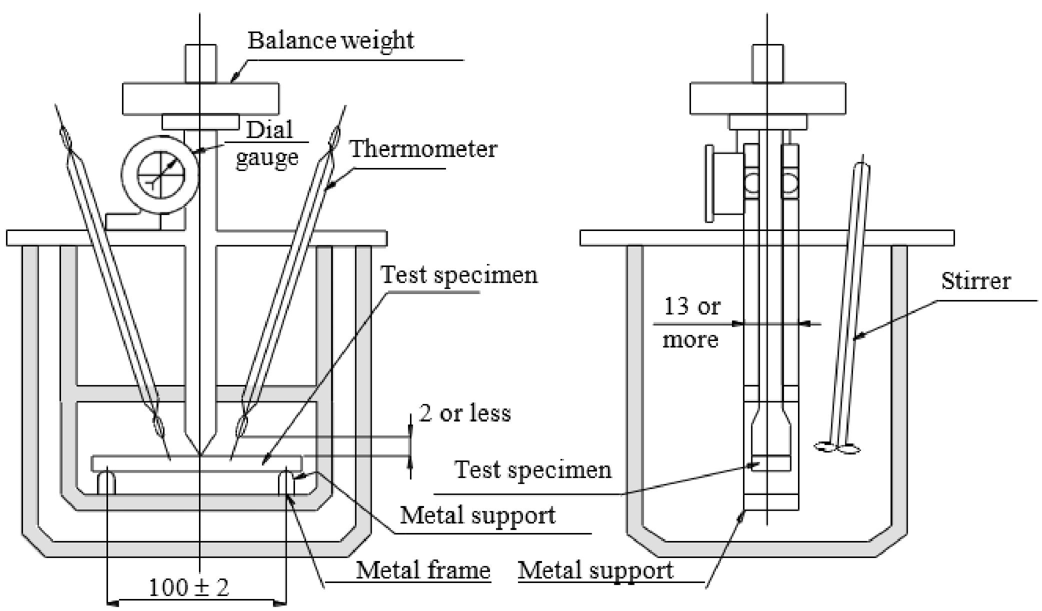
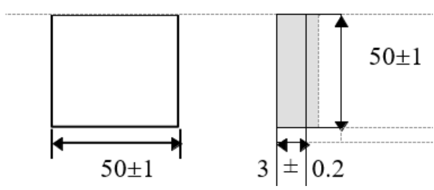
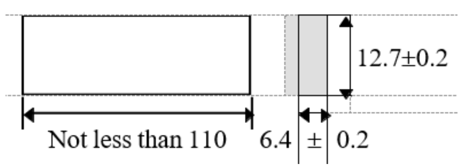
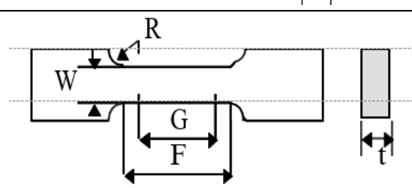
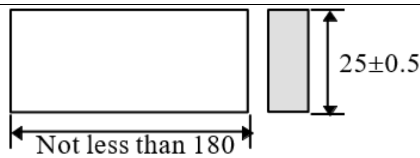


Fig. I 2-7
Load Deflection Temperature Measuring Arrangement

TABLE I 2-3
RESINS FOR LAMINATING (Unit: mm)

Paragraph 2.8.2		Shape and size of test specimen	Quantity	Selection of test specimen, etc.
(a)	Viscosityand thixotropy index	Resins	As required	When resins are sampled, the contents of vessel are to be stirred well to make them homogeneous, and take test resins into a suitable dry and clean vessel of two times the necessary volume for test and a light-proof plug is to be provided
(b)	Gel time, minimum cure time and peak exothermic temperature	Resins	50±1g(Note)	
(c)	Acid value	Resins	1 g	
(d)	Water absorption rate		5 cast test specimens	
(e) (h)	Barcol hardness	Cast test specimens Laminate test specimens		
(g)	Load deflection temperature		3 cast test specimens	
(f)	Tensile strength	 **Cast test specimens** t = 3 ± 0.2 (mm) F = 60 ± 0.5 (mm) G = 50 ± 0.5 (mm) W = 12.5 (mm) or more R = 60 (mm) or more **Laminate test specimens** t = original thickness F = 60 ± 0.5 (mm) G = 50 ± 0.5 (mm) W = 25 (mm) or more R = 60 (mm) or more	5 cast test specimens 5 laminate test specimens	

(j)	Bending strength of laminated test specimens		5	
(k)	High temperature characteristics of laminated test specimens	The same as in (h) and (i)		

Note: In the case of no-accelerated resins, the specified quantity of accelerators is to be added and stirred according to the weight of the resins.

2.8.3. Criteria

The acceptable criteria of the test results are to be not less than the value given in Table I 2-4.

TABL I 2–4
ACCEPTABLE CRITERIA FOR RESINS FOR LAMINATING

	TEST ITEM	ACCEPTABLE CRITERIA
(a)	Viscosity Thixotropy index	1.5 ~ 8 (Poise) 1.2 ~ 4
(b)	Gel time Minimum cure time Peak exothermic temperature	For reference For reference Not more than 190 °C
(c)	Acid value	For reference
(d)	Water absorption rate Cast test specimen	Mean value to be not more than 0.25%
 (e) (h)	Barcol hardness Cast test specimen Laminate test specimens	 Mean value to be not less than 35 Mean value to be not less than 40
(f) Cast test specimens	Tensile elongation Tensile strength	Mean value to be not less than 1.3% Test results of at least 4 test specimens are to be not less than 1.3% For reference.
(g)	Load deflection temperature	Mean value to be not less than 60 °C Test results of at least 2 test specimens are to be not less than 60 °C
(i)	Bending strength Modulus of bending elasticity	Mean value to be not less than 160 N/mm^2 Mean value to be not less than 7000 N/mm^2

(j) Laminated test specimens	Tensile strength Modulus of tensile elasticity	Mean value to be not less than 85 N/mm^2 Mean value to be not less than 7500 N/mm^2
(k)(1)	Barcol hardness	Mean value to be not less than 60% of the mean value of test (h)
(k)(2)	Bending strength Modulus of bending elasticity	Mean value to be not less than 70% of the mean value of test (i) Mean value to be not less than 50% of the mean value of test (i)

2.9. Test Procedures for Core Material for Sandwich Construction

2.9.1. Shapes and selection of Test Specimens

a. The shape and selection of test specimens used for the test of core materials for sandwich construction are to be in accordance with Table I 2-5.

b. The manufacturing methods of sandwich constructions for the test are to be in accordance with the following:

i. The core material is to be the largest thickness to be used as primary structural members of hull construction.

ii. On both sides of the core, the M-R-M-R-M laminates are to be applied, where M denotes chop mats (weight per unit area 600 g/m2) and R, woven roving (weight per unit area 810 g/m2).

iii. The glass content is to be approximately 30% at the portion of chops mats, and approximately 50% at the portion of woven roving.

iv. The direction of warp of the woven roving is to be aligned with the longitudinal direction of the test specimen.

v. In the case of the fiber reinforced plastics foam, test specimens of which longitudinal direction is aligned respectively with the direction of the maximum strength and the direction of the minimum strength of the core material are to be manufactured.

2.9.2. Test Procedures

a. The test procedures for the hard plastics foam specified in 2.5.2 are to be in accordance with the following:

i. Specific gravity:

1. The test specimens are to be in accordance with Table I 2-5.
2. Leave the test specimen in a thermostatic air oven (25 ± 0.5 °C) for about 30 minutes and measure the dimension and weight.
3. The size of the test specimen is to be measured to an order of 0.1 mm for the thickness, length, and breadth.
4. The weight of the test specimen is to be measured to the order of 0.1 g.
5. The specific gravity is to be for the value obtained from the following formula:

$$W/V$$

where:

W = Weight of test specimen, in g
V = Weight of pure water corresponding to the volume of test specimen, in g.

ii. Water abortion rate

1. The test specimens are to be in accordance with Table I 2-5.
2. The surface skin of the test specimen, if such is the case, is to be removed, and the dimensions are to be measured to the order of 0.1 mm.
3. The test specimen is to be submerged in fresh water (23 ± 3 °C, 60 mm in depth below the water surface) for 10 seconds.
4. The test specimens is to be placed on a wire gauze of 3 mm mesh titled at 30 degree to the vertical for 30 seconds, and then the reference weight (Wo) is to be measured to the order of 0.01g.
5. The test specimens of which reference weight has been measured is to be soaked in fresh water (23 ± 3 °C) for 24 hours with a pressure of 10 N/mm2.
6. The weight of the test specimen (W1) is to be measured by the same procedure as specified in
7. (4) above.
8. The water absorption rate is to be obtained from the following formula:

$$\frac{W_1 - W_0}{A} \times 100 \qquad g/100cm^2$$

where:

W_1 = Weight after the final water absorption, in g
W_0 = Reference weight, in g
A = Surface area of test specimen, in cm^2

iii. Compressive strength and modulus of compressive elasticity.

1. The test specimens are to be in accordance with Table I 2-5.
2. The size of the test specimen is to be measured to the order of 0.1 mm.
3. Compression to be applied in the direction thickness of the product.
4. The standard compression speed is to be 5 mm/min.
5. The compressive strength is to be obtained from the following formula:

$$\frac{P_c}{A} \quad N/mm^2$$

where:

P_c	=	Load at which 0.2% strain is occurred from the elastic limit, in N
A	=	Pressure bearing area of test specimen, in mm^2

6. The modulus of compressive elasticity is to be obtained:

$$\frac{t}{A}\frac{(dP)}{(dt)} \quad N/mm^2$$

where:

(dP/dt)	=	Gradient of the straight portion of load-contraction curve, in N/mm (See Fig. I 2-8)
t	=	Thickness of test specimen
A	=	Pressure bearing area of test specimen, in mm^2

iv. Softening rate
The modulus of compressive elasticity at a temperature of 60 °C is to be measured by suitable means.
The method specified in 2.8.2(g) may be applied correspondingly.

v. Tensile strength and modulus of tensile elasticity
1. The test specimens are to be in accordance with Table I 2-5.
2. The test procedure is to be in accordance with 2.7.2(f)

vi. Bending strength and modulus of bending elasticity
1. The test specimens are to be in accordance with Table I 2-5.
2. The testing arrangement of four-point bending is to be in accordance with Fig. I 2-9.
3. The standard loading speed is to be t/2 mm/min.
t = thickness of test specimen, in mm
4. The bending strength is to be obtained from the following formula:

$$\frac{3PL_1}{bt^2} \quad N/mm^2$$

where:

L_1	=	Outer span, in mm
b	=	Breadth of test specimen, in mm
t	=	Thickness of test specimen, in mm
P	=	Breaking load, in N

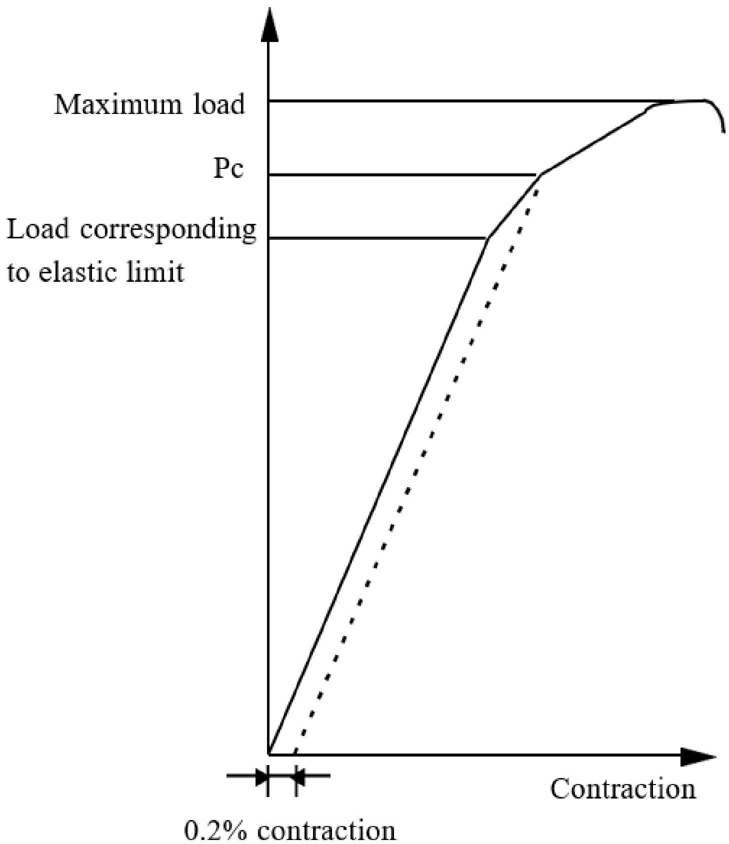


Fig. I 2-8
Load-Contraction Diagram

5. The modulus of bending elasticity is to be obtained from the following formula:

$$\frac{3}{4} \cdot \frac{L_1 L_2^2}{bt^3} \cdot \frac{dP}{d\delta} \qquad N/mm^2$$

Where:

L_1	=	Outer span, in mm
L_2	=	Mid span, in mm
$(dP/d\delta)$	=	Gradient of straight portion of load-deflection at mid-point of gauge length
δ	=	Deflection at mid-point of gauge length, in mm

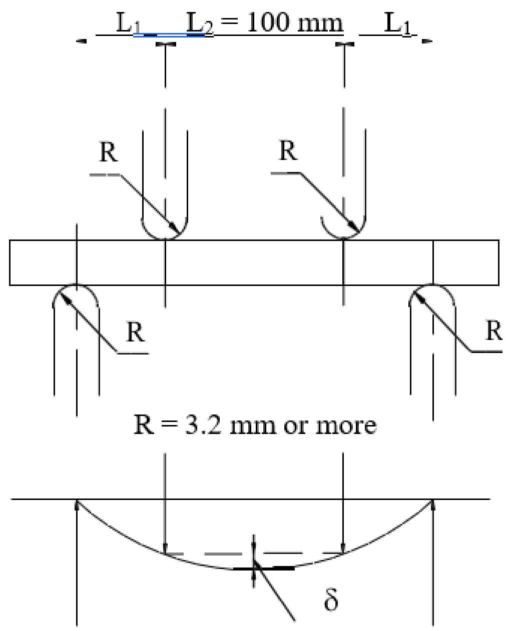


Fig. I 2-9
Testing Arrangement of Four Point Bending

vii. Shearing strength of sandwich constructions
1. The test specimens are to be in accordance with Table I 2-5.
2. The testing arrangement of four-point bending is to be in accordance with Fig. 2 -9
3. The standard loading speed is to be t/2 mm/min. t = thickness of test specimen, in mm
4. The shearing strength is to be obtained from the following formula

$$\frac{P_b}{2\left(t_f + t_c\right)b} \quad \text{N/mm}^2$$

Where:

P_b = Breaking load of core material, in N
t_f = Mean thickness of inner layer and outer layer of FRP laminates, in mm
t_c = Thickness of core material, in mm
b = Breadth of test specimen, in mm

5. The outer spam (L_1) is to be referred to the value obtained from the following formula. However, in case where either the outer or inner FRP laminates fails, retest is to be carried out with the smaller outer span.

$$L_1 < \frac{Z \cdot \sigma_f}{(t_f + t_c)\, b\tau_c}$$

Where:

Z	=	Section modulus of test specimen, in mm^3
t_f	=	Mean thickness of FRP laminates, in mm
t_c	=	Thickness of core material, in mm
B	=	Breadth of test specimen, in mm
σ_f	=	Tensile strength of FRP laminates, in N/mm^2
τ_c	=	Imaginary shearing strength of core material, in N/mm^2

b. The test procedures for balsa are to be in accordance with the following:

i. Specific gravity
The test procedure is to be in accordance with 2.9.2(a)(i). However, the size and weight are to be measured at room temperature.

ii. Moisture content

1. After having dried the test specimen in (i) above in the thermostatic air oven to a fixed weight, the weight is to be measured to the order of 0.1g.
2. The moisture content is to be of the value obtained from the following formula

$$\frac{W_1 - W_2}{W_2} \times 100\ (\%)$$

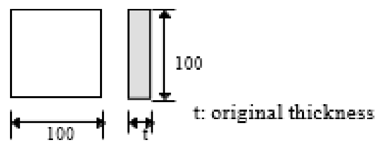
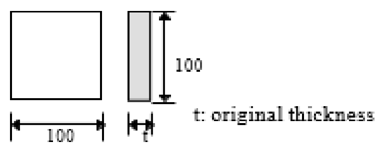
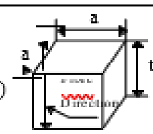
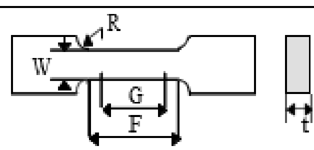
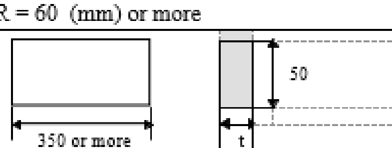
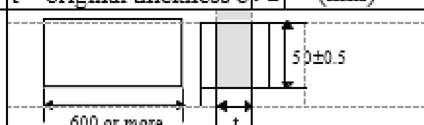
where:

W_1 = Weight at the standard condition, in g
W_2 = Weight after drying, in g

iii. (iii) Compressive strength in fibrous direction and modulus of compressive elasticity:
The test procedure is to be in accordance with 2.9.2(a)(iii). However, P_c shown in (5) is the maximum load (N). In this case, the specific gravity of the test specimen is to have been measured in accordance with (i) above.

iv. Shearing strength of sandwich constructions
The test procedure is to be in accordance with 2.9.2(a)(vii)

Table I 2-5
Core Materials for Sandwich Construction (Unit: mm)

Paragraph 2.9.2(a)/(b)		Shape and size of test specimen	Quantity	Selection of test specimen, etc.
(1)	Specific gravity	Hard plastic foam 	5	
		Balsa • Product balsa of original thickness • Compression test specimen (3) is tobe used	10 5	Product balsa boards (artificially dried balsa boards bonded in the same direction(block) to be cut at right angle to fibrous direction) are to be taken from different lots as far as practicable.
(2)	Water absorption	The same as in hard plastic foam	5	
(2)	Moisture content		10	One each test specimen is to be taken from each product balsa of which the specific gravity was measured.
(3)	Compression test	Hard plastic foam a = 50 (mm) Balsa a = 20 ~ 50 (mm) t = 50 (mm) 	5	Materials for test are to be selected as differently on specific gravity as possible among those forming a block of balsa products, and test specimens are to be taken from those respective materials.
(5)	Tensile test	 t = original thickness or 20 (mm) F = 60±0.5 (mm) G = 50±0.5 (mm) W = 25 (mm) or more R = 60 (mm) or more	5	
(6)	Bend test	 t = original thickness or 20 (mm)	5	
(7)	Shearing test	 t : to be in accordance with 2.9.1(b)(i)	5	

2.10. Test Procedures of FRP Strength Test

2.10.1. Manufacture of test laminates for FRP laminates and sandwich constructions.

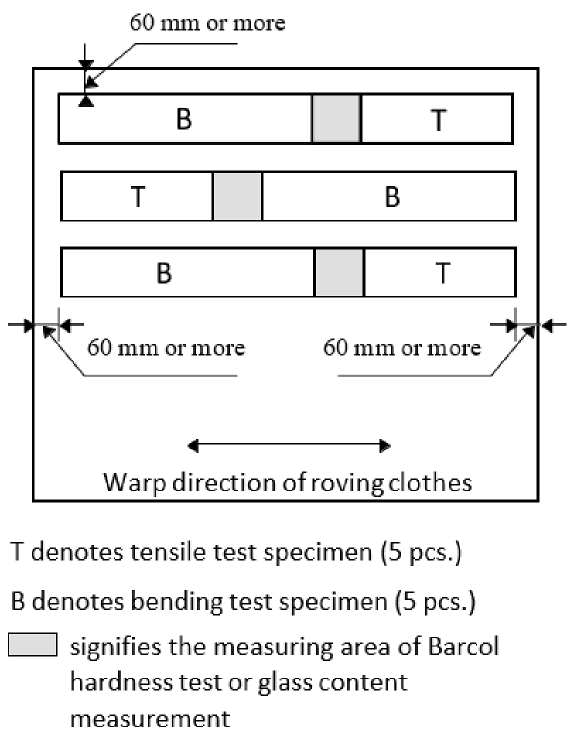


Fig. I 2-10
Location of Selection of Test Specimens

a. One each of FRP test laminates or test laminates of sandwich construction which are of the same laminate composition and the same moulding procedures as those for bottom laminates, side shell laminates and upper deck laminates is to be manufactured. However, when either of the bottom laminates, side shell laminates or upper deck laminates has the same laminate composition with the other, one test laminate may be manufactured for those of the same laminate composition.

b. The size of the test laminates is to be sufficient to cut all the test specimens specified in the following 2.10.2 (See Fig. I-2-10) and 2.10.3.

2.10.2. The selection of test specimens is to be in accordance with the following (a) and (b).

a. FRP laminates (including the FRP laminates of the inner layer and outer layer of sandwich construction).

   i. The tensile test specimens and bending test specimens are to be cut alternately from the test laminates clearing 60 mm belt from the periphery. (See Fig. I 2-10)

ii. The test laminates for Barcol hardness and glass content measurement are to be of those hatched sections in figure.

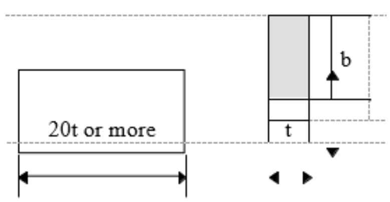
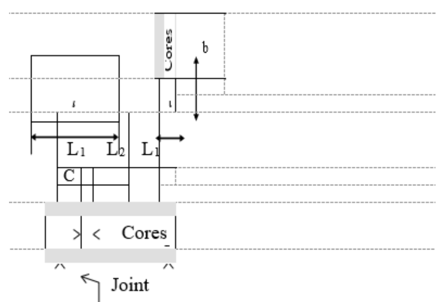
iii. The test laminates of the inner layer and outer layer of FRP laminates of sandwich construction are to be taken by cutting cores out of the moulded sandwich constructions and smoothing their surfaces.

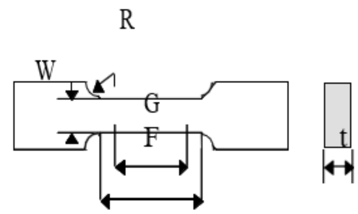
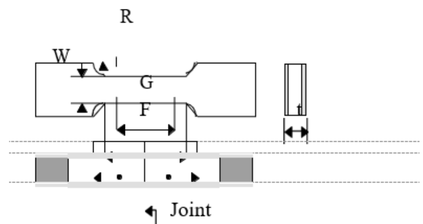
b. Sandwich constructions

i. For the selection of the bend test specimens, tensile test specimens and shearing test specimens, the requirements in (a)(i) above apply correspondingly. When the cores are reckoned in strength, a joint is to be provided.

2.10.3. The shape and size of the test specimens are to be in accordance with Table I 2-6

Table I 2-6
Shape and Size of Test Specimens

Item	Test specimen				Quantity
	FRP laminates		Sandwich construction		
Thickness of moulding	Bend test specimen and tensile test specimen are to be used		Bend test specimen, shearing test specimenand tensile test specimen are to be used		
Glass content	2g or more for each one The periphery is to be finished smoothly				
Bend test specimen and shearing test specimen	Bend test specimen  		Shearing test specimen  t = original thickness L_1 = 100 ~ 200 (mm) L_2 = 100 (mm) $l = 2L_1+L_2+60$ (mm) C = approx. 10 (mm) (When the cores are reckoned in strength, ajoint is to be provided at the position shown on the drawing.)		5
	t (mm)	b (mm)	t (mm)	b (mm)	
	Not more than 20 Over 20 but not more than 35Over 35 but not more than 50	30 ± 0.5 50 ± 0.5 80 ± 0.5	Not more than 20 Over 20 but not more than 35 Over 35 but not more than 50	30 ± 0.5 50 ± 0.5 80 ± 0.5	

Tensile test specimen	 t = original thickness F = 60±0.5 (mm) G = 50±0.5 (mm) W = 25(mm) or more R = 60(mm) or more	 t = original thickness F = 60±0.5 (mm) G = 50±0.5 (mm) W = 25 (mm) or more R = 60 (mm) or more • When the cores are reckoned in strength,a joint is to be provided at the center of the parallel part. • The gripped portion is to be reinforced.	5

2.10.4. The test procedures are to be in accordance with the following:

a. FRP laminate

i. Thickness of moulding
The thickness of five individual bend test specimens and tensile test specimens is to be measured.

ii. Barcol hardness
For the test procedures, the requirements in 2.8.2(e) apply correspondingly.

iii. Glass content (ratio in weight)

1. After drying a crucible in an electric muffle furnace (650±20 °C) till its weight reaches constant, cool the pot in a desiccator and measure weight of the crucible (W_1).
2. Place the test sample (2 g or more specified in 2.10.2 above into the crucible and measure weight (W_2).
3. Apply heat with a Bunsen burner or an electric muffle furnace so that the test sample continues burning properly.
4. After completion of burning, apply heat in the electric muffle furnace at 625 °C until the carbon content completely disappears.
5. Cool the test object in a desiccator for 30 minutes and measure its weight (W_3).
6. The glass content is to be obtained from the following formula:

$$\frac{W_3 - W_1}{W_2 - W_1} \times 100\ (\%)$$

iv. Bending strength and modulus of bending elasticity
   1. The test specimens are to be in accordance with Table I 2-6
   2. For the test procedures, the requirements in 2.7.2(d) apply correspondingly.

v. Tensile strength and modulus of tensile elasticity
   1. The test specimens are to be in accordance with Table I 2-6.
   2. For the test procedures, the requirements in 2.7.2(f) apply correspondingly.

b. Sandwich constructions

i. Thickness of moulding

The thickness of the shearing test specimens and tensile test specimens is to be measured.

ii. Tensile strength
   1. The test specimens are to be in accordance with Table I 2-6.
   2. The standard tensile speed is to be 5mm/min.
   3. When the test specimen fails at position outside the gauge length, the measured values of the test specimen are not to be accepted and an additional test specimen is to be tested additionally.
   4. The tensile strength is to be of the value obtained from the following formula:

$$\frac{P}{A_f + A_c \frac{E_c}{E_f}} \qquad N/mm^2$$

where:

P	=	Breaking load, in N
A_c	=	Sectional area of core, in mm^2
A_f	=	Sectional area of FRP laminates, in mm^2
E_c	=	Modulus of tensile elasticity of core obtained by the test in 2.5.2 of Part I, in N/mm^2
E_f	=	Modulus of tensile elasticity of FRP laminates obtained by (a) above, in N/mm^2

iii. Shearing strength
   1. The test specimens are to be in accordance with Table I 2-6.
   2. The test procedures are to be in accordance with 2.9.2 (a)(vii). The side of FRP with a thicker layer is to be taken as the compression side.}

2.10.5. The acceptable criteria of the test results are to be not less than the value given in Table I 2-7.

TABLE I 2 – 7
ACCEPTABLE CRITERIA OF FRP STRENGTH TEST

Item	Acceptable criteria
Thickness of moulding	for reference
Barcol hardness	mean value not less than 40
Glass content	for reference but subject to the design criteria mentioned hereunder
Bending strength	not less than the value given in the design criteria
Bending modulus	not less than the value given in the design criteria
Shearing strength	not less than the value given in the design criteria
Shearing modulus	not less than the value given in the design criteria
Tensile strength	not less than the value given in the design criteria
Tensile modulus	not less than the value given in the design criteria

CHAPTER 3 – WORKS

3.1. General

3.1.1. Works intended to manufacture FRP ships are to be approved in accordance with the requirements in this Chapter.

3.1.2. In application for works approval, the manufacturer is required to submit detailed data and documents introducing the workshop, facilities, productions, and quality control system, etc. The facilities of the works, storage of materials and quality control system are to be inspected to the satisfaction of the Society.

3.1.3. In the works approval procedure, a qualification test of sample panels assembled by the works under environmental conditions and using material and process as actual production are to be carried out if deemed necessary. The test conditions and result are to be in accordance with those requirements for laminates in Chapter 2.

3.2. Storage of Raw Materials

3.2.1. 3.2.1 Storage facilities for raw materials are to be of sound construction and of reasonable standard that material supplier's instruction for storage and handling can be followed.

3.2.2. Fiberglass materials are to be stored in clean and dry spaces.

3.2.3. Resins, accelerators, sclerotic, and gelcoats are to be stored in cool spaces and shielded from direct sunlight. Storage temperature and storage periods are to be within the limits specified by the material supplier. Tanks for polyesters are to be arranged as far as possible so that the contents can be stirred every day.

3.2.4. Core materials are to be stored dry and protected against mechanical damage.

3.3. Moulding Shops

3.3.1. Moulding shops are to be constructed free from penetration of draught, dust, moisture, etc. and so arranged as to be reasonable in consideration of handling materials, laminating process, and curing condition.

3.3.2. 3.3.2 The air temperature in the moulding shops while laminating is to be kept suitable for the resins used with consideration of the blending proportion. The temperature is not to be lower than 18°C unless expressly specified otherwise. It is recommended that the temperature is not to vary by more than ± 3°C during moulding. If necessary, temperature conditioners are to be provided in the shops.

3.3.3. The relative humidity of the air is to be kept at a preferable not lower than 60% and is not to exceed 80% that condensation is avoided. In areas where spray moulding is taking place, the air humidity is not to be less than 40%. If necessary, suitable appliances are to be provided for reducing the humidity.

3.3.4. Air temperature and relative humidity are to be recorded regularly. The number and location of the instruments in the shops are to present the environmental conditions as neutral as possible.

3.3.5. Ventilation facilities are to be so arranged that the curing process of laminates is adapted without any bad influences.

3.3.6. Shops lighting is to be adequate but not to accelerate the cure of resin. Suitable means of shielding the skylights and windows are to be provided so that lamination and curing process are not exposed to direct sunlight.

3.3.7. Sufficient scaffoldings are to be arranged so that lamination work can be carried out without operator standing on surfaces where lamination is taking place.

3.4. Quality Control

3.4.1. The works is to have an efficient system for quality control to ensure that the product quality meets the specific requirements.

3.4.2. Quality control system shall be formalized through containing following objects:

a. Organization and responsibility of quality control
b. Production guidance and workmanship
c. Procedures for inspection and test
d. Documentation and records of all quality related activities.

3.4.3. The quality control system shall at least comprise inspection and control routines for the followings:

a. Raw material procurement and quality,
b. Storage conditions for raw materials
c. Environmental conditions during manufacturing
d. Production procedures
e. Workmanship
f. Compliance with specification and drawings
g. Testing
h. Finish inspection.

3.4.4. The system shall also include methods for corrective action in case of deviations from the specified standard.

CHAPTER 4 – MONITORING

4.1. General

4.1.1. The requirements in this Chapter are applied to the FRP moulding techniques of hand lay-up and spray lay-up methods. The moulding methods other than those specified above are to be in accordance with the discretion of the Society.

4.1.2. The moulding of FRP is to be carried out under appropriate environmental conditions by competent workers. The work is to be carried out in accordance with approved procedure under adequate supervision.

4.1.3. It is Recommended that the structural members are moulded in one body with the hull laminates before they advance in cure. However, the structural members separately moulded may be bonded to hull laminates afterward with proper design and treatments.

4.2. Environmental Conditions of Moulding Shops

4.2.1. The requirements of environmental condition as specified in 3.3 are to be complied with during FRP moulding.

4.3. Gel Coats

4.3.1. Gel coat resins are to be applied as an even film about 0.5 mm in thickness and may be of one or two- coat application by either spray, brush, or roller.

4.3.2. The time interval between application of first, second gel coats and next layer of reinforcement is to be within the limits specified by the material supplier. It is recommended that each coat or layer is to follow closely without undue delay.

4.4. Manual Lamination

4.4.1. Laminates are to be free from defects, such as voids, blisters, delamination, resin starved areas and undue concentration of resin.

4.4.2. Fiberglass reinforcements are to be so arranged to have seams as few as practicable. The seams in the same layer are to have overlaps not less than 50 mm. The adjacent overlaps of various layers are to be at least 100 mm apart from each other.

4.4.3. Resin is to be applied on each layer of reinforcement having the layer thoroughly impregnated.Gas bubbles in the resin and air pockets in the laminate are to be driven out by degassing rollers or rubber pallets. Rolling of the layers are to be made carefully and keep glass content proper. Excessive squeezing of resins is not desirable, and care is to be taken in confined areas, sharp corners, and transitions to avoid excess resin areas.

4.4.4. In laminating, the glass content (ratio in weight) is approximately 30% in case of chopped mats or 50% in case of woven roving.

4.4.5. The quantity of curing agents and the time interval between application of each layer of reinforcement are to be kept within the time limits specified by the material supplier. For thicker laminates, care is to be taken to ensure the time interval sufficient to avoid excessive heat generation.

4.4.6. The laminating of final ply is to be carried out by suitable means to provide complete curing of the surface.

4.5. Spray Moulding

4.5.1. Moulding by spray lay-up is the method of moulding by spraying resin and fibreglass reinforcement simultaneously. Moulding process using this method is subject to special approval.

4.5.2. The equipment used for spray moulding is to give an even and homogenous glass content and mechanical properties of the laminate. Spray moulding is to be carried out by skilled operators.

4.5.3. When even application over the spray moulding surface with laminate of certain suitable thickness, regular rolling of the spray-on layers is to be carried out to ensure adequate compression and removal of air bubbles.

4.5.4. Where spray lay-up adjoins hand lay-up, continuity of strength of the laminate is to be ensured.

4.6. Sandwich Construction

4.6.1. Sandwich constructions are fabricated either by lamination on the core material, application of the core against a wet laminate or gluing the core against a cured skin laminate.

4.6.2. Bonds between the skin laminate and core and between the individual core elements are to be made effectively in association with shear or tensile properties. All joints are to be filled with resin, glue, or filling material. In non-structural panels, the butts and seams of cores need not be bonded but should be staggered.

4.6.3. When the core is applied to a skin laminate, the surface is to be a wet reinforcement of chopped strand mat of 450 g/m2 in plane surface and 600 g/m2 in curved surface. Otherwise, or when a prefabricated skin laminate is glued to a sandwich core, measures are to be taken to evacuate air from the surface between skin and core.

4.6.4. Sudden change in thickness or any discontinuity of strength between sandwich laminates and adjacent solid laminates is to be avoid. Change in core material thickness is to be made by a taper not less than 1 in 3.

4.7. Curing and Mould Releasing

4.7.1. Mouldings are to be kept for at least 48 hours at an air temperature of minimum +18°C that effective curing can be achieved. Where post curing at higher temperatures to short curing time is intended, the procedures are to be approved by the Society.

4.7.2. Mouldings are not to be removed from the mould until a satisfactory state of cure has been attained to avoid subsequent distortion. Mould releasing operation is to be carefully carried out to prevent permanent deformation or damage harmful to the laminates. The released laminates are to be properly supported so that they may subject to uniform force.

CHAPTER 5 – CONNECTION AND FASTENING

5.1. General

5.1.1. The lay-up of laminates forming hull, deck, tanks, bulkhead, and structural members is to be either by primary or secondary bonding depending on the size of moulded unit and working procedure. Laminating is to be carried out as a continuous process, as far as practicable, with the minimum delay between successive plies.

5.1.2. Internal stiffening members, structural bulkheads, etc. are generally secondary bonded to the hull. Secondary bonding is the application of laminating on structure surface which is effectively cured.

5.1.3. The connection of various moulded units into assemblies and connection of any fitting to main structure can be of bonded joint, mechanically fastened or both types.

5.2. Matting-in Connection

5.2.1. The surface ply of a laminate subject to secondary bonding and the first ply of the bonding laminate is normally to be of chopped strand mat. The cured surface in way of secondary bonding is to be ground and properly treated to obtain a surface free from oil, stain, wax, and dust. A generous coat of resin is to be applied to the cured surface and the first ply laid on and further resin applied. Bonding is to be carefully executed so as not to cause shrinkage or deformation due to excessive exothermic effect.

5.2.2. "T" joints are normally to be used in matting-in connection of structural members. Double angles of the joints are to be applied with layers of reinforcements. Where adoption of T joints is difficult due to accessing the reverse side cannot be achieved, matting-in single angle as L joints can be used provided it is suitably increased in width and thickness.

5.2.3. The aggregated thickness of matting-in laminates and overlap dimensions of T joints are to be in accordance with Fig. I 5-1A to 5-1C. In order to reduce effect of shrinkage, a small gap is leaving between the stiffening member and the laminate. The gap is filled with resin putty or compressible materials such as plastic foam, etc.

5.2.4. Further examples of matting-in T joints are shown in Fig. I 5-2A to 5-2E. These sketches apply to members constructed of single skin or sandwich laminates as well as to internal members of plywood and timber materials.

a. Fig. I 5-2A is a typical connection of a member which are subjected to considerably heavy load or vibration, such as engine girders, bulkheads, etc. Shell laminates are to be matted with extra plies of reinforcement to increase thickness in way of the connection and to distribute the load that the member is bedded down on wet reinforcement, with suitable resin mixture if necessary.

b. For members other than specified in (a), connections such as shown in Fig. I 5 -2B and 5-2C may be used. Low density foam core or resin pastes is to be applied to the square corners.

c. For plywood and timber members, a coat of thin primer resin is to be applied to the contact area prior to laying-up the matting-in laminates in order to improve the bond quality of the connection. Holes with appropriate pitch may be drilled along the bonding area and reinforcement pushed into the holes to form a key as shown in Fig. I 5-2D.

d. (d) Fig. I 5-2E is a member bolted to a double angle T joint. The connection is formed by laying-up a single angle against a suitable template, which is then removed, and further angle laid up against the first one.

5.3. Mechanical Fastening

5.3.1. Mechanical fasteners may be used for connecting laminates to each other or attachment of metallic fittings to laminates. Fasteners such as bolts, screws, rivets, etc. are to be of corrosion resistant metal or to be properly protected against corrosion.

5.3.2. Metal fasteners are to be affixed vertically to the laminates as far as practicable and to be dipped with activated resin along with the fastening holes.

5.3.3. Bolt diameter is to be approximately equal to the laminate thickness. The distances between the center of each bolt hole and the edge of laminates are not to be less than three times the diameter of the hole. Bolts and nuts are to be fitted with washers on either side of the laminate.

5.3.4. Self-tapping screws can be used for connection of lightly loaded items where a better type of connection cannot be employed. If the laminate is insufficient to give enough penetration and holding power, the screws are to be screwed into a metal tapping strip or equivalent.

5.3.5. Laminates fastened by cold driven revits of steel, alloy or copper are to be fitted with washers or strips under the head and point of the rivet. the washer is to be of the same material as the rivet.

5.3.6. Where sandwich panels constructed with cores of hard plastic foam are connected by bolts, screws, rivets, etc. piercing through the panels, well-seasoned timbers or plywood's are to be inserted in such parts of the cores in advance.

5.3.7. Where mechanical fasteners are used in way of a location required to be watertight, suitable means are to be taken to ensure the watertightness.

5.4. Attachment of Metal Fittings

5.4.1. The metal fittings may be bolted to laminates in conventional manner or may be bonded and matted-in by layers of reinforcements.

5.4.2. Bolting through the hull is to be avoided as far as possible or kept to a minimum. The size of the holes is to be just sufficient to carry the bolt and which can be dipped in with activated resin.

5.4.3. Metal plates can be moulded into the laminate of structure members or matted-in on the reverse side of structure members to take heavy loads from the fittings. The plates are to be beveled and to have sufficient surface area in contact with the laminate.

5.4.4. The laminate in way of deck fittings such as bollards, eye plates, deck blocks, etc. which may carry a considerable load, is to be increased in thickness to prevent damage caused by heavy loading. Fittings are to be bedded down on a flexible sealing compound or neoprene gasket to ensure watertightness.

5.4.5. A special consideration is to be paid to the installations and reinforcements of fishing gear.

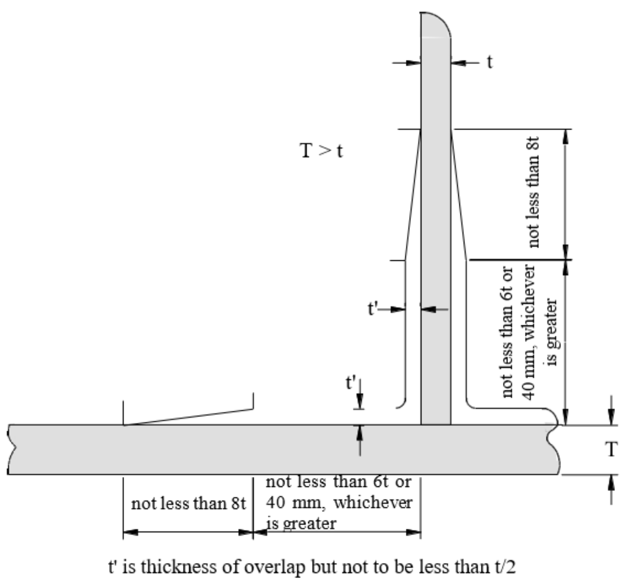
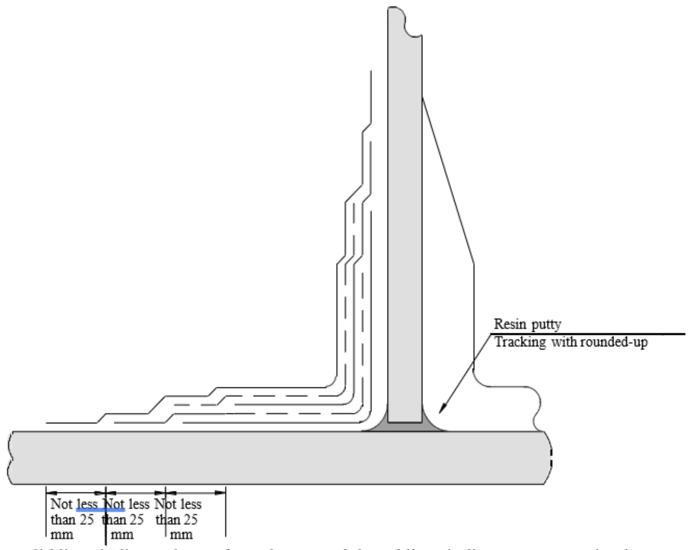


Fig. I 5–1A
Dimensions of Overlap of T-Joints



(a) Solid lines indicate chopped mat layers and dotted lines indicate woven roving layers.
(b) Woven roving layers are not to overlap each other.
(c) The first and final layers are to be a chopped mat layer.

Fig, I 5–1B
In case Chopped Matts and Woven Rovings Jointly Used

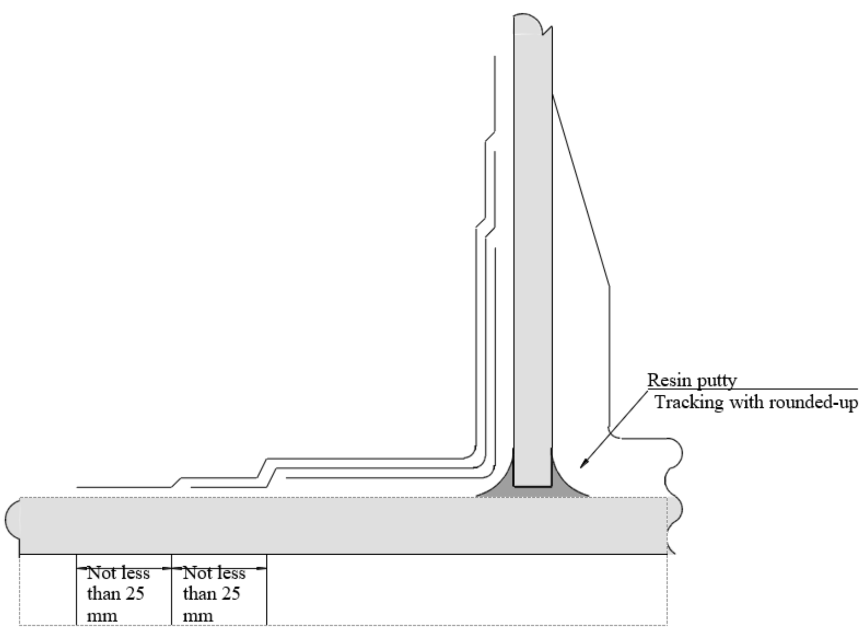


Fig. I 5-1C

In case Chopped Mats Used

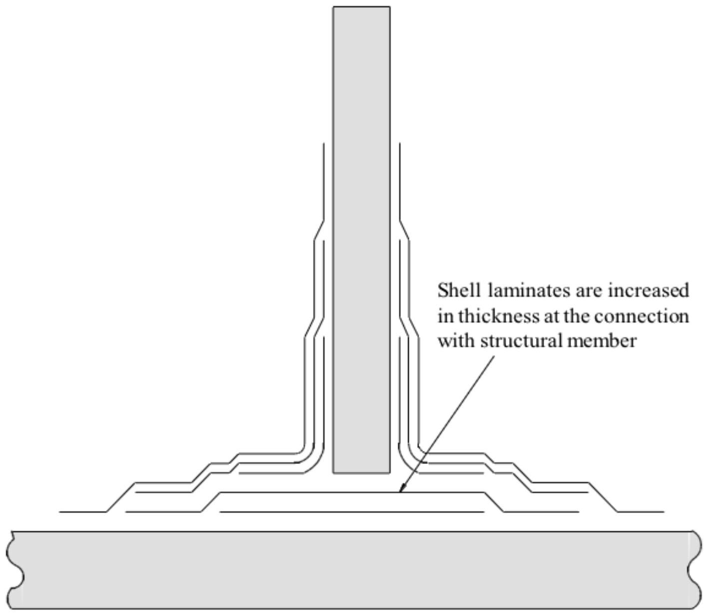


Fig. I 5–2A

In case Consideration to be paid to Load or Vibration

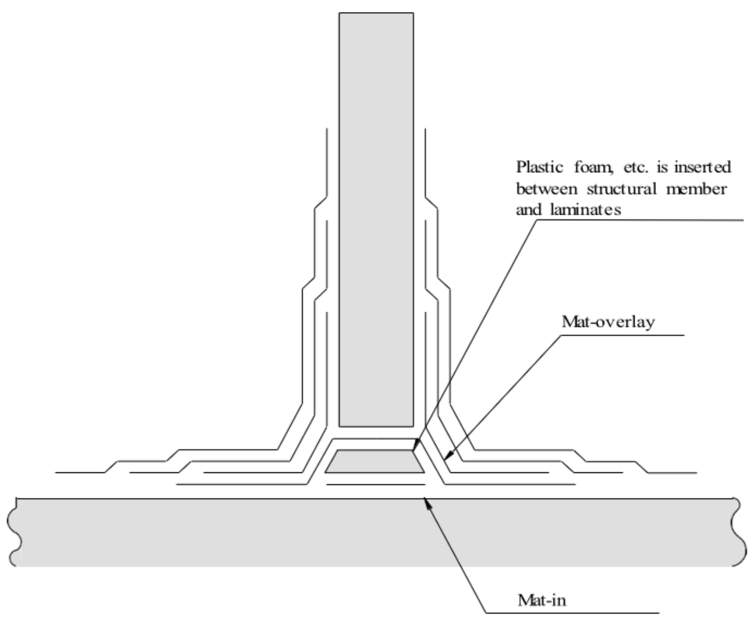


Fig. I 5-2B

Standard Form of T-Joints

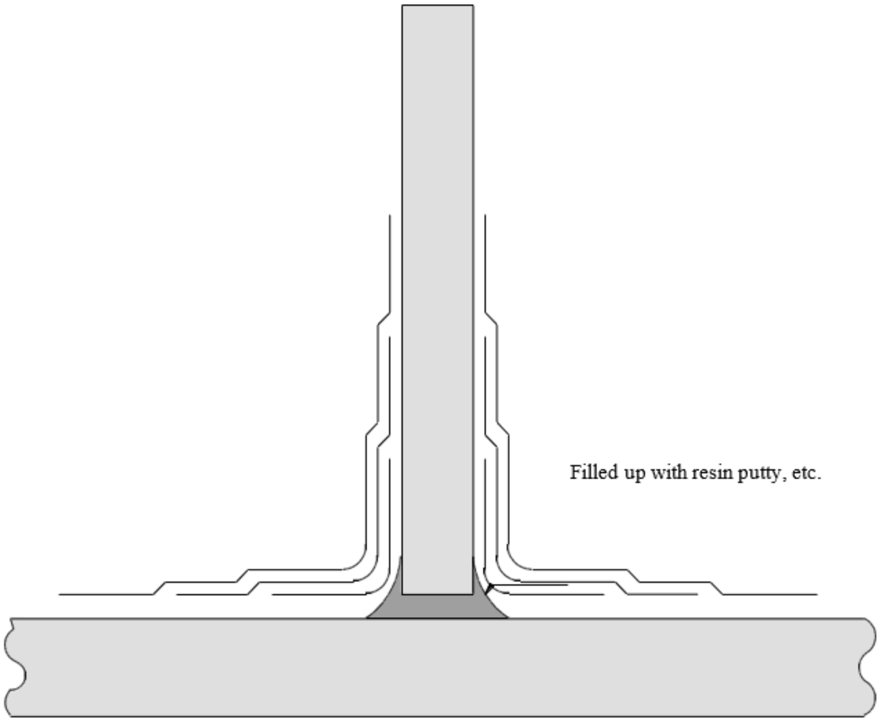


Fig. I 5-2C
Standard Form of T-Joints

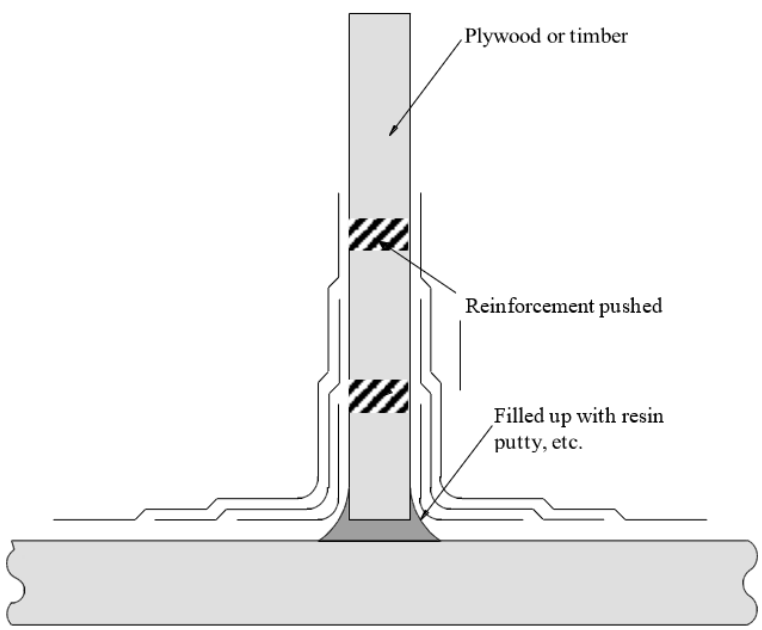


Fig. I 5–2 D

Typical Matting-in Connections of Structural Members

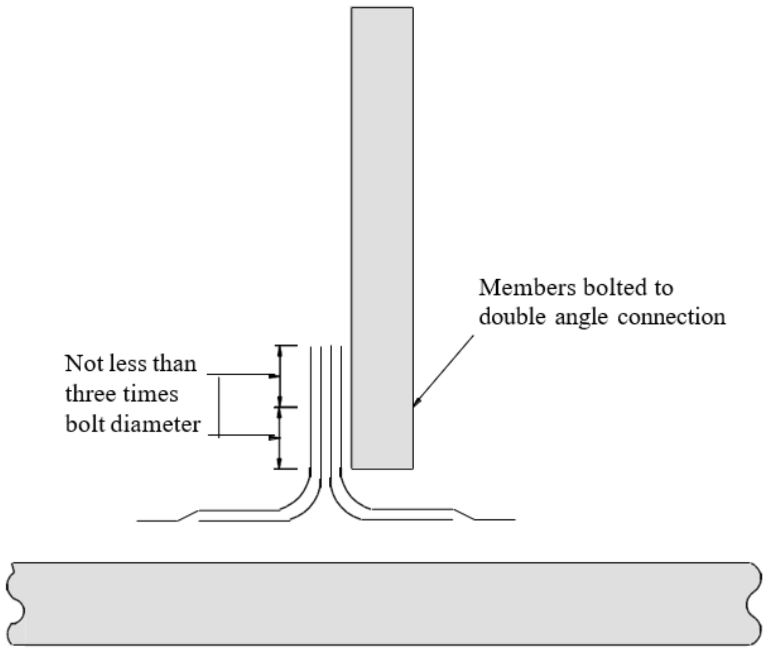


Fig. I 5–2 E
Typical Matting-in Connections of Structural Members

PART II – HULL CONSTRUCTION

CHAPTER I – SHELL LAMINATES

1.1. Construction and Arrangement

1.1.1. The requirements in this Part apply to ship's hull of a single skin construction consisting FRP shell and deck laminates stiffened by a system of supporting members, or of a sandwich construction consisting FRP laminate on either side of a core material which is assumed to be efficient bonded between skins and core that when a sandwich panel is exposed to a lateral load the bending moments are carried by the skins and the shear forces by the core.

1.1.2. In single skin construction, hull laminates are generally supported by primary members in a collective term of girder. Stiffener is a collective term for secondary supporting members. Other terms concerned are:

a. Floor - bottom transverse girder
b. Web frame and / web beam - side and deck transverse girder
c. Stringer - side shell or bulkhead horizontal girder
d. Vertical web - bulkhead girder
e. Beam - deck stiffener
f. Frame - side stiffener
g. Longitudinal - bottom, side, and deck stiffener
h. Transverse - bottom transverse stiffener.

1.1.3. Bottom and deck are normally to be longitudinally stiffened while the side shell may be longitudinally or vertically stiffened. The longitudinal stiffeners are to be preferably continuous through transverse members and supported by bulkhead and/or web frames. Ends of longitudinals are to be fitted with brackets or to be tapered out beyond the point of support.

1.1.4. Sufficient transverse strength is to be provided by means of transverse bulkheads or girder structures. Web frames are to be continuous around a cross section. i.e., floor, web frame and web beam are to be efficiently connected. Longitudinal girders supporting the bottom panels and for docking purposes are to be carried continuously through bulkheads. Engine girder and floor in way of thrust bearings are to be additionally provided with suitable local reinforcements.

1.1.5. Structural continuity of the primary supporting members is to be maintained by fitting rounded brackets at the conjunctions or tapered to zero at their ends. In superstructures and deckhouses, the exposed and internal bulkheads are to be in line with bulkheads in the hull or effectively supported by girders, frame, or pillars. The transition at the break of superstructure is to be smooth without local discontinuities. Openings for doors and windows are to have rounded corners and substantially strengthened along the edge.

1.2. Scantlings

1.2.1. The scantling required in the Rules are specified on the basis of the plastics, reinforced by chopped mats and woven rovings, of which the mechanical properties excluding gel coat are to be in compliance with the followings.

a. Tensile strength 110 N/mm²
b. Modulus of tensile elasticity 7000 N/mm²
c. Bending strength 160 N/mm²
d. Modulus of bending elasticity 7200 N/mm²

1.2.2. The scantlings required may be modified as specified in the following, in case of a single skin construction moulded by the FRP having the strength higher than those specified in 1.2.1.

a. Thickness requirements may be multiplied by a factor obtained from the following formula:

$$(160/\sigma_B)^{1/2}$$

where:

σ_B= Bending strength of the laminate obtained from the strength tests specified in 2.6 of Part I , in N/mm²

b. Requirements of section modulus can be multiplied by a factor obtained from the following formula:

$$110/\sigma_T$$

where:

σ_T = Tensile strength of the laminate obtained from the strength tests specified in 2.6 of Part I, in N/mm²

1.2.3. The section modulus of the structure members required in the Rules are for those sections including effective breadth on the laminate by 150 mm either side of the web.

1.2.4. In addition to the requirement of section modulus, stiffeners of hat-type construction either moulded to a hollow form or moulded covering cores are to be of suitable proportions.

a. The widths and heights of the stiffeners are not to be greater than the value obtained from the following formula:

Width of crown: $20\, t_C\, K$ mm
Height of webs: $30\, t\, K$ mm

where:

t_c = Thickness of crown, in mm

t = Thickness of webs and flanges, in mm
K = 1 and may be taken as $(Z_r/Z_a)^{1/2}$

where:

Z_r = Required section modulus for the stiffener, in cm^3
Z_a = Actual section modulus of the stiffener, in cm^3

b. Where laminates forming hat-type stiffeners are bonded to the skin with flanges, the minimum lap of joint is to be 0.2 height of the stiffener but not less than 50 mm and need not to be greater than 6t.
c. The core for moulding of stiffeners may be reckoned in the strength at the discretion of the Society.

1.2.5. In design of a sandwich construction, the scantlings of inner and outer skin of FRP laminates are to be determined by the modulus of bending elasticity obtained from the material test. The thickness ratio of outer and inner layer is not to be less than 0.8, otherwise, the scantlings are subject to special consideration.

1.2.6. 1.2.6 The core composing a sandwich panel is to be, as a rule, formed by one layer. The thickness of the core is not to be larger than 25 mm, except for those core of special composition and design, the thickness may be increased at the discretion of the Society. The core may be reckoned in the strength where the material test involving joint of cores are included.

1.3. Weight of Fiberglass Reinforcements and Thickness of Laminates

1.3.1. Thickness of laminates per ply of chopped mats or woven rovings may be determined by following formula

$$\frac{W_g}{10\gamma_R G} + \frac{W_g}{1000\gamma_G} - \frac{W_g}{1000\gamma_R} \quad \text{mm}$$

where:

W_g = Weight per unit area of chopped mats or woven rovings, in g/m^2
G = Glass content of laminate, ratio in weight, in %
γ_R = Specific gravity of cured resin
γ_G = Specific gravity of chopped mats or woven rovings

1.3.2. The glass content (G) specified in the preceding formula is preferable to be the value per ply for the actual laminates. However, it may be taken as the mean glass content of the whole laminates.

1.3.3. 1.3.3 In calculating the thickness of laminates, specific gravity of chopped mats or woven rovings (ɣG) may be taken as 2.5, if no special variation is to be considered. Specific gravity of cured resin (ɣR) may be taken as 1.2, except for those cases that fillers are used in order to make the resin heavier.

1.3.4. Calculation of the thickness of laminates with fiberglass reinforcements other than chopped mats and woven rovings is to be in accordance with the properties specified by the material manufacturer at the discretion of the Society.

1.3.5. The thickness of laminates obtained by the calculation is an average value for design purpose. Actual laminate thicknesses have been known to vary as much as 15% over or under the average thickness without being excessively resin rich or resin dry. Actual thicknesses of hull laminates are to be checked with design scantlings to the satisfaction of the Society.

1.4. Scantling Reduction for Service Restriction Ships

1.4.1. Application

a. The requirements of this section are applicable to the ships intended to the following restricted service for the purpose of reduction of structural scantling.

b. Coasting service restriction means the service in the sea area within 20 nautical mile off the shore and a passenger ship does not proceed in the course of its voyage more than 4 hours, or a cargo craft 8 hours at operational speed from a place of refuge when fully laden.

c. Sheltered water service restriction means the service in the sea area between the islands with a distance of less than 10 nautical miles which form a comparatively good, sheltered condition with a little wave; or within 10 nautical miles off the shore, and a ship does not in the course of its voyage more than 2 hours at operational speed from a place of refuge when fully laden.

d. Smooth water service restriction means the service in the lake, dam or inside harbour.

1.4.2. Reductions of Scantlings

a. The scantlings of structural members may be reduced by the ratios given in Table II–1 in relation to the requirements in the relevant chapters.

b. Reductions of scantlings of members other than given in Table II 1-1 may be made at the discretion of the Society.

c. The scantlings of the deck structural members supporting deck cargoes, inner bottom structural members supporting heavy cargoes and deep tank structural members are not to be reduced from the values specified in the relevant Chapters, notwithstanding the provisions in (a) and (b).

TABLE II 1–1
SCANTLINGS REDUCTIONS TO STRUCTURAL MEMBERS

Items	Coasting service	Sheltered Water service	Smooth Water service
Longitudinal strength	5%	7.5%	10%
Bottom and shell platings (including keels)	5%	7.5%	10%
Weather deck platings if designed not based on cargo load	5%	7.5%	10%
Section modulus of bottom and shell internal members	10%	15%	20%
Section modulus of deck internal members	10%	12.5%	15%

Thickness of inner bottom	10%	15%	20%
Section modulus of inner bottom	10%	15%	20%
Thickness and section modulus of superstructure and deckhouse	5%	7.5%	10%

CHAPTER II – LONGITUDINAL STRENGHT

2.1. Application

For ship of ordinary hull form with length not more than 20 m and L/D less than 12, the longitudinal strength is normally satisfied for scantling calculated from local strength requirements specified in the pertinent provisions of the Rules.

2.2. Section Modulus

The section modulus of the hull at midship is not to be less than the value obtained from the following formula:

$$SM = CL^2 B_W (C_b + 0.7) \qquad cm^3$$

where:

- C = Coefficient, obtained from the formula, 0.4L + 36, with a minimum value of 44
- B_w = Horizontal distance between the outside of side shell laminates at the designed maximum load line, in m
- C_b = Block coefficient at the designed maximum load line

2.3. Moment of Inertia

The moment of inertia of the athwartship section at midship is not be less than the value obtained from the following formula:

$$I = 4.2\ ZL \qquad cm^4$$

where:

Z = Section modulus of the athwartship section specified in 2.2, in cm^3

2.4. Calculation of Section Modulus

The calculation of section modulus of the athwartship section is to be comply with the requirements specified in the following 2.4.1 to 2.4.4:

2.4.1. Below the strength deck, all longitudinal members which are considered as continuous for 0.4L amidships are to be included in the calculation. However, above the strength deck longitudinal members which are considered effective to the longitudinal strength of the ship may be included in the calculation.

2.4.2. The section modulus at the strength deck is to be calculated by dividing the moment of inertia corresponding to the horizontal neutral axis of the athwartship section by the vertical distance from the neutral axis to the top of strength deck beam at side, or the top of the longitudinal members above the strength deck in case of which included in the calculation in accordance with the provision specified in 2.4.1. The section modulus at the bottom is to be calculated by diving the above-mentioned moment of inertia by the vertical distance from the neutral axis to the base point of D, or the bottom of keel provided that the keel is of hat-type construction.

2.4.3. If timbers or structural plywood were included in such longitudinal calculation the sectional area in question is to be multiplied by the ratio of the modulus of tensile elasticity of the relevant material to that of the FRP. If the ratio of timbers, structural plywood and other core materials reckoned in the longitudinal strength may be generally specified as follows:

a. Pine and lauan－1.0
b. Plywoods－0.8
c. Other core materials - the value obtained by the tests specified in 2.5 of Part I of the Rules.

2.4.4. 2.4.4 If core materials of sandwich laminates or core materials moulding were included in such longitudinal strength calculation, the sectional area in question shall be multiplied by the ratio of the modulus of tensile elasticity of the pertinent core material to that of the FRP is to be included in the calculation.

2.4.5. Provided that any material mentioned in 2.4.3 and 2.4.4 was reckoned in the longitudinal strength calculation it is to be provided with scarf joints of which the joint length is to be not less than 6 times the thickness as usual.

2.5. Continuity of Strength Materials

Longitudinal strength members are to be of such a construction as to maintain good continuity of strength.

CHAPTER III – SHELL LAMINATES

3.1. General

3.1.1. Application

The scantlings of shell laminates specified in this chapter are applied to single skin construction or sandwich construction.

3.1.2. Small boats

Small boats less than 12 meters in length may be built as unstiffened, i.e., there is no stiffener added to shell laminates. In this type of hull, the scantling of bottom and side laminates is to be suitably increased, subject to specially consideration by the Society. The necessary stiffeners are to be provided in way of the internal assemblies, such as tanks, fuel tanks, cabin bulkheads, etc.

3.2. Keels

3.2.1. The keels are to be continuous from fore end to after end as far as practicable.

3.2.2. The width and thickness of keel laminates over the whole length of the ship are not to be less than the value obtained from the following formula:

a. Plate keels (Fig. II 3-1)

$t_b = 1.5\ t_b$ mm

$W = B/10$ mm

where:

t_b	=	Thickness of bottom shell plating as specified in 3.3.2 and 3.4.2
W	=	Width of keel, in m
B	=	Breadth of vessel, in m

b. Vertical Keels and Skegs (Fig. II 3-2)

$t = 1.5\ t_b$ mm

$W = 0.25H$ mm

where:

t_b	=	Thickness of bottom shell plating, in mm, as specified in 3.3.2
W	=	Width of extension of keel or skeg thickness t onto the bottom of the vessel, in mm
H	=	Maximum depth of keel or skeg, in (mm)

c. Ballasted Vertical Keels (Fig. II 3-3)

$t = 2.0\ t_b$ $H_1 = 0.5W_1$

where:

t_b	=	Thickness of bottom shell plating as specified in 3.3.2, in mm
H_1	=	Height of extension of thickness of bottom of keel up each side of the keel, in mm
W_1	=	Width of bottom of keel laminate or 250 mm, whichever is greater, in mm

3.3. Shell Laminates for Midship Part

3.3.1. Side Shell Laminates of Single Skin Construction

The thickness of side shell laminates, of single skin construction is not to be less than the value obtained from the following formula:

$$t = 14.6S\sqrt{d + 0.026L} \quad \text{mm}$$

where:

S = Spacing of frames, in m

3.3.2. Bottom Shell Laminates of Single Skin Construction

The thickness of bottom shell laminates, is not to be less than the value obtained from the following formula:

$$t = 15.3\, S\sqrt{d + 0.026L} \quad \text{mm}$$

where:

S = Spacing of frames, in m

3.3.3. Shell Laminates of Sandwich Construction

a. The aggregated thickness of inner skin, outer skin and core of sandwich construction is not to be less than the value obtained from the following formula, whichever is greater.

$$C_1S(d + 0.026L) \quad \text{mm; or}$$
$$C_2t_f \quad \text{mm}$$

where:

C_1	=	Coefficient obtained from the formula: $\frac{C_3}{\tau_a}$
τ_a	=	Shearing strength of sandwich laminates obtained from the test specified in 2.5 of Part I, in MPa.
S	=	Spacing of frames, in m
C_2 and C_3	=	As given in Table II 3-1. For the intermediate values of α and β, C_2 and C_3 are to be obtained by linear interpolation
t_f	=	Thickness of single skin construction specified in 3.3.1 or 3.3.2, in mm

Table II 3-1 Value of C2 and C3

β		0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
C_2	α =0.8	1.57	1.38	1.27	1.20	1.16	1.13	1.11	1.11	1.07
	α =1.0	1.49	1.32	1.21	1.15	1.12	1.09	1.07	1.05	1.04
C_3		20.7	21.5	22.2	22.8	23.4	24.0	24.5	24.9	25.4

where:

α= The ratio of outer skin thickness and/or inner skin thickness dividing the lesser one by the greater one

β= The ratio of dividing total thickness of outer skin and inner skin by the thickness of core

b. The respective thickness of inner skin and outer skin of shell laminate of sandwich construction is, notwithstanding the requirements in the preceding (a), not to be less than the value obtained from the following formula. In no case, however, is it to be less than 2.4 mm.

$$t = 73.5 \sqrt[3]{C_4 S^4 (d + 0.026L)^4} \quad \text{mm}$$

where:

C_4 = Coefficient obtained from the following formula: $\frac{1}{t_c} \cdot \frac{E_c}{E_f} \left(\frac{1}{\sigma_c} \right)^4$

E_f = Modulus of bending elasticity of inner skin or outer skin specified in 2.6 of Part I, in N/mm^2

E_c = Modulus of compressive elasticity of core specified in 2.5 of Part I, in N/mm^2

σ_c = Compressive strength of core specified in 2.5 of Part I, in MPa

t_c = Thickness of core, in mm

S = Spacing of frames, in m

3.4. Shell laminates for End Parts

3.4.1. Thickness of Shell Laminates for End Parts

a. The thickness of shell laminates of single skin construction may be gradually reduced beyond the midship part to 0.85 times the thickness of shell laminates amidships for end parts.

b. Shell laminates of sandwich construction beyond the midship part are to be of the same construction as that for the midship part.

c. For the portion subject to local loads such as propeller load, etc., the shell laminates are to be properly strengthened

3.4.2. Strengthened Forward Bottom

a. The strengthened forward bottom is the part of flat bottom forward from the position specified in the following (i) or (ii). The flat bottom is the bottom of which slope measured at the respective athwartship sections (See Fig. II 3-4) is not more than 15 degrees.

i. Where $V/\sqrt{L}$ is not more than 1.5:

0.25 L from the fore end

ii. Where $V/\sqrt{L}$ exceeds 1.5:

0.3 L from the fore end

Where V is the maximum speed in knots which the ship with clean bottom can attain at the maximum continuous output on calm sea in loading condition corresponding to the designed maximum load line.

b. The thickness of shell laminates at the strengthened forward bottom of single skin construction is not to be less than the value obtained from the following formula:

$$t = CS\sqrt{L} \quad \text{mm}$$

where:

C	=	Coefficient given in Table II 3-2. However, for the intermediate values of α, C is to be obtained by linear interpolation.
S	=	Spacing of frames, or spacing of girders or shell longitudinals, whichever is smaller, in m.
α	=	Spacing of frames, or spacing of girders or shell longitudinals, whichever is greater, in m, divided by S.

Table II 3-2
Value of C

α	1.0	1.2	1.4	1.6	1.8	2.0 and above
C	5.20	5.80	6.18	6.42	6.55	6.61

c. The thickness of shell laminates at strengthened forward bottom of sandwich construction is not to be less than the value obtained from the formula specified in 3.3.3(a). However, in application of the formula, C_3 is to be taken as 1.8 times the value given in Table II 3-1 and t_f as the thickness of shell laminates specified in 3.3.3(a).

d. In FRP Ships of which L is less than 20 m and V is less than 14 knots or in FRP Ships which are deemed by the Society to have sufficient bow draught, the thickness specified in the preceding (b) and (c) may be properly reduced.

3.4.3. Shell laminate for Tramson Sterns and Hard Chin Form

In way of hard chin form, the thickness of the shells in way of both sides of the knuckles and the distances these thicknesses are to be carried from the knuckles (Fig. II 3-5) are not to be less than the value obtained from the following formula:

$$t = 1.5\,t' \text{ mm}, \quad W = B/40 \text{ m}$$

where

t'	=	Thickness of bottom shell laminates specified in 3.3.2 and 3.3.3, in mm
W	=	Width, in m
B	=	Breadth of vessel, in m

The thickness of the transoms is not to be less than that of side shell laminates specified in 3.3.1 and 3.3.3.

3.5. Side shell Laminates in Way of Superstructures

3.5.1. The side shell laminates in way of superstructures are to be in accordance with the requirements in the following:

a. The thickness of side shell laminates in way of superstructures for 0.25L from the fore end and that of side shell laminates in way of sunken forecastle or sunken poop is not to be less than that of side shell laminates at the place.

b. The thickness of side shell laminates in way of superstructures other than specified in the preceding (a) may be 0.8 times that of side shell laminates at the place.

3.6. Local Strengthening of Shell Laminates

3.6.1. Strengthening of Shell Laminates fitted with Hawse Pipes and Adjacent Shell Laminates.

The side shell laminates which are in danger of contact with anchors and chain cables are to be properly strengthened.

3.6.2. Local Strengthening for Sailing Vessels

In ships equipped with sails the required side shell thickness 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 breadth of the vessel at the mast.

3.6.3. Local Strengthening for Fishing or Research Vessels

a. In ships 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.

b. 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 3.3.1 and 3.3.3. 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 3.3.1 and 3.3.3. Half-round metal rub bars are to be installed at the top of the bulwark, the top of the sheerstrake, and the designed waterline. These bars are to extend from not less than 0.0225L forward of the forward leg of each gallows 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.

c. 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 3.3.1 and 3.3.3. The minimum thickness of the chute sides is to

be 10% greater than the thickness of the side shell plating obtained from 3.3.1 and 3.3.3. Metal wear plates are suggested at parts of the chute bottom and sides subject to severe wear.

3.6.4. Reinforcements

Reinforcements are 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.

3.6.5. Structure interruptions

The side plating of superstructures, including forecastles and poops, is to extend beyond the ends of the superstructures in such fashions 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 structure. Any holes that must unavoidably be cut in the shell adjacent to the interruptions are to be kept as small as possible and are to be circular or oval in form.

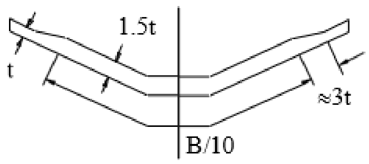


Fig. II 3-1
Plate Keels

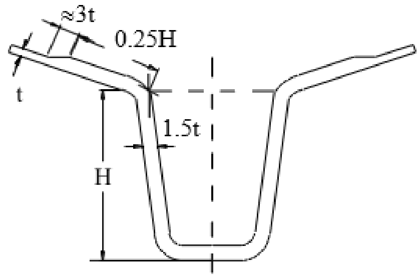


Fig. II 3-2
Vertical Keels and Skegs

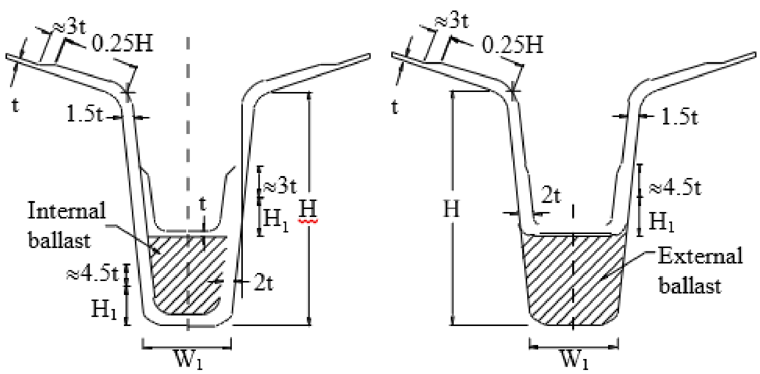


Fig. II 3-3
Ballasted Vertical Keels

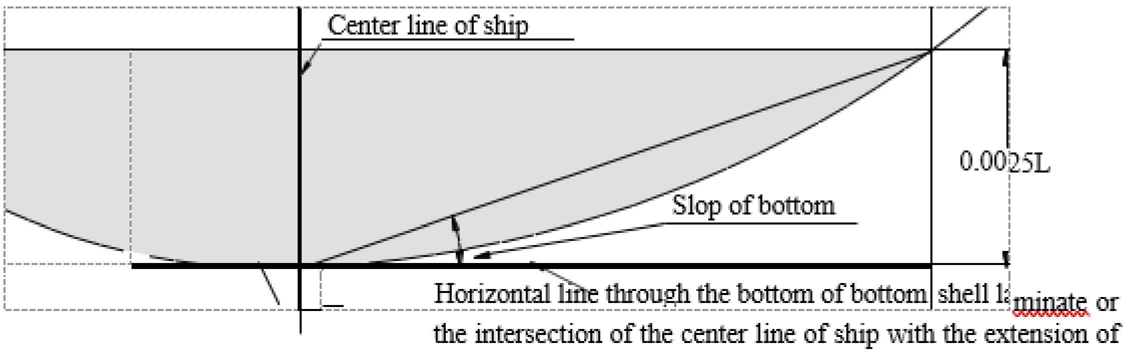


Fig. II 3-4
Slop of Bottom

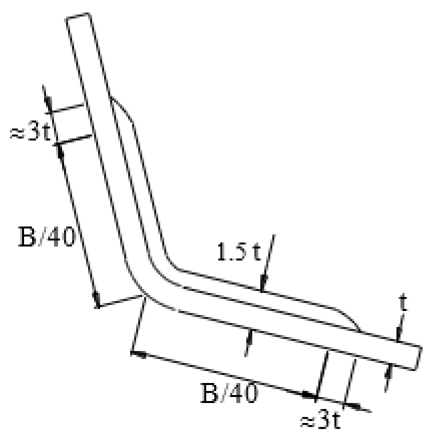


Fig. II 3-5

Reinforcement for Shell Knuckles

CHAPTER IV – DECKS

4.1. General

4.1.1. Application

a. The requirements in this chapter are applied to the construction and scantlings of decks moulded with FRP. The decks such as wooden decks which are composed of other materials than FRP are to be in accordance with the discretion of the Society.

b. The construction and scantlings of decks specified in this chapter are applied to single skin construction or sandwich construction.

4.1.2. Watertightness of Decks: The construction of decks is to be made watertight except being specially approved by the Society.

4.1.3. Continuity of Decks:

Where the upper decks change in level, the change is to be accomplished by gradually sloping the decks, or each of structural members which form decks is to be extended and to be effectively connected together by suitable means.

4.2. Minimum Thickness of Deck Laminates

4.2.1. Thickness of Deck Laminates of Single Skin Construction

a. The thickness of upper deck laminates for 0.4L amidships, is not to be less than the value obtained from the following formula:

i. For longitudinal framing system

$$t = 14.3S\sqrt{h} \quad \text{mm}$$

ii. For transverse framing system

$$t = 17.4S\sqrt{h} \quad \text{mm}$$

where:

S = Spacing of deck longitudinals or transverse beams, in m

h = As specified in 4.2.3, in m

b. The thickness of upper deck laminates for outside of 0.4L amidships and that of other deck laminates are not to be less than the value obtained from the following formula.

$$t = 12.4S\sqrt{h} \quad \text{mm}$$

where:

S = Spacing of deck longitudinals or transverse beams, in m

h = As specified in 4.2.3, in m

4.2.2. Deck laminates of Sandwich Construction

a. The aggregated thickness of inner skin, outer skin and cores of sandwich construction is not to be less than the value obtained from the following formula whichever is greater:

$$t = C_1 S h \quad \text{mm}$$

$$t = C_2 t_f \quad \text{mm}$$

where:

C_1 and C_2 = As specified in 3.3.3(a) of this Part

S = Spacing of deck longitudinals or transverse beams, in m

h = As specified in 4.2.3, in m

t_f = Thickness of deck laminates constructed specified in 4.2.1, in mm

b. The respective thickness of the inner skin and outer skin of sandwich construction are, notwithstanding the requirements in the preceding (a), not to be less than the value obtained from the following formula. In no case, however, is it to be less than 2.4 mm

$$t = 73.5 \sqrt[3]{C_4 (Sh)^4} \quad \text{mm}$$

where:

C_4 = As specified in 3.3.3(b)

S = Spacing of deck longitudinals or transverse beams, in m

h = As specified in 4.2.3, in m

4.2.3. Deck Head

a. Deck head h intended to carry cargoes, etc. is to be as specified in the following:

i. For decks intended to carry cargoes and stores, h is to be 0.72 times the tween deck height at side from the deck to the deck immediately above it (m), or cargo weight per unit area of the deck converting into waterhead (m), whichever is greater.

ii. Where cargoes are intended to be carried on the weather deck, h is to be cargo weight per unit area of the deck converting into waterhead (m) or the value stipulated in (b), whichever is greater.

iii. For decks intended to carry cargoes which weight is considerably light, h may be suitably modified

b. For decks without loading cargoes, the deck load h is to be specified as follows:

i. For exposed freeboard decks and first tier superstructure decks afore 0.3L from the fore end

$$h = 0.027L + 0.76 \quad m$$

ii. For freeboard deck inside enclosed superstructures and exposed first tier superstructures deck abaft 0.3L from the fore end:

$$h = 0.010L + 0.62 \quad m$$

iii. For other superstructure decks not specified in (i) & (ii)

$$h = 0.017L + 0.47 \quad m$$

iv. For enclosed accommodations

$$h = 0.47 \quad m$$

c. In case where fishes carried on deck in fishing vessels, the deck load h is to be the value specified in 4.2.3(b)(i) and (ii) or the value obtained from the following formula, whichever is the greater.

$$h = 0.023L + 1 \quad m$$

4.3. Local Compensation of Decks

4.3.1. Compensation for Large Openings

a. Deck laminated in way of the corners of large openings are to be suitably increased in thickness.

b. Corners of openings are to be suitably rounded.

4.3.2. Location of Openings

The distance between the ship side or hatch side and the opening is not to be less than 1.5 times the diameter of the opening. Where, however the distance is necessary made less than this specified value, suitable compensation is to be provided.

4.3.3. Decks in Danger of Abrasion

Deck laminates under abrasion by heavy loads, etc. are to be suitably protected from abrasion by means of increasing thickness or providing with coverings.

4.3.4. Deck to Hull Connection

a. All connections are to be lapped and bolted unless otherwise specially approved. Connections differing from those shown are to be specially considered by the Society.
b. 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.
c. Faying surfaces are to be set in bedding compound polyester putty, or other approved material.
d. 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 the thicker.
e. Widths of overlaps, metal bolt diameters metal bolt spacing and width of the flanges of FRP bonding angles are to be in accordance with the following formulae. Intermediate values may be obtained by linear interpolation.
   i. Metal bolt diameters and spacing

$$d = 0.417\,L + 2.75 \quad \text{mm}$$
$$S_b = 4.24L + 114 \quad \text{mm}$$

where:

d = Bolt diameter, in mm

S_b= Bolt spacing, in mm

   ii. Widths of overlaps and widths of flanges of FRP bonding angles

$$b = 4.17L + 25 \quad \text{mm}$$

f. (f) Each connection is to be protected by a guard, molding, fender or rail cap of metal, wood, rubber, plastic, or other approved material.

CHAPTER V – FRAMES

5.1. General

5.1.1. Application

a. The requirements in this chapter are applied to the construction and scantlings of transverse or longitudinal frames moulded with FRP.
b. For FRP vessels with especially long holds or with especially large hatch openings, the transverse stiffness of the hull is to be suitably increased by increasing the scantlings of frames or by providing web frames additionally.
c. In vessels equipped with sails, web frames or transverse bulkheaded are to be provided in way of masts.

5.1.2. Frames in Way of Deep Tanks

The strength of frames in way of deep tanks is not to be less than the section modulus required for the stiffeners on deep tank bulkheads.

5.2. Construction

5.2.1. Construction of Fames

a. Frames are so constructed as to avoid lateral buckling.

b. Where the length of ship is small, corrugated side shell laminates may be adopted in lieu of normal framing construction.

5.2.2. Core material

a. Timbers used for cores are to be well seasoned, free from sapwood and treated with a suitable wood preservative, if necessary. Care is to be taken to prevent the timbers laminated in FRP from dry rot.

b. Plastic foams used for cores are to be non-hygroscopic.

c. The requirement of this section also applies to other chapters.

5.3. Spacing of Frames

5.3.1. The standard spacing of frames is 500 mm for transverse system or 600 mm for longitudinal system.

5.3.2. The spacing of frames afore 0.2L from the fore end is not to exceed 500 mm.

5.3.3. Where the spacing of frames is 750 mm or over, special considerations are to be given to the construction and scantlings of the primary hull structural members.

5.4. Transverse System

5.4.1. Transverse Frames

a. The section modulus of transverse frames abaft 0.15L from the fore end is not to be less than the value obtained from the following formula:

$$SM = 29Sh\,l^2 \quad cm^3$$

where:

S = Spacing of frames, in m

h = Waterhead, in m; vertical distance from the lower end of *l* at the place of measurement to a pointd + 0.026L above the base point of D. Where, however, the head is not to be less than 0.5D.

l = Vertical distance from the top of inner bottom laminates or single bottom floor at side to the top of upper deck beams at side, in m. For frames abaft 0.25L from the fore end, *l* is to be measured at midship. For frames between 0.25L and 0.15L from the fore end, *l* is to be measured at 0.25L from the fore end.

b. The section modulus of transverse frames afore 0.15L from the fore end is not to be less than the value obtained from the following formula:

$$SM = 34\,Sh\,l^2 \quad cm^3$$

where:

S, h, and l = As specified in the preceding (a). However, l is to be measured at 0.15L from the fore end.

5.4.2. Side Stringers Supporting Transverse Frames

All transversely frame vessels having depths above the hard chine or upper turn of bilge greater than 2.4 m are to have side stringers. The maximum spacing between stringer and from top stringer to freeboard deck is to be 2.4 m. The section modulus thereof is not to be less than the value obtained from the following formula:

$$SM = 24\ Sh\ l^2 \quad cm^3$$

where:

S	=	Spacing of stringers, in m
h	=	Waterhead, in m; vertical distance from the stringer to a point d + 0.026L above the base point of D.Where, however, the head is not to be less than 0.5D
l	=	Span, in m; distance between frames or between frame and bulkhead

5.5. Longitudinal System

5.5.1. Side Longitudinal

a. The section modulus of side longitudinals below the upper deck for the midship part is not to be less than the value obtained from the following formula:

$$SM = 44.5Sh\ l^2 \quad cm^3$$

where:

S	=	Spacing of longitudinals, in m
h	=	Waterhead, in m; vertical distance from the longitudinals to a point d + 0.026L above the basepoint of D. Where, however, the distance is less than 0.5D, h is to be taken as 0.5D
l	=	Span, in m; distance between the transverse bulkhead, where web frames are provided, distancebetween the web frames or between the transverse bulkhead and web frame

b. Beyond the midship part, the section modulus of side longitudinals may be gradually reduced toward the ends of ship and may be 0.85 times that obtained from the formula in the preceding (a) for the end parts. However, the section modulus of side longitudinals afore 0.15L from the fore end is not to be less than the value obtained from the formula in the preceding (a).

5.5.2. Web Frames Supporting Side Longitudinals

Where the ship's sides are longitudinally framed, web frames supporting side longitudinals are to be provided in a spacing not exceeding 2.4 m. However, the section modulus thereof is not to be less than the value obtained from the following formula:

$$SM = 32Shl^2 \quad cm^3$$

where:

S = Spacing of web frames, in m h and l = As specified in 5.4.1(a)

5.6. Hat-type Construction

5.6.1. Typical Configuration

The typical configurations of such sections are shown in Fig. II 5-1. Such configurations are also applicable to similar construction specified in the Rules.

5.6.2. Requirement

With respect to the scantling of frames of hat-type construction, the requirements in 1.2.4 of this Part, in addition to the requirements in this chapter, are to be complied with.

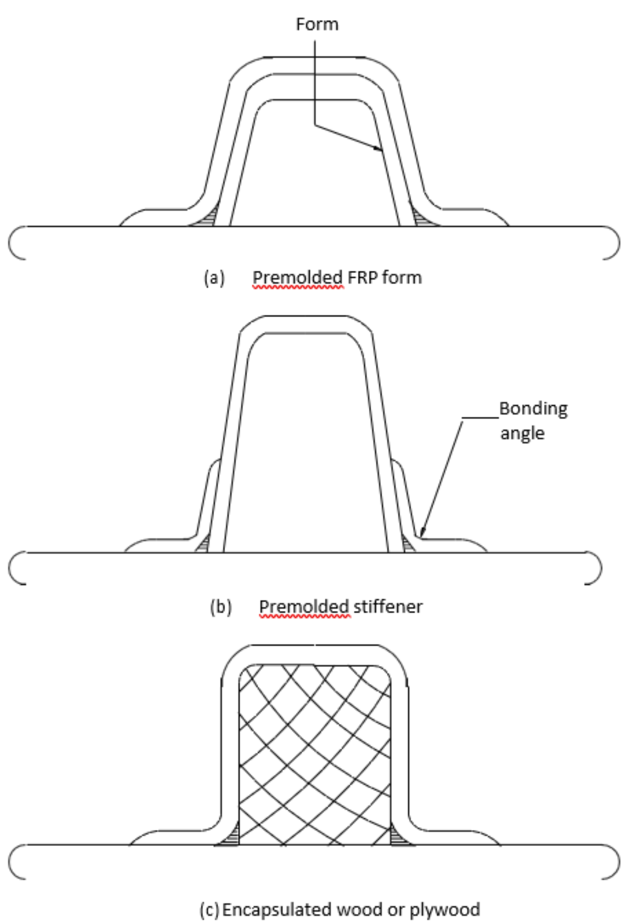


Fig. II 5-1

CHAPTER VI – BOTTOM CONSTRUCTION

6.1. General

6.1.1. Application

a. The requirements of this chapter are applied mainly to the single bottoms supported by the transverse system where bottom transverses or transverse bulkheads and girders to be provided, or the longitudinal system where floors or transverse bulkheads and bottom longitudinals to be provided.

b. Where bottoms are constructed in double bottom partially or wholly, the structural members of double bottoms are to be complied with the requirements of 6.6 of this chapter.

c. Longitudinal structural members such as bulkheads, engine bed girders, vertical keels and skegs may be considered as girders.

6.1.2. Drain and Air Holes

Drain holes are to be molded or cut in the bottom structures and non-tight bulkheads to assure the free drainage of bilges to suction wells. The edges of the holes are to sealed with proper resin. Drain and air holes are to be provided in all non-watertight members of double bottom with the same method to ensure that liquid or air does not remain stagnated in any part of tanks.

6.1.3. End Construction

Unless otherwise specifically approved, the end construction of girders, web frames, frames and longitudinals are to be attached to their supporting members.

6.2. Center Girders

6.2.1. Arrangements

a. Center girders are to extend from the collision bulkhead to the aft peak bulkhead as far as practicable.

b. For ships with hat-type keel of suitable height, the center girder may be omitted.

6.2.2. Construction and Scantlings

a. The thickness of FRP laminated webs of center girders is not to be less than the value obtained from the following formula. However, beyond the midship part, the thickness may be gradually reduced toward the ends, and it may be 0.8 times the midship value for the end:

$$t = 0.4L + 4.7 \quad \text{mm}$$

b. The thickness and breadth of the face plates are not to be less than the value obtained from the following formula respectively. However, beyond the midship part, the sectional area of the face plates may be gradually reduced toward the ends, and it may be 0.8 times the midship value for the end:

$$t = 0.4L + 4.7 \quad \text{mm}$$

$b = 4L + 30$ mm

c. The webs of center girders are to extend to the top of bottom transverse floors.

6.2.3. Center girder in way of M/E

The thickness of webs and face plates of center girders in way of M/E are not to be less than 1.25 times the values specified in the preceding 6.2.2(a) and (b) respectively.

6.3. Side Girders

6.3.1. Arrangement: Where the breadth of ship measured at the top of floors exceeds 4.8 m, side girders are to be arranged at a suitable spacing.

6.3.2. Construction and Scantlings

a. The thickness of webs of side girders for the midship part is not to be less than the value obtained from the following formula. However, beyond the midship part, the thickness may be gradually reduced toward the ends, and it may be 0.8 times the midship value at the end:

$$t = 0.3L + 3.5 \quad \text{mm}$$

b. The thickness and breadth of face plates of side girders are not to be less than the values obtained from the following formulae respectively. However, beyond the midship part, the sectional area may be gradually reduced toward the ends, and it may be 0.8 times the midship value at the end:

$$t = 0.3L + 3.5 \quad \text{mm}$$
$$b = 3.2L + 24 \quad \text{mm}$$

c. The heights of side girders at their ends are to extend to the top of bottom transverse floors.

6.3.3. Side Girders in way of M/E

The thicknesses of webs and face plates of side girders in way of M/E are not to be less than the thicknesses of webs and face plates of center girders specified in 6.2.3.

6.4. Transverse System

6.4.1. Arrangement and Scantlings of Floors

a. Where transverse framing is adopted in the bottom construction, floors are to be fitted at each frame and the section modulus of floors is not to be less than the value obtained from the following formula.

$$SM = 34Sh\,l^2 \quad \text{cm}^3$$

Where:

S = Spacing of transverse floors, in m

h = Waterhead, in m; vertical distance from the middle of l to a point d + 0.026L above the base point of D, where, however, h shall not less than 0.5D

l = Span, in m; distance between the girders

b. Beyond 0.5L amidships, the section modulus of floor plates may be gradually reduced toward the ends, and it may be 0.8 times the value specified in the preceding (a) at the end. However, the floors in the strengthened bottom forward are to be in accordance with the requirements in 6.7.2.
c. The thickness of face plate provided on the upper edges of floors is not to be less than the thickness of web of floor at the place.
d. The section modulus of floors under the main engine seatings is not to be less than 1.5 times the value specified in the preceding (a).

6.4.2. Floors Forming Part of Bulkheads

Floor forming part of bulkheads are to be in accordance with the requirements for watertight bulkheads in Chapter 8 and those for deep tanks in Chapter 9 in addition to those specified in this chapter.

6.5. Longitudinal System

6.5.1. Construction

Where longitudinal framing is adopted in the bottom construction, bottom longitudinals are to be fitted continuously by penetrating floors or similar construction or to be attached to thereof so as to have sufficient fixing strength against bending and tension.

6.5.2. Spacing of Bottom Longitudinals

The standard spacing of bottom longitudinals is 600 mm.

6.5.3. Section Modulus

The section modulus of bottom longitudinals is not to be less than the value obtained from the following formula:

$$SM = 48\ Sh\ l^2 \quad cm^3$$

Where:

S = Spacing of longitudinals, in m
h = Waterhead, in m; vertical distance from the bottom longitudinals to a point d + 0.026L above the base pointof D. Where, however, the distance is not to be less than 0.5D
l = Span, in m; distance between the floors

6.5.4. Bottom Floors Supporting Bottom Longitudinals

Where longitudinal framing is adopted in the bottom construction, bottom floors supporting bottom longitudinals are to be provided at a spacing not exceeding 2.4 m. The bottom floors are to be fitted at every web frame and the scantlings are not to be less than the value specified in 6.4.1 of this chapter.

6.6. Double Bottoms

6.6.1. General

a. Where bottoms are partially or wholly of double bottom construction, the scantlings of structural members are to be in accordance with the requirements in 6.6.2 to 6.6.7 of this section.

b. Bottom laminates under the sounding pipes are to be increased in thickness or to be protected against damages due to striking of sounding rods by suitable means.

c. The thickness of watertight girders and floors, and the scantlings of stiffeners attached to them are to be in accordance with the respective requirements for the relevant girders and floors, and in addition, in accordance with the requirements for deep tanks in Chapter 9.

d. Cofferdams are to be provided in the double bottom between oil tanks and freshwater tanks used for living, boiler feed water, etc., which may cause trouble when oil mixed therein.

e. In transverse system, center girder and/or side girders, if necessary, solid floors or open floors are to be provided. In longitudinal system, center girder and/or side girders, if necessary, solid floors are to be provided.

6.6.2. Center Girders

a. Webs of center girders are to extend the whole length of the bottom as far as practicable.

b. The thickness of webs of center girders is to be in accordance with the requirements in 6.2.2.

6.6.3. Side Girders

a. Where the breadth of ship measured at the top of floors exceeds 4.8 m, side girders are to be arranged at a suitable spacing.

b. The thickness of webs of side girders is to be in accordance with the requirements in 6.3.2.

6.6.4. Solid Floors

a. Solid floors are to be provided at a spacing not exceeding 2.4 m

b. In addition to complying with the requirement in preceding (a), solid floors are to be provided at the following locations:

   i. At each frame in main engine room, solid floors may, however, be provided at alternative frames outside the engine bed.
   ii. Under thrust bed, if provided.
   iii. Under transverse bulkheads.
   iv. Forward bottom specified in 6.7.2

c. The scantlings of floors are to be in accordance with the requirements in 6.4.1.

d. Where floors are of single skin construction, stiffeners are to be provided on floors at a spacing not exceeding 1.2 m.

e. Lightening holes or manholes may be provided without effecting the strength of floor, and, if necessary, suitable strength compensation is to be taken by increasing the floor depth or by other means.

f. All tanks are to have access holes, and the non-tight members in such tanks are to have lightening holes, sufficient in size and number to assure accessibility to all spaces of the tanks. Tank access covers are to be metal or FRP and secured to the tanks. The diameter of bolts or stud's "d" are to be not less than 6.5 mm, their spacing, center to center, is to be not more than 6d, and they are to be set in from the edges of the covers a distance not less than 3d for FRP cover or 2d for steel cover. In cargo holds if no ceiling provided, the covers are to be protected against damage caused by the cargo.

g. Floor plates forming of bulkheads are to be in accordance with the requirements for watertight bulkheads in Chapter 8 in addition to those in this chapter.

6.6.5. Open Floors

a. Where the double bottom is framed transversely, open floors are to be provided at each frame between solid floors.

b. The section modulus of bottom transverse without vertical struts is not to be less than the value obtained by the following formula.

$$SM = 30\,Sh l^2 \quad cm^3$$

where:

S = Spacing of frames, in m

h = Waterhead, in m; d + 0.026L or cargo load head, whichever is greater.

l = Span, in m; distance between primary structures such as center girder, side girder, bilge / hard chine construction etc.

c. The section modulus of inner bottom transverse without vertical struts is not to be less than the value obtained by the following formula:

$$SM = 25.5\,Sh\,l^2 \quad cm^3$$

where:

S = Spacing of frames, in m

h = Waterhead, in m; d + 0.026L or cargo load head, whichever is greater.

l = Span, in m; distance between primary structures such as center girder, side girder, bilge / hard chine construction etc.

d. The section modulus of bottom transverse and inner bottom transverse with vertical struts may be reduced depending on the scantling and arrangement of vertical struts.

6.6.6. Inner Bottom Laminates

a. The thickness of inner bottom laminates is not to be less than the value obtained from the following formula:

$$t = 11S\sqrt{d} \quad mm$$

Where:

S = Spacing of floors or longitudinals, in m.

b. Inner bottom laminates are to be rigidly connected with side shell laminates, bulkhead laminates, etc.

6.6.7. Bottom Longitudinals

a. Bottom longitudinals and inner bottom longitudinals are to be provided at a spacing not exceeding 600 mm.

b. The construction, scantlings and spacing of bottom longitudinals without struts are to be in accordance with the requirements in preceding 6.5.1, 6.5.2, 6.5.3, 6.5.4 and 6.8.

c. The section modulus of longitudinals provided on the inner bottom laminates are not to be less than the value obtained from the following formula:

$$SM = 45.6Sh\, l^2 \quad cm^3$$

Where:

S = Spacing of longitudinals, in m.

h = Waterhead, in m; vertical distance from the middle of *l* to a point d + 0.026L above the base point of D, or cargo load head, whichever is greater.

l = Span, in m; distance between the solid floors

6.7. Forward Strengthened Bottom

6.7.1. Strengthened Portion: Strengthened bottom forward is the area specified in 3.4.2.

6.7.2. Construction and Scantlings: The scantlings of floors, bottom longitudinals, side girders and center girders in the forward strengthened bottom are to be properly increased.

6.8. Hat-type Construction

6.8.1. Construction and Scantlings

a. The thickness on one side of webs of center girders and side girders of hat-type construction are not to be less than 0.7 times the values specified in preceding 6.2.2(a) and 6.3.2(a) respectively.

b. The sectional areas of top plate laminates of center girders and side girders of hat-type construction are not to be less than the products of the breadth and the thickness of face plate laminates specified in preceding 6.2.2(b) and 6.3.2(b) respectively.

c. The section modulus of floors and bottom longitudinals of hat-type construction are not to be less than the values specified in preceding 6.4.1, 6.4.2, 6.5.3, 6.5.4, 6.6.4(b), 6.6.4(c), 6.6.6(b) and 6.6.7(c) respectively.

d. The scantlings of structural members of hat-type construction are to be in accordance with the requirements in 1.2.4, in addition to those in the preceding (a) to (c).

CHAPTER VII – UNDER DECK CONSTRUCTION

7.1. General

7.1.1. Either transverse system or longitudinal system may be adopted for under deck construction.

7.1.2. It is recommended that the camber of weather deck is to be B/50.

7.1.3. At the places where beams need to be supported, under deck girders or equivalent structures are to be provided in accordance with the requirements in this chapter.

7.1.4. Deck girders or web beams are to be provided, as necessary, under masts, derrick posts, deck machinery and other heavy concentrated loads.

7.1.5. Pillars supporting under deck structures are to be in accordance with the requirements in this chapter.

7.2. Spacing

7.2.1. Standard Spacing: The standard spacing is 500 mm for transverse system and 600 mm for longitudinal system.

7.2.2. Consideration for Especially Large Spacing: Where the spacing of beams is 750mm or over, special consideration are to be given to the construction and scantling of the primary hull structural members.

7.3. Transverse System

7.3.1. Section Modulus of Beams: The section modulus of beams is not to be less than the value obtained from the following formula:

(a) For ordinary beams: $SM = 26.5Sh\,l^2$ cm^3

(b) For web beams: $SM = 33Sh\,l^2$ cm^3

where:

S = Spacing of beams, in m

h = As specified in 4.2.3, in m

l = Horizontal distance from the inner edge of beam brackets to the primary structure of deck or between primary structure of deck, in m. Where *l* is less than 0.25B in the upper deck beams except those at the end, *l* is to be taken as 0.25B. Where *l* is less than 0.2B in the beams at the end of upper deck or in the superstructure deck beams, *l* is to be taken as 0.2B.

7.3.2. End connections: Beams and frames are to be connected each other by means of brackets. The length of arms of the brackets is not to be less than ⅛ of *l* specified in 5.4.1.

7.3.3. Beams of Decks Carrying Especially Heavy Loads: Beams of decks which carry heavy loads such as deck machinery and others are to be properly strengthened as web beams or girder.

7.3.4. Girders supporting deck beams: Where transverse system is adopted in deck construction, girders supporting deck beams are to be provided in a spacing of about 2.4m, in this case, the section modulus thereof, are to be in accordance with the requirement of 7.4.2.

7.4. Longitudinal System

7.4.1. Construction of Girders: Under deck girders are to be uniform in depth throughout the part between bulkheads and to have sufficient bending rigidity.

7.4.2. Section modulus of Girders and Deck Longitudinals: The section modulus of under-deck girders and longitudinals is not to be less than the value obtained from the following formula:

$$SM = Cbh\, l^2 \quad cm^3$$

Where:

b = Distance between the mid-points of spaces from the girder to the adjacent girders or the inner edges of brackets, in m. (See Fig. II 7-1)

l = Distance between the primary structure girders, in m. (See Fig. II 7-1)

h = As specified in 4.2.3, in m. Where, however, h is to be in accordance with the requirements in 4.2.3(b), h is to be as specified in the following (a) and (b).

(a) Afore 0.3L from the fore end:

$h = 0.014L + 0.47$

(b) Abaft 0.3L from the fore end:

$h = 0.012L + 0.47$

C = Coefficient given below:

(i) for girders

Midship part	40
Elsewhere	31

(ii) for longitudinals

Midship part	31
Elsewhere	25

7.4.3. Supports and Connections at Ends

a. The ends of under-deck girders are to be supported by bulkhead stiffeners. These stiffeners are to be properly strengthened.

b. Where two adjacent under-deck girders or an under-deck girder and longitudinal bulkhead are not in line in way of a transverse bulkhead, etc., each of them is to be extended beyond the transverse bulkhead, etc. for at least one frame space.

7.4.4. Web Beams supporting Deck Longitudinals: Where longitudinal system is adopted in the under-deck construction, web beams supporting deck longitudinal are to be provided in a spacing of about 2.4m. In this case, the section modulus thereof is to be in accordance with the requirement of 7.3.1.

7.4.5. Longitudinals of Decks Carrying Especially Heavy Loads: Longitudinals of decks which carry heavy loads such as deck machinery and others are to be properly strengthened as girders or web beams.

7.5. Hat-Type Construction

7.5.1. The scantlings of under-deck construction of hat-type are to be in accordance with the requirements in 1.2.4 of part I, in addition to those in this chapter.

7.6. Pillars

7.6.1. Pillars under concentrated Loads: Special supports, by providing pillars or by other suitable means, are to be arranged at the ends and corners of deckhouses, in machinery spaces, at the ends of partial superstructures and under heavy concentrated loads.

7.6.2. Sectional area of Pillars

a. The sectional area of pillars which are made of steel, is not to be less than the value obtained from the following formula:

$$A = \frac{2.14Sbh}{2.72 - \frac{l_0}{k_0}} \qquad cm^2$$

Where:

S	=	Distance between the mid-points of the spaces from the pillar to the adjacent pillars or to the bulkhead, in m. (See Fig. II 7-1)
b	=	Distance between the mid-points of the spaces from the pillar to the adjacent pillars or to the lower surface of girder or beam supported by the pillar, in m. (See Fig. II 7-1)
h	=	As specified in 7.3.1
l_0	=	Distance from the lower end of pillar to the lower surface of girder or beam supported by the pillar, in m.
k_0	=	$\frac{I}{A}$
I	=	Minimum moment of inertia of pillars, in cm^4
A	=	Sectional area of pillars, in cm^2

b. The sectional area of pillars which are made of aluminum alloys, is not to be less than the value obtained from the following formula:

$$A = \frac{1.89\,Sbh}{1.72 - \frac{l_0}{k_0}} \qquad cm^2$$

Where: S, b, h, l_0 and k_0: As specified in the preceding (a).

c. The sectional area of pillars which are made of wood, is not to be less than obtained from the following formula:

$$A = \frac{2.14\,Sbh}{1.51 - \dfrac{l_0}{k_0}} \qquad cm^2$$

Where: S, b, h, l_0 and k_0: As specified in the preceding (a).

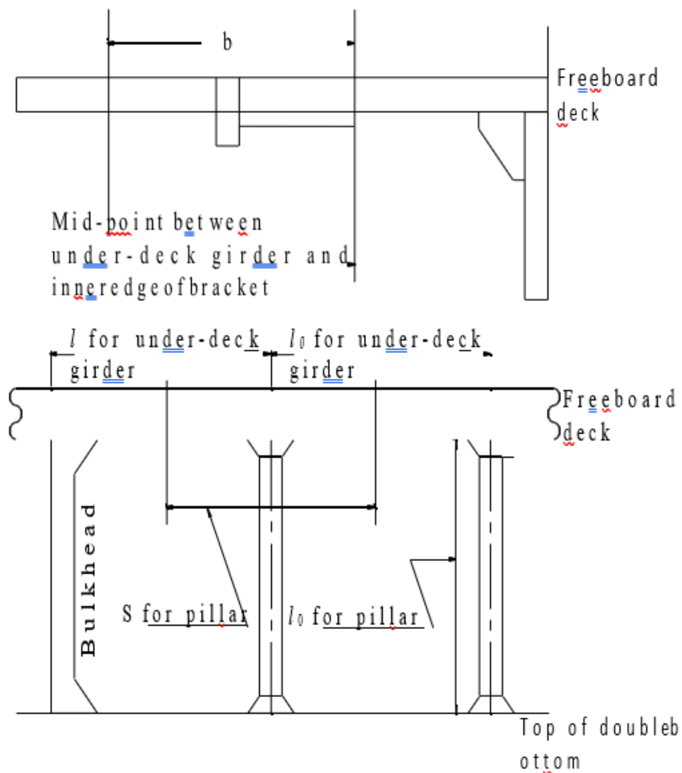


Fig. II 7-1

Measurement of b, *l*, S and l_0

CHAPTER VIII – WATERTIGHT BULKHEADS

8.1. Arrangements

8.1.1. Collision Bulkhead

a. FRP Ships are to be provided with a collision bulkhead at a position between 0.05L (m) and 1.35 + 0.05L (m) from the fore side of the stem on the load line. In ships having a collision bulkhead with step or recess, the measurement of the distance is to be subjected to approval by the Society.

b. Special consideration is to be taken to alternative arrangements for pleasure craft. Watertight doors or watertight openings may be installed in collision bulkhead of pleasure craft less than 24 m in length. These doors and openings are to be kept closed at all times while the vessel is at sea.

8.1.2. Aft Peak Bulkhead

a. All FRP ships are to be normally provided with aft peak bulkhead at a suitable position.

b. Stern tubes are to be provided in a watertight compartment by means of an aft peak bulkhead or any other suitable arrangements.

8.1.3. Bulkheads of Machinery Space: A watertight bulkhead is to be provided at each end of the machinery space. Aft peak bulkheads may be used as a bulkhead of machinery space.

8.1.4. Height of Watertight Bulkheads

The watertight bulkheads required in 8.1.1 to 8.1.3 are to extend at least to the upper deck except for those specified in the following:

a. The watertight bulkhead in way of the sunken poop or the sunken forecastle is to extend to the sunken poop deck or the sunken forecastle deck.

b. Where a forecastle having openings without closing appliances led to a space below the freeboard deck is provided or where a long forecastle not less than 0.25L in length is provided, the collision bulkhead is to extend up to the superstructure deck. In this case, the extend part may have steps within the limit of distance specified in 8.1.1(a) and may be made weathertight.

c. The aft peak bulkhead may terminate at the first deck above the load water line provided this deck as made watertight to the stern. However, the transverse strength of the hull are to be maintained by providing suitable structures extending up to the upper deck.

8.1.5. Chain Lockers

a. Chain lockers located abaft the collision bulkhead or in the fore peak tank are to be watertight and provided with means of drainage by proper means.

b. Chain lockers are to be subdivided by screen walls.

8.2. Construction of Watertight Bulkheads

8.2.1. Thickness of Bulkhead Laminates of Single Skin Construction

The thickness of bulkhead laminates of single skin construction is not to be less than the value obtained from the following formula:

$$t = 11.6S\sqrt{h} \quad \text{mm}$$

where:

S = Spacing of stiffeners, in m

h = Waterhead, in m; vertical distance from the lower edge of bulkhead laminate to the top of upper deck laminate at the center line of the ship. However, for the collision bulkhead, the value specified above is to be multiplied by 1.25.

8.2.2. Thickness of Bulkhead Laminates of Sandwich Construction

a. The aggregated thickness of the inner skin, outer skin and cores of bulkhead laminates of sandwich construction is not to be less than the value obtained from the following formula, whichever is greater:

$$t = C_1Sh \quad \text{mm; or}$$
$$t = C_2t_f \quad \text{mm}$$

where:

t_f = Thickness in case of single skin construction specified in 8.2.1, in mm

S = Spacing of stiffeners, in m

h = Waterhead; As specified in 8.2.1, in m

C_1 and C_2 = As specified in 3.3.3(a)

b. The respective thickness of the inner skin and outer skin of bulkhead laminated of sandwich construction are, notwithstanding the requirements in the preceding (a), not to be less than the value obtained from the following formula. In no case, however, is it to be less than 2.4 mm.

$$t = 73.5\sqrt[3]{C_4(Sh)^4} \quad \text{mm}$$

where:

S = Spacing of stiffeners, in m

h = As specified in 8.2.1, in m

C_4 = As specified in 3.3.3(b)

8.2.3. Bulkhead Laminates of Structural Plywood

Where structural plywoods are used for bulkhead plates, the thickness of plywood's is not to be less than specified by the requirements in 8.2.1 multiplied by the coefficient given in 1.2.2. However, σB is to be taken as bending strength, in N/mm^2, of plywoods.

8.2.4. Bulkhead Stiffeners

The section modulus of ordinary bulkhead stiffeners is not to be less than the value obtained from the following formula:

$$SM = CShl^2 \qquad cm^3$$

where:

S = Spacing of stiffeners, in m

h = Waterhead, in m; 0.8 times the vertical distance from the mid-point of l to the top of upper deck laminate at the center line of ship plus 1.2. However, for the collision bulkhead the above-mentioned value is to be multiplied by 1.25.

l = Span, in m; distance between the heels of the end attachments. Where horizontal stringers are provided, l is the distance from the heels of the end attachment to the first stringer, or the distance between the horizontal stringer.

C = Coefficient given below:

a. Where both ends of stiffeners are attached by brackets 19.4
b. Where the ends of stiffeners are snipped 29.1

8.2.5. Stringers and web supporting Bulkhead Stiffeners

Where stringers supporting bulkhead stiffeners are provided to connect to the bulkhead laminates, the section modulus of stringers is not to be less than the value obtained from the following formula:

$$SM = 33Shl^2 \qquad cm^3$$

where:

S = Sum of the half stringer space length on each side of the vertical stiffeners supported by the stringer, in m

h = Waterhead, in m; 0.8 times the vertical distance from the mid-point of S to the top of upper deck laminate at the center line of ship plus 1.2. However, for the collision bulkhead, the above-mentioned value is to be multiplied by 1.25.

l = unsupported span of stringer, in m

8.2.6. Hat-Type Construction: The scantlings of bulkhead stiffeners and stringers of hat-type construction are to be in accordance with the requirements in 1.2.4, in addition to those in this chapter.

CHAPTER IX – DEEP TANKS

9.1. General

9.1.1. Application

a. All watertight division, aft peak tank bulkhead and deep tanks excluding deep oil tanks for carriage of oils having a flashpoint below 60°Cis to be in accordance with the requirements specified in this chapter. The part concurrently serving as a watertight bulkhead is to be in accordance with the requirements for watertight bulkheads specified in chapter 8.

b. The construction of deep oil tanks for carriage of oils having a flashpoint below 60 ℃ is to be in accordance with the discretion of the Society.

9.1.2. Division Walls in Tanks

a. Deep tanks are to be of proper size and to be provided with longitudinal division walls to meet the necessity for stability under service conditions as well as during filling or discharging.

b. Fresh water tanks, fuel oil tanks and other deep tanks which are not intended to be kept entirely filled in service conditions are to be provided with additional division walls or deep wash plates as necessary as to minimize the sloshing loads acting on the structural members.

c. Where it is impracticable to be in accordance with the requirements in the preceding (b), the scantlings of structural members specified in this chapter are to be properly increased.

9.2. Bulkhead Laminates

9.2.1. Laminates of Single Skin Construction

The thickness of bulkheads laminates of single skin construction is not to be less than the value obtained from the following formula:

$$t = 12.4S\sqrt{h} \quad \text{mm}$$

Where:

S = Spacing of stiffeners, in m

h = Waterhead, in m; vertical distance measured from the lower edge of bulkhead laminate to top of overflowpipe

9.2.2. Laminates of Sandwich Construction

a. The aggregated thickness of the inner skin, outer skin, and core of the bulkhead laminates of sandwich construction is not to be less than the value obtained from the following formula, whichever is greater:

$$t = C_1Sh \quad \text{mm}$$
$$t = C_2t_f \quad \text{mm}$$

where:

t_f = Thickness in case of single skin construction specified in 9.2.1, in mm

S = Spacing of stiffeners, in m

h = Waterhead, in m; as specified in 9.2.1

C_1 and C_2 = As specified in 3.3.3(a)

b. The respective thicknesses of the inner skin and outer skin of bulkhead laminates of sandwich construction are, notwithstanding the requirements in the preceding (a), not to be less than the value obtained from the following formula. In no case, however, is it to be less than 2.4 mm.

$$t = 73.5\sqrt[3]{C_4(Sh)^4} \quad \text{mm}$$

where:

S = Spacing of stiffeners, in m

h = Waterhead, in m; as specified in 9.2.1

C_4 = As specified in 3.3.3(b)

9.2.3. Laminates of Structural Plywood

Where structural plywoods are used for bulkhead plates, the thickness of plywoods is not to be less than the value specified by the requirements in 9.2.1 multiplied by the coefficient given in 1.2.2. However, σB is to be taken as bending strength (N/mm²) of plywoods.

9.2.4. Bulkhead Stiffeners

The section modulus of bulkhead stiffeners is not to be less than the value obtained from the following formula:

$$SM = CSh l^2 \quad (cm^3)$$

Where:

S and *l* = As specified in 8.2.4.

h = Vertical distance measured from the mid-point of *l* to the top of overflow pipe, in m

C = Coefficient given below:

a. for both ends of stiffeners with brackets: 26.5
b. for both ends of stiffeners with snips: 40

9.2.5. Stringers Supporting Bulkhead Stiffeners

The section modulus of stringers supporting frames and bulkhead stiffeners is not to be less than the value of the following formula:

$$SM = 40Sh l^2 \quad cm^3$$

where:

S and *l* = As specified in 8.2.5

h = Waterhead, in m; vertical distance measured from the mid-point of S to the top of overflow pipe

9.2.6. Hat-Type Construction

The scantling of bulkhead stiffeners and stringers of hat-type construction are to be in accordance with the requirements in 1.2.4, in addition to those in this chapter.

9.2.7. Structural Members Forming Top and Bottom of Deep Tanks

The scantling of the structural members forming the top and the bottom of deep tanks are to be in accordance with the requirements specified in this chapter regarding the members as the bulkheads of deep tanks at the location. In no case, however, are they to be less than that requirement for the deck laminates in way as specified in chapter 4.

9.3. Additional Requirements

9.3.1. Drain and Air Holes

a. In deep tanks, suitable drain and air holes are to be provided in the members to ensure that liquid or air does not remain stagnated in any part of the tanks.

b. The treatment of drain holes and air holes as specified in 6.1.2 of this Part is also applicable to this chapter.

9.3.2. Access and Covers

a. All tanks are to have access holes, and the non-tight members in such tanks are to have lightening holes, sufficient in size and number to assure accessibility to all parts of the tanks.

b. Tank access covers are to be metal or FRP, and secured to the tanks. The diameter of bolts or studs (d) are to be not less than 6.5 mm, their spacing, center to center, is to be not more than 6d, and they are to be set in from the edges of the covers a distance not less than 3d for FRP cover or 2d for steel cover. In cargo holds if no ceiling provided, the covers are to be protected against damage caused by the cargo.

9.3.3. Cofferdams

a. Cofferdams are to be provided between oil tanks and freshwater tanks need for and those for carrying living water, boiler feed water, etc., which may cause trouble if oil was mixed therein.

b. Crew spaces and passenger spaces are not to be directly adjacent to the tanks for carriage of fuel oil. Such spaces are to be separated from the fuel oil tanks by cofferdams which are well ventilated and accessible. Where the top of fuel oil tanks has no opening and is applied with non-combustible coverings of not less than 38 mm in thickness, the cofferdam between such spaces and the top of fuel oil tanks may be omitted.

9.3.4. Sparring or Lining

a. Sparring or lining is to be provided on the hold side of bulkhead dividing deep oil tanks from cargo holds, leaving suitable clearance between the bulkhead and the sparring or lining. Gutterways are to be provided along the bulkhead.

b. Where the oil tank boundaries are bonded by T-connections in way of the parts required oiltight, the sparring or lining specified in preceding (a) may be omitted, except where specially required.

CHAPTER X – MACHINERY SPACES

10.1. General

10.1.1. Application

The construction of machinery spaces is to be in accordance with the requirements in the relevant chapter, in addition to those specified in this chapter.

10.1.2. Strengthening

Machinery spaces are to be provided with web frames, web beams, strong girder, strong floor, widely spaced pillars, etc. or to be reinforced by any other suitable means.

10.1.3. Supporting Structures

Machinery, shaftings, etc. are to be effectively supported and the adjacent structures are to be properly strengthened.

10.1.4. Means of Escape

In main engine room, at least one set of means of escape which is composed of a door installed up to the machinery casing and steel ladders leading to the door is to be provided.

10.1.5. Fire Protection

In machinery space, flame retardation and flame resistance resins are to be provided at least for the last lamination or coatings of the same characteristic are to be applied on all surfaces exposed to machinery spaces with major fire hazard.

10.2. Construction under Main Engines

10.2.1. Girders of ample scantlings upon which main engines are installed are to be of sufficient length as to the engine foundations, and care is to be taken to avoid any abrupt changes or discontinuities.

10.2.2. Girders are to be effectively supported by floors and brackets in order to maintain sufficient lateral strength and rigidity.

10.2.3. Where engines which have large unbalanced inertia force or large unbalanced moment of inertia are existed, the strength and rigidity of the girders supporting such engines are to be specially considered.

10.2.4. Fixing bolts for main engines are to have adequate shank length to lower their rigidity and effective means to prevent from loosening.

10.2.5. Where engines which are subjected to large exciting force due to piston side thrust are installed, the connections of girders with floors and brackets are to be made rigid, and resonance is to be avoided against the vibration in the horizontal direction.

10.2.6. Webs of girders may be constructed with timbers interposed between FRP in order to increase the rigidity against compression or bending. In this case, the connections of FRP with timbers and of timbers with bottom shell laminates are to be effectively bonded.

10.2.7. The bonded connections of girders with bottom shell laminates, floors, and brackets, as well as their mutual connections are to be T-type joints using ample woven rovings and the width of joints is to be sufficient. In this case, the direction of woven roving fibers is not, as a rule, to be oblique to the connecting line.

10.3. Auxiliary Machinery Foundations

Foundations for auxiliary machinery such as generator, steering gear … etc., are to be rigidly attached to the hull construction.

CHAPTER XI – SUPERSTRUCTURES AND DECKHOUSES

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11.1. General

11.1.1. For FRP Ships with especially large freeboard, the requirements specified in this chapter may be properly modified, subject to the approval by the Society.

11.1.2. Bulkheads, walls, or web frames are to be fitted over the hull main structures to get effective rigidity of the structure.

11.2. Construction

11.2.1. Scantlings of Bulkheads and Walls

The thickness of plates and the section modulus of stiffeners of superstructure end bulkheads and the value obtained from the following formula:

$$t = 12.4S\sqrt{h} \quad \text{mm}$$

$$SM = 20.2Sh l^2 \quad \text{cm}^3$$

Where:

S = Spacing of stiffeners, in m
h = As specified in 11.2.2, in m
l = Span of support, in m

11.2.2. Load Acting on Bulkheads and Walls

For superstructure bulkheads and walls, the load h is to be specified as follows:

a. For superstructure front plating and stiffeners afore 0.3L from the fore end:

$$h = 0.027L + 0.76 \quad \text{m}$$

b. For superstructure front plating and stiffeners abaft 0.3L from the fore end:

$$h = 0.027L + 0.46 \quad \text{m}$$

c. For superstructure aft end and side plating/ and stiffeners:

$$h = 0.017L + 0.32 \quad m$$

11.2.3. Closing Means for Access Openings and Sill Height

a. The doors provided on the access openings in the end bulkheads of enclosed superstructures and those in the deckhouses protecting companionways giving access to the spaces under the freeboard deck or the spaces in the enclosed superstructures are to be in accordance with the requirements specified in the following:
   i. The doors are to be permanently and rigidly fitted up to the walls
   ii. The doors are to be rigidly constructed, to be of equivalent strength to that of intact wall and to be weathertight when closed
   iii. The means for securing weathertightness are to be consist of gaskets and clamping devices or other equivalent devices and to be permanently fitted up to the wall or the door itself
   iv. The doors are to be capable of operating from the both sides of the wall
   v. Hinged doors are, as a rule, to open outward.
b. The height of sills of access openings specified in the preceding (a) is to be at least 380 mm above the upper surface of the deck. The sill heights in limited-service vessels are to be subjected to special consideration.

11.2.4. Scantling of Superstructure Decks

The scantling of superstructure deck is specified in chapter 4 of this Part.

11.3. Windows

11.3.1. General

Structures and fastening types for all external windows of superstructure and deckhouse are to ensure weathertightness. The windows in passenger cabins and the front windows are to be of toughened safety glass or polycarbonate glass.

11.3.2. Thickness

The thickness of glass is not to be less than:

$$t = 3.17b\sqrt{\frac{f \cdot h}{\sigma_{max}}} \quad mm$$

Where:

b	=	Breadth of window opening, in mm
h	=	Pressure head (m) according to 11.2.2 for windows in way of superstructures and deckhouses or not lessthan (d + 0.026L) for windows in way of side shell plating below the freeboard deck
σ_{max}	=	147 N/mm², Maximum breaking stress of toughened glass
σ_{max}	=	98 N/mm², Maximum breaking stress of polycarbonate glass

f = Form factor taken from table II 11-1

The minimum value of t is given as follows:

t_{min} = 5.0 mm for toughened glass

t_{min} = 6.0 mm for polycarbonate glass

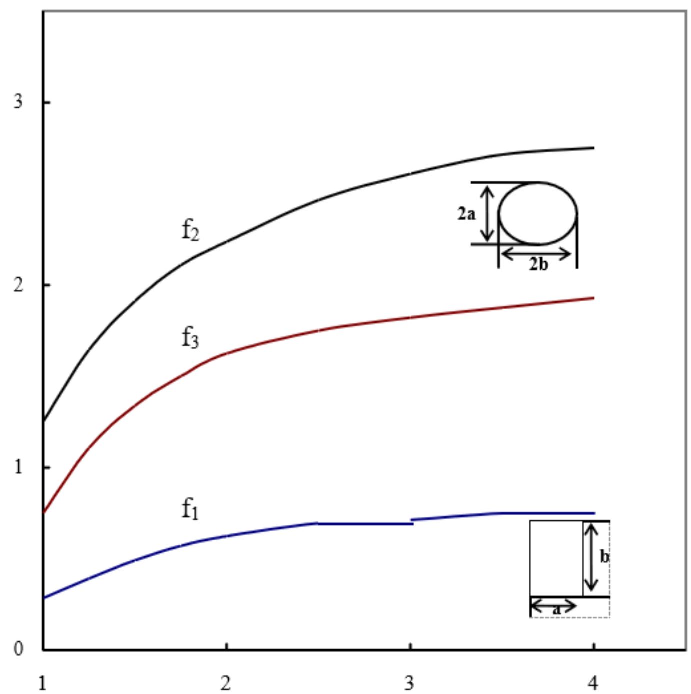

Fig. II 11-1

Aspect Ratio: Larger Dimension/Smaller Dimension = b/a

Table II 11-1

Kind of window	Window shape	Form factor (f)
Watertight	Rectangle	$f = f_1$, where aspect ratio is less than 1.5, or $f = 1.25f_1$, where aspect ratio is 1.5 and over, meanwhile f_1 given in Fig. II 11-1 based on aspect ratios.
	Circle	1.24
	Ellipse	$f = f_2$ given in Fig. II 11-1 based on aspect ratios.
Weathertight	Rectangle	$f = f_1$ given in Fig. II 11-1 based on aspect ratios.
	Circle	0.75
	Ellipse	$f = f_3$ given in Fig. II 11-1 based on aspect ratios.

11.3.3. Deadlight

Side scuttles to the spaces below the free board deck are to be fitted with efficient hinged inside deadlights so arranged that they can be effectively closed and secured watertight.

CHAPTER XII – HATCHWAY OPENINGS, MACHINERY OPENINGS AND OTHER DECK OPENINGS

12.1. General

12.1.1. All openings on decks are to be reinforced as necessary to provide efficient support and attachment to the ends of the deck structures.

12.1.2. For ships applying to the International Convention on Load Lines, the arrangements and constructions of deck openings are to comply with the requirements of the conventions.

12.1.3. Where the ships engaged only in restricted area or domestic area comply with the relevant requirements of the ship's Administration, the relevant requirements of the ship's Administration may be deemed as substitute for the requirements specified in this chapter at the discretion of the Society.

12.2. Hatchway Openings

12.2.1. Height of Hatch Coamings

a. The height of hatch coamings above the upper deck laminates is not to be less than the value specified as follows:

   i. For L ≥ 24 m, non-fishing vessels
      600 mm position 1; 450 mm position 2

   ii. For L ≥ 24 m, fishing vessel
      600 mm position 1; 300 mm position 2

   iii. For L < 24 m, non-fishing vessels
      450 mm position 1; 300 mm position 2

   iv. For L < 24 m, fishing vessels
      300 position 1; 300 mm position 2

Where position 1 and position 2 as defined in International Convention on Load Lines.

b. With respect to hatchway openings which are maintained weathertight by means of gaskets and clamping devices and closed with substantial weathertight covers, the height of hatch coamings may be reduced from the value required in the preceding (a) subject to the approval by the Society.

12.2.2. Hatch Covers

a. Covers are to be constructed in accordance with the requirements given in Table II 12-1 & Table II 12-2.
b. Materials for wooden covers are to be of good quality, straight grained and reasonably free from knots, sapwood, and shakes.
c. The ends of wooden covers are to be protected by circling steel bands.
d. Hatch rests are to be provided with at least 65 mm bearing surface and are to be bevelled, if required, to suit the slope of the hatchways.

Table II 12-1
Thickness of Hatch Covers

Material	Minimum Thickness	Remark
Wood	$32S\sqrt{h}$	but not less than 48 mm
FRP	$16S\sqrt{h}$	-
Al Alloy	$11S\sqrt{h}$	-
Steel	$5.5S\sqrt{h} + 1.0$	but not less than 4.5 mm
Where: S = Spacing of portable beam, in m (wood) Spacing of stiffeners, in m (other material) h = As given in 12.2.3, in m		

Table II 12-2
Section Modulus of Stiffeners for Hatch Covers

Material	Min. Section Modulus (cm^3)
FRP	$23.4\ Shl^2$
Al Alloy	$13.3\ Shl^2$
Steel	$9.4\ Shl^2$
Where: S = Spacing of stiffeners, in m h = As given in 12.2.3, in m l = Span of supports, in m	

12.2.3. Load acting on Hatch Covers

For hatch covers, the load h is to be specified as follows.

a. Position 1

$h = 0.010L + 0.76$ m

b. Position 2

$h = 0.008L + 0.58$ m

c. Cover intended to carrying cargo

h = Cargo load head, in m, or (a)/(b), whichever is greater.

12.2.4. Tarpaulins and Securing Arrangements for Hatchways closed by Portable Covers

a. At least two layers of tarpaulin are to be provided for each exposed hatchway on the freeboard or superstructure decks and at least one layer of such tarpaulin is to be provided for each exposed hatchway elsewhere.
b. Battens are to be efficient for securing the tarpaulins and not to be less than 65 mm in width and 9 mm in thickness.
c. Wedges are to be of tough wood or other equivalent materials. They are to have a taper of not more than 1 in 6 and not to be less than 13 mm in thickness at the point.
d. Cleats are to be set to fit the taper of the wedges. They are to be at least 65 mm wide and to be spaced not more than 600 mm from center to center; the cleats along each side or end are to be arranged not more than 150 mm apart from the hatch corners.
e. For all hatchways in the exposed freeboard and superstructure decks, steel bands or other equivalent means are to be provided in order to efficiently secure each section of hatchway covers after the tarpaulins are battened down. Hatchway covers of more than 1.5 m in length are to be secured by at least two such securing appliances. At all other hatchways in exposed positions on weather decks, ring bolts or other fittings for lashing are to be provided

12.3. Machinery Openings

12.3.1. Protection of Machinery Openings

Machinery openings are to be as small as possible, and to be enclosed by casings.

12.3.2. Casings of Machinery Openings in Exposed Parts

a. Exposed machinery openings on the upper decks and superstructure decks are to be in accordance with the requirements in the following:
   i. The thickness of casings and the section modulus of stiffeners thereupon, are to be equivalent to those of boundary walls of superstructures specified in 11.2.1.
   ii. The thickness of top laminates of casings and the section modulus of stiffeners thereupon, are not to be less than 4.0 mm and 24 cm3 respectively.
b. The height of casings is, except special cases, not to be less than that of bulwark.
c. Where access openings are provided on the exposed machinery casings, these openings are to be located in protected spaces as far as practicable, the doors thereof are to be in accordance with the requirements 11.2.3(a) and the height of sills above the upper surface above of deck laminates is to be in accordance with the requirements in 11.2.3(b).

12.3.3. Position of Fittings

Skylights provided on the top laminates of machinery casings are to be of substantial construction and coamings of funnels and ventilators are to be provided as high as possible above the weather deck laminates.

12.4. Other Openings

12.4.1. Manholes and Flush Deck Openings

Manholes and flush deck openings which are provided in exposed parts of freeboard deck and superstructure decks or in the superstructures other than those enclosed, are to be closed with substantial covers capable of keeping watertightness.

12.4.2. Companionways

a. Companionways on the freeboard deck are to be protected by enclosed superstructures or by deckhouses or companions which have strength and weathertightness equivalent to those of enclosed superstructures.
b. Companionways on exposed superstructure decks and those on the top of deckhouses which give access to spaces below the freeboard deck or spaces within enclosed superstructures, are to be protected by effective deckhouses or companions.
c. Access openings in the deckhouses or companions specified in the preceding (a) and (b) are to be provided with doors in accordance with the requirements in 11.2.3(a). And the height of sills of the access openings above the surface of deck laminates is to be in accordance with the requirements in 11.2.3(b).

12.4.3. Openings to Cargo Spaces

All of access and other openings to cargo spaces are to be provided with weathertight closing means capable of being operated from outside the spaces in case of fire.

PART III – EQUIPMENT AND FITTINGS

CHAPTER I – BULWARKS, GUARDRAILS, FREEING ARRANGEMENTS, AND GANGWAYS

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1.1. Bulwarks and Guardrails

1.1.1. General

Efficient guardrails or bulwarks are to be provided on all exposed parts of the freeboard and superstructure decks or the top of similar deckhouses.

1.1.2. Dimensions

a. The height of bulwarks or guardrails specified in 1.1.1 is to be at least one meter from the upper surface of deck, provided that where this height would interfere with the normal operation of the ship, a less height may be permitted where adequate protection is provided.

b. The clearance below the lowest course of guardrails in (a) is not to exceed 230 mm. The clearance between other courses is not to exceed 380 mm.

1.1.3. Construction

a. Bulwarks are to be strongly constructed according to their height and effectively stiffened on their upper edges. The laminated thickness of bulwarks on the freeboard deck is generally to be at least 80% of the side shell laminate.

b. Bulwarks are to be supported by stays connected to the deck in way of the beams or at effectively stiffened positions. The spacing of these stays on the freeboard deck is not to be more than 1.8 meters.

1.1.4. Miscellaneous

a. Gangways and other openings in bulwarks are to be keep well clear of the ends of superstructures.

b. Where bulwarks are cut to form gangways or other openings, stays of increased strength are to be provided at the ends of the openings.

c. The plating of bulwarks in way of mooring pipes is to be increased in lamination.

d. At ends of superstructures, the bulwark rails are to be bracketed either to the superstructure end bulkheads or to the stringer plates of the superstructure decks, or other equivalent arrangements are to be made so that the abrupt change in strength can be avoided.

1.2. Freeing Arrangements

1.2.1. General

a. Where bulwarks on the weather parts of freeboard or superstructure deck form wells, ample provision is to Chapter 2 Materials be made for rapidly freeing the water of decks, and for draining them.

b. Ample freeing ports are to be provided for draining water from any space other than wells, where lots of water is liable to remain.

c. In ships having superstructures which are open at either or both ends, adequate provision for freeing the space within such superstructures is to be provided.

d. In ships having a reduced freeboard, guardrails are to be provided for at least a half of the length of the exposed parts of the weather deck or other effective freeing arrangements are to be considered, as required by the Society.

1.2.2. Freeing Port Area

a. The area of the freeing port specified in 1.2.1(a) on each side of the ship for each well on the freeboard deck is not to be less than the value obtained by the following formulae. The area for each well on superstructure decks is not to be less than one-half of that obtained by the formula:

i. Where *l* is not more than 20 meters:

$$A = 0.7 + 0.035l + a \quad m^2$$

ii. Where *l* is more than 20 meters:

$$A = 0.07\,l + a \quad m^2$$

Where:

l = length of bulwark in way of the well, in m, but if the length is 0.7L or more, it is taken as 0.7L

a = as obtained by the following formula:

where h is more than 1.2 meters:

$$0.04\,l\,(h - 1.2) \quad m^2$$

where h is not more than 1.2 meters, but not less than 0.9 meters:

$$0 \quad m^2$$

where h is less than 0.9 meters:

$$-0.04\,l\,(0.9 - h) \quad m^2$$

h = average height of bulwarks above the deck, in m.

b. In ships either without sheer or with less sheer than the standard, the minimum freeing port area obtained by the formula in (a) is to be increased by multiplying the factor obtained from the following formula:

$$f = 1.5 - \frac{S}{2S_0}$$

Where:

S = average of actual sheer, in mm

S_0 = average of the standard sheer given by the International Convention on Load Lines, 1966, in mm.

c. Where a ship is provided with a trunk or a hatch side coaming which is continuous or substantially continuous between detached superstructures, the area of freeing port is not to be less than the value given in Table III 1-1.

Table III 1-1
Area of Freeing Ports

Breadth of hatchway or trunk (m)	Area of freeing ports in relation to the total area of bulwark
$0.4B_f$ or less	0.2
$0.75B_f$ or more	0.1

Note: The area of freeing ports where the breadth of trunk or hatchway assumes an intermediate value given in thetable is to be obtained by linear interpolation.

d. Notwithstanding the requirements in preceding (a) to (c), in ships having trunks on the freeboard deck, guardrails are to be provided for more than half of the length of trunk instead of bulwarks on both sides of the freeboard deck in way of trunks.

1.2.3. Arrangement of Freeing Ports

a. Two-thirds of the freeing port area required by 1.2.2 is to be provided for the half of the well near the lowest point of the sheer curve, and the remaining one-third is to be evenly spread along the remaining length of the wall.

b. The freeing ports are to have well rounded corners and their lower edges are to be as near the deck as practicable.

1.2.4. Construction of Freeing Ports

a. Where both the length and the height of freeing ports exceed 230 mm respectively, freeing ports are to be protected by rails spaced approximately 230 mm apart.

b. Where shutters are provided on freeing ports, ample clearance is to be provided to prevent jamming. Hinge pins or bearings of the shutters are to be of non-corrodible materials.

c. Where the shutters referred to in preceding (b) are not to be provided with securing appliances.

1.3. Ventilators

1.3.1. Height of Ventilator Coamings

The height of ventilator coamings above the upper surface of the deck is to be at least 900 mm in Position I and 760 mm in Position II. However, where the ship has an unusually large freeboard or where the ventilator serves spaces within unenclosed superstructures, the height of ventilator coamings may be suitably reduced.

1.3.2. Thickness of Ventilator Coamings

a. The thickness of ventilator coamings in Positions 1 and 2 leading to spaces below the freeboard deck or within enclosed superstructures is not to be less than the value given by Line 1 in Table III 1 -2. Where the height of coamings is reduced by the provisions in 1.3.1, the thickness may be suitably modified.

b. Where ventilators pass through superstructures other than enclosed superstructures, the thickness of ventilator coamings in the superstructures is not to be less than the value given by Line 2 in Table III 1 -2.

Table III 1-2

Thickness of Ventilator Coamings

Inside diameter of ventilator d(mm)		d < 70	70 ≤ d < 100	100 ≤ d < 130	130 ≤ d < 160	160 ≤ d < 190	190 ≤ d
Thickness of coaming - FRP laminate plate (mm)	Line 1	12.2	13.7	15.4	15.4	15.4	15.4
	Line 2	8.7	8.7	8.7	8.7	10.4	12.2

1.3.3. Connection

Ventilator coamings are to be efficiently connected to the deck and, where their height exceeds 900 mm, are to be specially supported.

1.3.4. Cowls

Ventilator cowls are to be fitted up closely to the coamings and are to have housing not less than 380 mm, except that a less housing may be permitted for ventilators not greater than 200 mm in diameter.

1.3.5. Closing Appliances

a. Ventilators for machinery and cargo spaces are to be provided with means for closing means capable of being operated from outside the spaces in case of a fire.

b. All ventilator openings in exposed positions on the freeboard and superstructure decks are to be provided with efficient weathertight closing appliances. However, where the height of their coaming exceeds 4.5 m above the freeboard and above the superstructure deck for 0.25L forward or 2.3 m above the other superstructure decks, such closing appliances may be omitted except those required in preceding (a).

1.3.6. Ventilators for Deckhouses

The ventilators for the deckhouses which protect the companionways leading to the spaces below the freeboard deck are to be equivalent to those for the enclosed superstructures.

1.4. Gangways

1.4.1. General

Satisfactory means e.g., guardrails, lifelines, gangways or under deck passages are to be provided for the protection of the crew in getting to and from their quarters, the machinery space and all other parts used in the necessary work of the ship.

1.4.2. Construction of Gangways

The permanent gangways are to be, in general, at least 600 mm wide and to be provided with guardrails which are at least one-meter-high complying with the requirements in 1.1.2(b) on their both sides.

1.5. Vessels not Applying to Load Line Conventions

For ships not applying to load line convention, the requirements of bulwarks, guardrails, freeing arrangements, ventilators, and gangways specified in 1.1 to 1.4 are to be in accordance with the discretion of the Society.

CHAPTER II – RUDDERS AND SHAFT STRUTS

2.1. Rudders

2.1.1. Applications

The following requirements generally apply to the rudder constructed as a double-plated streamline section of ordinary shape and single plate, as well as not more than two pintles, designed with a moving angle not more than 35° on each side without any special arrangement for increasing the rudder force, such as fins, flaps steering propellers, etc. Rudders not confirming with the ordinary types are to be approved under special consideration by the Society.

2.1.2. Materials

a. Rudder stocks, pintles, flanges, coupling bolts, keys and cast parts of rudder are to made of rolled, forged steel or cast carbon manganese steel confirming to the requirements of Part XI of the Steel Ship Rules.

b. Welded part of rudders are to be made of approval rolled hull materials.

c. Required scantlings may be reduced with consideration of the material factor K as specified in 1.5.2(c) of Part II of the Steel Ship Rules when higher tensile material are used.

d. Before significant reductions in rudder stock diameter due to the application of higher tensile steels are granted, the evaluation of the large rudder stock deformations is to be submitted for consideration in order to avoid excessive edge pressure in way of bearings.

2.1.3. Arrangements

a. Effective means are to be provided for preventing the rudder from jumping and for supporting the weight of the rudder without excessive bearing pressure. They are to be arranged to prevent accidental unshipping or undue movement of the rudder which may cause damage to the steering gear.

b. A sealing devices or stuffing box is to be fitted to prevent water from entering the steering gear spaces and the lubricant from being washed away the rudder carrier.

2.1.4. Rudder force

The rudder force upon which the rudder scantlings are to be based is to be determined from the following formula:

$$F = 145K_1K_2AV^2$$

Where:

F = Rudder force, in N

A = Area of rudder blade, in m^2

V = Maximum service speed of ship, in knots, with the ship on designed load line, when the service speed ³ 10 knots

= $\frac{1}{3}$ (V + 20), where the service speed < 10 knots

K_1 = Factor depending on the aspect ratio ƛ of the rudder area

= $\frac{1}{3}(ƛ + 2)$

ƛ = $\frac{h^2}{A_t}$

≤ 2

h = mean height of ruder area, in m, as shown in Fig. III 2-1

A_t = Sum of rudder blade area A and area of rudder post or rudder horn, if any, within the mean height h, in m^2

K_2 = 0.8 for rudders outside the propeller jet

= 1.15 for rudder behind a fixed propeller nozzle

= 1.0 otherwise

2.1.5. Rudder Torque

The rudder torque is to be calculated for both the ahead and astern condition from the following formula:

$$Q = Fr \quad Nm$$

Where:

Q = Rudder torque, in Nm

r = b(0.33-k), in m

≥ 0.1b

b = Mean breadth of rudder area, in m, see Fig. III 2-1

k = Balance factor

= $\frac{A_f}{A}$

A_f = Portion of the rudder blade area situated ahead of the center line of the rudder stock

A = Area of rudder blade, in m^2

2.1.6. Rudder strength calculation

a. The rudder strength is to be sufficient against the rudder force and rudder torque as given in 2.1.4 and 2.1.5. When the scantling of each part of a rudder is determined the following moments and forces are to be considered:

i. For rudder body:

bending moments and shear forces

ii. For rudder stock:

bending moments and torque

iii. For pintle bearing and rudder stock bearing:

supporting force.

b. The bending moments, shear forces and supporting forces to be considered are to be determined by a direct calculation or by an approximate simplified method as deemed appropriate by the Society.

2.1.7. Rudder Stock

a. The rudder stock diameter for the transmission of the rudder torque is not to be less than the value obtained from the following formula:

$$d_u = 4.2 \sqrt[3]{QK} \quad \text{mm}$$

Where:

d_u = Diameter of upper rudder stock in way of the tiller
K = Defined in 2.1.2 (c)

b. The diameter of the lower stock subjected to combined forces of torque and bending moment is to be determined such that the equivalent stress in the rudder stock does not exceed:

$$\frac{118}{K} \ (\text{N/mm}^2)$$

The equivalent stress is to be determined by the formula:

$$\sigma_c = \sqrt{\sigma_b^{\,2} + 3\tau_t^{\,2}} \quad \text{N/mm}^2$$

Bending stress $\sigma_b = 10.2 \dfrac{M}{d_l^{\,3}}$ N/mm²

Torsional stress $\tau_t = 5.1 \dfrac{Q}{d_l^{\,3}}$ N/mm²

Where:

M = Bending moment, in Nm, at the section of the rudder stock considered.
Q = As specified in 2.1.5 above.
dl = Lower stock diameter, in mm
Therefore, the lower stock diameter is not to be less than that obtained from the following formula

$$d_l = d_u \sqrt[6]{1 + \frac{4}{3}\left(\frac{M}{Q}\right)^2} \quad \text{mm}$$

d_u = Upper rudder stock diameter, in mm, as given in (a) above.

2.1.8. Rudder Plates, Ridder Webs, and Rudder Main Pieces

a. The thickness of the rudder side, top and bottom plating made of ordinary hull structural steel is not to be less than the value obtained from the following formula:

$$t = 5.5 s \beta \sqrt{d_f + \frac{F 10^{-4}}{A}} + 2.5 \quad \text{mm}$$

Where:

d_f = Designed load line draught of the ship (m)
F = Rudder force (N)
A = Rudder area (m^2)

$$\beta = \sqrt{1.1 - 0.5\left(\frac{s}{b}\right)^2} \quad \text{Max. 1.00 for } \frac{b}{s} \geq 2.5$$

s = Smallest unsupported width of plating, in m

b = Greatest unsupported width of plating, in m

b. The plating is to be suitable stiffened by vertical and horizontal webs. The thickness of web plates is not to be less than 70% of the rudder side plating, however, not less than 8 mm. For higher tensile steels the material factor according to 2.1.2(c) is to be adopted.

c. Mainpiece

i. The thickness of the plating of the rudder with plate frames may require to be increased in way of vertical webs which replace the mainpiece.
ii. Horizontal webs and vertical webs not replacing the mainpiece are to have the same thickness as the rudder plating, but plates forming the top and the bottom of the rudder are to be of increased thickness.
iii. Vertical webs replacing the mainpiece may be required to be increased in thickness.

iv. The spacing of vertical webs are generally not to be larger than 1.5 times the horizontal web spacing.

2.1.9. Single plate rudder

a. The mainpiece diameter is to be calculated according to 2.1.8, for space rudders the lower third may taper down 0.75 times stick diameter.

b. The blade thickness, t_b is not to be less than the value obtained from the following formula:

$$t_b = 1.5\, s\, V + 2.5 \quad \text{mm}$$

where:

s = Spacing of stiffening arms, in m, not to exceed 1 m.
V = Speed, in knots, as specified in 2.1.4.

c. The thickness of the arms, t_a, is not to be less than the blade thickness, t_b

$$t_a \geq t_b$$

d. The section modulus, Z, is not to be less than the value obtained from the following formula:

$$Z = 0.5\, s\, x^2 V^2 \quad \text{cm}^3$$

Where:
s = Spacing of stiffening arms, in m, not to exceed 1 m
V= Speed, in knots, as specified in 2.1.4
x = Horizontal distance from the aft edge of the rudder to the centreline of the rudder stock, in m

e. For higher tensile steels the material factor is to be adopted according to 2.1.2(c).

2.1.10. Horizontal rudder stock couplings

a. Coupling bolts are to be reamer bolts. The diameter of the coupling bolts is not to be less than the value obtained from the following formula:

$$d_b = 0.62 \sqrt{\frac{d^3 K_b}{n e K_s}} \quad \text{mm}$$

where:

d	=	Stock diameter, in mm, the greater of the d_u or d_l as specified in 2.1.7
n	=	Total number of bolts
	≥	6
e	=	Mean distance of the bolt axis from the center of the bolt system
K_b	=	Material factor for the bolt as specified in 2.1.2 (c)
K_s	=	Material factor for the stock as specified in 2.1.2 (c)

b. The thickness of the coupling flanges is not to be less than the value obtained from the following formula

$$t_f = d_b \sqrt{\frac{K_f}{K_b}} \quad \text{mm}$$

where:

t_f = Thickness of coupling flanges, in mm
≥ 0.9 d_b
d_b = Bolt diameter (mm) for a number of bolts not exceeding 8
K_b = Material factor for the bolt as specified in 2.1.2 (c)
K_f = Material factor for the flange as specified in 2.1.2 (c)

c. The width of material outside the bolts holes is not to be less than 0.67 d_b

2.1.11. Pintles

a. Pintles are to have a conical attachment to the gudgeon with a taper on diameter of:

i. 1:8 to 1:12
For keyed and other manually assembled pintles applying locking by slugging nut.

ii. 1:12 to 1:20
For pintles mounted with oil injection and hydraulic nut.

b. The length of the pintle housing in the gudgeon is not to be less than the minimum pintle diameter:

$$d_p = 0.35\sqrt{F_b K_p}$$

Where:

F_b = The relevant bearing force, in N
= 0.5 F for bottom pintles
F = Rudder force (N) as specified in 2.1.4(a)
K_p = Material factor for the pintle as specified in 2.1.2(c)

2.1.12. Rudder stock bearings and pintle bearings

a. The bearing surface, Ab, defined as the projected area: length x outside diameter of sleeve, is not to be less than the value obtained from the following formula:

$$A_b = \frac{F_b}{q_a} \quad \text{mm}^2$$

Where:

Fb = Reaction force, in N, as specified in 2.1.11

qa = Allowable surface pressure as listed in Table III 2-1

b. An adequate lubrication is to be ensured.
c. The length/diameter ratio of the bearing surface is not to be greater than 1.2.
d. Metal bearings clearances are not to be less than $\frac{d_b}{1000}$ +1.0 mm on the diameter. Where db: Inter diameter of bush, in mm. If nonmetallic bearing material is applied, the bearing clearance is to be specially determined considering the materials swelling and thermal expansion properties. This clearance in no way is to be taken less than 1.5 mm on bearing diameter.

Table III 2-1

Allowable Surface Pressure, q_a

Bearing material	q_a (N/mm²)
Lignum-vitae	2.5
White metal, oil lubricated	4.5
Synthetic material with hardness between 60 and 70 Shore D (Note 1)	5.5
Steel (Note 2) and bronze and hot-pressed bronze- graphite materials	7.0

Notes:

1. Indentation hardness test at 23°C and 50% moisture, according to a recognized standard. Synthetic bearing materials to be of approved type.
2. Stainless and wear-resistant steel in an approved combination with stock liner. Higher values than given in the Table may be taken if they are verified by tests.

2.2. Shaft Struts

2.2.1. General

Shaft struts may be of V or I type. The thickness of the strut barrel or boss is to be at least one-fifth the required diameter of the tail shaft. Special consideration will be given to the use of materials other than steel or aluminum. The following equations are for struts having streamline cross-sectional shapes. Other methods of determining scantlings may be considered.

2.2.2. Width and thickness

The thickness and width of each strut area is to be not less than those obtained from the following formula:

a. V strut $t = 0.365d$ $w = 2.27d$
b. I strut $t = 0.515d$ $w = 3.22d$

Where:

t = thickness of strut (minor axis)
w = width of strut (major axis)
d = required diameter of forging steel tail shaft, in mm
where the included angle of V strut is less than 45°, the sizes in above may be specially considered.

2.2.3. Strut Length

The length of the longer leg of a V strut or the leg of an I strut, measured from the outside of the strut barrel or boss to the outside of the shell plating, is not to exceed 10.6 times the required diameter of the tail shaft. Where this length is exceeded, the width and thickness of the strut are to be increased, and the strut design may be given a special consideration.

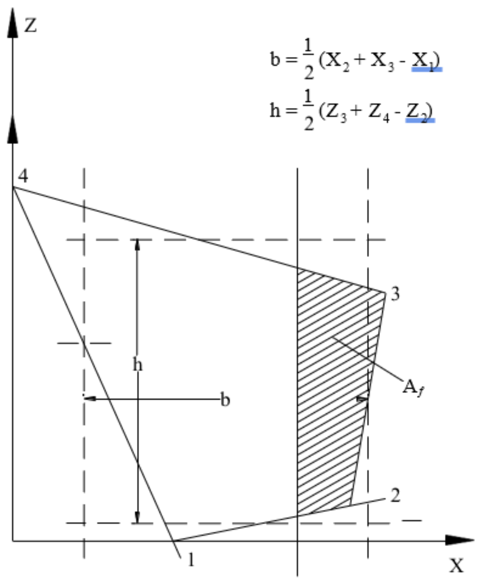

Fig. III 2-1
Rudder Blade without Cutout

CHAPTER III – EQUIPMENT

3.1. General

3.1.1. If a ship is provided with a complete equipment of the anchor, the chain, and the mooring rope in accordance with the requirements specified in chapter 25 Part II of the Steel Ship Rules, the letter E will be placed after the symbol of classification of Hull.

3.1.2. In the case of ships classed for a special or restricted service, if approved by the Society that requirements of the Rules are not necessary to apply, no equipment symbol is to be affixed.

3.1.3. The number and mass of anchors and the length and the size of the chain, and the mooring rope for a classed ship are to be determined from Table II 25-1 of Part II of the Steel Ship Rules.

3.1.4. If an ordinary stocked or stockless type of anchor was adopted, the relevant requirements specified in chapter 25 of Part II of the Steel Ship Rules are to be complied with.

3.1.5. The equipment for fishing ships may be based on the "Equipment Number" which is less than 10% the value determined as mentioned above.

3.1.6. For ships to be classed for Protected Waters Service, equipment numeral in Table II 25-1 of Part II of the Steel Ship Rules may be degraded one rank.

3.1.7. For ships to be classed for Coastal Service, the mass of one of the two anchors may be reduced 15% of the mass required in Table II 25-1 of Part II of the Steel Ship Rules.

CHAPTER IV – FIRE PROTECTION, DETECTION AND EXTINCTION

4.1. General

4.1.1. In addition to comply with the requirements of the Administration of the ship, the requirements specified in this chapter are also to be complied with.

4.1.2. Fire protection appliances are to be kept in good order and available for immediate use at all times.

4.2. Equipment and Arrangements

4.2.1. Ship of 12 meters or more in length are to be provided with the following fire-fighting equipment. However, the requirements in (a) through (e) do not apply to ships with a gross tonnage of less than 300 tons.

a. One fire pump driven by independent power.
b. One emergency hand fire pump provided outside the machinery space.
c. Fire hydrants to be so arranged that one jet of water by a single fire hose is available (cargo spaces assumed to be in empty condition) to reach any part of the ship normally accessible to the passengers or crew while the ship is being navigated.
d. Three fire hoses.
e. Three nozzles (spray/jet) with valves.
f. Portable fire extinguishers;
    i. One portable foam fire extinguisher or portable chemical powder fire extinguisher per every 750 kW of output in space where internal combustion engine is installed (minimum two, maximum six in number).
    ii. Three portable fire extinguishers in accommodation space and service space (to be distributed to each space as appropriate).

4.2.2. Ships of less than 12 meters in length are to be provided with the following fire-fighting equipment:

a. Ships equipped with inboard engine or in/outboard engine are to be provided with three portable liquid fire extinguishers or portable chemical powder fire extinguishers.
b. For ships equipped with outboard engine only, the quantities of portable fire extinguishers may be reduced by one from the quantities specified in (a) above.

4.2.3. Fixed Fire Fighting System

For passenger ships, a fixed firefighting system with a capacity sufficient for the volume of machinery space where normally unattended by crewmembers is to be provided and remotely controlled from the operation compartment.

4.3. FRP Ships not Engaged in International Voyages

Light structure FRP ships with a designed speed exceeding the speed as specified in 1.1.2 of Part I of the Rules and not to proceed in the course of their voyage more than the time as specified in 1.3.4 of the "Rules for the Construction and Classification of High-Speed Craft" from a place of refuge, are to comply with Chapter 4, Chapter 7, and Chapter 8 of the "Rules for the Construction and Classification of High-Speed Craft".

PART IV – MACHINERY INSTALLATIONS

CHAPTER I – GENERAL

1.1. General

1.1.1. Scope

a. The requirement of this Part applies to the main propulsion machinery, deck machinery and power transmission system, shafting systems, propellers, waterjet propulsion systems, prime movers other than main propulsion machinery and piping system.
b. Machinery installations which are unusual and considered impracticable to meet the requirements of this Part may be accepted provided they are deemed by the Society to be equivalent to those specified in this Part.
c. The Society will be prepared give special consideration to the novel features of design in respect of the machinery based on the best information available at the time.
d. Passenger Ships or with special service limitations or restrictions Ships intended for classification are to be construction in accordance with the requirements of the Society as well as Governmental Regulations.

1.1.2. Units and formula

a. Unit and formula including in the Rules are shown in SI units.
b. Pressure gauges may be calibratded in bar

Where: 1 bar = 0.1 MPa

1.1.3. Ambient reference conditions

Ambient reference conditions are to be in accordance with the requirements specified in 1.2.3, Part IV of the Rules for the Construction and Classification of Steel Ships.

1.1.4. Power rating.

Power rafting is to be in accordance with the requirements specified in 1.2.4, Part IV of the Rules for the Construction and Classification of Steel Ships.

1.2. Drawings and Data

1.2.1. For machineries built under special survey during construction, drawings showing the proposed arrangements of machinery compartments and such drawings of the machineries as stated in the subsequent Chapters of this Part are to be submitted for approval before proceeding with the work.

1.2.2. The proposed dimensions and quality of materials as well as all important arrangements and details are to be made clear in the drawings.

1.2.3. For any novel design of machinery, detailed drawings of parts and necessary data are to be submitted for consideration.

1.3. Materials

1.3.1. Material intended to be used for machinery installations are to be selected considering the purpose and condition of their service. Materials intended for principal components are to be of those tested and inspected in accordance with the requirements specified in this Part and Part XI of the Rules for the construction and Classification of Steel Ships.

1.3.2. Materials used for machinery installations which are not specified in 1.3.1 of this Chapter are to be submitted for consideration.

1.4. General Construction

1.4.1. General

a. The machinery installations are to be properly fixed and to be of construction and arrangement to facilitate operation, inspection, and maintenance.
b. The machinery installations are to be of a design and construction adequate for the service for which they are intended and are to be so installed and protected as to reduce to a minimum any danger to persons on board, due regard being paid to moving parts, hot surface, and other hazards.
c. Machinery installations are to be fitted with adequate safety monitoring and control devices in respect of speed, temperature, pressure, and other operation functions.
d. Special consideration is to be given to the design, construction, and installation of the machinery installations so that any mode of vibrations, accelerations, shocks, etc., shall not cause undue stresses in normal operating ranges.

1.4.2. Inclination of ships

The designs and constructions of machinery installations are to be in compliance with accepted marine engineering practices and the machineries are to be operable with complete reliability in all positions and motions with the ship under the conditions as shown in Table IV 1-1, Part 1V of the Rules for the construction and classification of Steel Ships.

1.4.3. Astern power

a. Sufficient power for going astern is to be provided to secure proper control of the ship in all normal circumstances.
b. For the main propulsion system with reversing gear, controllable pitch propellers, waterjet propulsion systems, or electric propulsion systems, running astern is not to lead to the overload of propulsion machinery.

1.4.4. Welded construction

The welded construction are to be in compliance with the requirements specified in Part XII of the Rules for the Construction and Classification of Steel Ships.

1.4.5. Safety devices on moving parts

a. Efficient means are to be provided to prevent the loosening of nuts and screws of moving parts.
b. The moving parts of machinery and shafting are to be efficiently protected by means of handrails, screens, etc.

1.4.6. Installation of machinery.

a. Propulsion machinery, except for those of small output, are to be installed on the bottom girders through the steel engine seatings of sufficient strength and rigidity.
b. Where machinery having large, unbalanced inertia force or large unbalanced moment of inertia or subjected to large, exciting force due to piston side thrust are installed, it is recommended that the steel engine seatings are of sufficient length for the engines and the steel engine seatings on both sides have connected each other or the steel engine seatings are of solid construction.
c. Where the temperature of the bedplates for propulsion machinery or engine seatings in contact with the FRP girders may become the value to give bad influence on the creeping property of FRP in a normal operating condition, an effective insulation is to be provided between the bedplates or seatings and FRP girders.
d. Considerations are to be given to installation of all machinery onto the FRP girders so that an excessive creep deformation does not occur due to the weights and clamping forces of bolts.
e. The accessories of machinery as well as spare parts of large dimensions are to be strongly secured so that they cannot move or become loose under the movements of the ship.

1.4.7. Ventilating systems for machinery spaces.

Machinery spaces are to be adequately ventilated so as to ensure that when machinery therein are operating at full power in all weather conditions, an adequate supply of air is maintained to the spaces for the safety and comfort of personnel, for the operation of the machinery and for the prevention of accumulation of flammable gases.

1.4.8. Dead ship start.

Means are to be provided so that the machinery can be brought into operation from a dead ship condition (e.g. a condition under which the main propulsion machinery, and auxiliaries are not in operation due to an absence of power and normal starting energy sources are depleted).

1.4.9. Protection against noise.

Measures are to be taken to reduce machinery noise in machinery spaces to acceptable levels as determined by the National Regulations of the country in which the ship is registered. If this noise cannot be sufficiently reduced the source of excessive noise is to be suitably insulated or isolated or a refuge from noise is to be provided if the space is required to be manned. Ear protectors are to be provided for personnel required to enter such spaces, if necessary.

1.4.10. Limitation in the use of fuel oil.

Except for cases as specified in (a) to (c) below, no fuel oil with a flash point (to be determined by means of closed-cup test) of less than 60°C is to be used.

a. In emergency generators, fuel oil with a flash point of not less than 43°C may be used.
b. Subject to such additional precautions as it may consider necessary and on condition that the ambient temperature of space in which such fuel oil is stored or used shall not be allowed to rise to within 10°C below the flashpoint of the fuel oil, the general use of fuel oil having a flashpoint of less than 60°C but not less than 43°C may be permitted.
c. The use of fuel oil having a flashpoint of less than 43°C may be permitted provided that such fuel oil is not stored in any machinery space and subject to the approval by this Society.

1.4.11. Automatic trips.

A description of all automatic trips that may affect the vessels propulsion system is to be submitted for review.

1.4.12. Boilers, pressure vessels and turbines.

When fitted, boilers and pressure vessels are to be designed and constructed in accordance with Part V of the Rules for the Construction and Classification of Steel Ships, turbines are to comply with Part IV of the Rules for the Construction and Classification of Steel Ships.

1.5. Test and Inspections

1.5.1. Shop test and inspections

The machinery for ships classed or intended to be classed, built under the special survey during construction, is normally to be tested and inspected in the presence of the surveyor in accordance with the requirement of Rules and the approved drawings:

a. Approval of proper material used and their material tests for component parts of machinery set out in the relevant Chapters of this Part.
b. Workmanship for machining from the commencement of work until the finish inspections for component parts of machinery.
c. Tightness, balancing and non-destructive tests etc. for component parts of machinery set out in the relevant Chapters of this Part.
d. Trial testing of machinery.

1.5.2. Tests and inspections after installation on board.

After installation on board, the following tests and inspections are to be carried out:

a. Verification inspection of installation or fixing condition of machinery.
b. On-board tests and inspection of machinery and essential systems are to be carried out in accordance with the requirements of the relevant Chapters of this Part.
c. Other test and inspections not included in this Part may be required if deemed necessary by the society.

1.5.3. The society will be prepared on application to adopt the alternative methods of inspection for the production line machinery and component parts subject to approval of manufacturer's production procedure and quality control.

1.5.4. Where the machinery or component part of machinery have appropriate certificates, the tests and inspections may be wholly or partially dispensed with subject to further considerations and special approval by the Society.

CHAPTER II – DIESEL ENGINES

2.1. General

2.1.1. The construction and installation of diesel engines for main propelling and essential service are to be carried out in accordance with the following requirements under the supervision and to the satisfaction of the surveyor.

2.1.2. Diesel engines which drive electric propulsion generators are to be constructed and installed in accordance with the following requirements as well as the requirements stated in 3.2 of Part VII of the Rules for the Construction and Classification of Steel Ships.

2.2. Drawings and Data

Drawings and data to be submitted for approval are generally to comply with the requirements specified in 3.2. part IV of the Rules for the Construction and Classification of Steel Ships.

2.3. Material

2.3.1. Materials intended for the component parts of diesel engines are to be tested and inspected in the presence of the Surveyor in accordance with the requirements of Part XI of the Rules for the Construction and Classification of Steel Ships or with the requirements of the specification approved in connection with the design.

2.3.2. Engine parts subject to stress are to be made of sound materials, and cylinders, cylinder liners, cylinder covers, pistons, etc. under high temperature or pressure are to be made of materials suitable for the stress and temperature to which they are exposed.

2.4. Construction

2.4.1. General

a. Diesel engines are to be designed to have construction and strength adequate for the service for which they are intended, the working conditions to which they are subjected and the environmental conditions on board.
b. Frames and bedplates are to be of rigid and oiltight construction. Crank cases are to be strongly built and doors or covers securely fastened and made air and oiltight so that they can withstand a considerable excessive pressure within the crankcases without any risk of damage.
c. Passages for cooling water and lubricating oil are to be carefully cleaned of sand and scale.
d. Clutches or reversing gear built in engines are to be in accordance with the requirements stated in Chapter 4 of this Part.

2.4.2. Cylinder relief valves

Each cylinder of a diesel engine having a bore exceeding 230mm is to be provided with a relief valve adjusted to be activated at not more than 40% above the maximum combustion pressure at the maximum continuous output, and so arranged that when discharged no damage to operators can occur. The relief valves may be replaced by effective warning devices for overpressure in each cylinder.

2.4.3. Protection against crankcase explosion

Engines are to comply with the following requirements from crankcase explosion:

a. 2.4.1 (b) of this Chapter.
b. 3.4.3, Part IV of the Rules for the Construction and Classification of Steel Ships.
c. 2.4.5 and 2.4.6 of this Chapter.

2.4.4. Crankcase ventilation

a. Provision is to be made for ventilation of an enclosed crankcase by means of a small breather or by means of slight suction not exceeding 25 mm of water. Crankcase are not to be ventilated by a blast of air. Otherwise, the general arrangements and installation are to be such as to preclude the possibility of free entry of air to the crankcase.
b. Crankcase ventilation piping is not to be directly connected with any other piping system. Crankcase ventilation pipes from each engine are normally to be led independently to the weather and fitted with corrosion resistant flame screens.
c. Crankcase ventilation pipes from two or more engines may lead to a common oil mist manifold. Where a Common oil mist manifold is employed, the vent pipes from each engine are to be led independently to the manifold and fitted with a corrosion resistant flame screen within the manifold. The arrangement is not to violate the engine manufacturer's recommendations for crankcase ventilation. The common oil mist manifold is to be accessible at all times under normal conditions and effectively vented to the weather. where venting of the manifold to the weather is accomplished by means of a common vent pipe, the clear open area of the common vent pipe is not to be less than the aggregate cross-sectional area of the individual vent pipes entering the manifold, and the outlet to the weather is to be fitted with a corrosion resistant flame screen. The manifold is also to be fitted with an appropriate draining arrangement.

2.4.5. Warning notice.

Suitable warning notices are to be attached in a conspicuous place on each engine and are to caution against the opening of a hot crankcase for a specified period of time after shutdown based upon the size of the engine, but not less than 10 minutes in any case. Such notice is also to warn against restarting an overheated engine until the cause of overheated has been remedied.

2.4.6. Speed governors and overspeed protective devices of main diesel engines and generator prime movers.

The speed governors and overspeed protective devices of main diesel engines and generator prime movers are to be in compliance with the requirements specified in 3.4.8 and 3.4.9, Part IV of the Rules for the Construction and Classification of Steel Ships.

2.5. Starting Arrangements

2.5.1. Air starting

Compressed air starting arrangements are to be in compliance with the requirements specified in 3.6.1, Part IV of the Rules for the Construction and Classification of Steel Ships.

2.5.2. Electric starting

a. Where main propelling and auxiliary engines are fitted with electric starters, at least 2 starting batteries are to be installed sufficient in their combined capacity without recharging to provide the consecutive starts, as required in 4.6.2, Part IV of the Rules for Construction and Classification of Steel Ships for air starting, within 30 minutes.
b. The connections to the starting batteries are to be such that the batteries can be used alternately. Two charging facilities are required for the starting batteries, one automatic device supplied from a charging dynamo on the engine, and another device may be of manually, supplied from the

ship's electric system. Each of the charging devices is to be able to recharge one battery completely within 6 hours.

c. The starting battery is not to be used for any purpose other than starting and running the engine. If it is also used for other purposes, the battery capacity is to be increased accordingly and the circuits are to be completely separated from the starting system.

2.6. Air Intake and Exhaust Arrangements

2.6.1. Exhaust gas turbo-superchargers

Where the exhaust gas turbo-superchanger is fitted on the engine, it is to be so arranged that the ship can proceed with the safe voyage in case of failure of the turbo-supercharger.

2.6.2. Exhaust arrangements

a. The exhaust pipes are to be water jacketed or effectively insulated. Engine exhaust systems are to be so installed that the vessels structure cannot be damaged by heat from the systems. Exhaust pipes of several engines are not to be connected together. Where these pipes are connected to a common silencer, effecti ve means are to be provided to prevent the exhaust gas from returning into cylinders of non-operating engines.

b. Exhaust lines which are led overboard near the waterline are to be protected against the possibility of the water finding its way inboard.

c. Where necessary, the exhaust pipe is to be fitted with suitable draining arrangement and means to allow for expansion.

2.7. Fuel, lubrication, and Cooling Arrangements

2.7.1. Fuel oil arrangements

Fuel oil arrangements are to be in accordance with the requirements of 4.4, Part VI of the Rules for the Construction and Classification of Steel Ships in addition to the following:

a. The high-pressure fuel oil injection pipes are to be effectively shielded and secured to prevent the fuel or fuel mist from reaching a source of ignition on the engine or its surroundings. And fuel oil leakage within the sheath is to be drained through drainage system of engine. Where flexible hoses are used for shielding purposes, they are to be of an approved type.

b. The surfaces of FRP fuel oil tank facing the spaces such as main engine room, etc. where there may be the source of fire are to be provided with the application of covering with non-combustible material or application of not less than 3 mm thickness of laminates impregnated with fire-reguardent resins. The final total thickness of FRP laminated plating for fuel oil tank, whichever is chosen as mentioned above, shall be not less than 6 mm.

2.7.2. Lubricating oil arrangements.

Lubricating oil arrangements are to be in accordance with the requirements of 4.5, Part VI of Rules for the Construction and Classification of Steel Ships in addition to the following:

a. If enclosed crankcase are used as lubricating oil sumps, they are to be so arranged that the contained oil can be drained at any time and that purifiers or suitable filters for lubricating oil are provided.

b. Lubricating oil lines are to be provided with pressure gauges or other adequate means at suitable positions to indicate that proper circulation is being maintained.
c. The lubricating oil arrangements for rotor shafts of exhaust gas turbochargers are to be designed so that the lubricating oil may not be drawn into charging air.
d. Main engines and auxiliary engines with maximum continuous output exceeding 37 kw are to be provided with alarm devices which give visible and audible alarming in the event of failure of supply of lubricating oil or appreciable reduction in lubricating oil pressure, and with devices to stop the operation of the engine automatically by lower pressure after the function of alarms.

2.7.3. Cooling arrangements

Cooling arrangements are to be in accordance with the requirements of 4.3, Part VI of the Rules for the Construction and Classification of Steel Ships in addition to the following:

a. Discharge pipes for cooling water or cooling oil are to be provided with thermometer and preferably be fitted with adequate means to indicate the proper circulation.
b. Drain arrangements are to be provided on water jackets and cooling water lines at their lowest positions. Relief valves are to be fitted in the main lines to the jackets to release excessive pressure.

2.8. Test and Inspections

2.8.1. Hydraulic pressure tests on diesel engine parts are to be carried out under the conditions specified in Table IV 3-3, Part 1V of the Rules for the Construction and Classification of Steel Ships.

2.8.2. Material and non-destructive tests required on diesel engine parts.

a. Material intended for the principal components of diesel engines and their non-destructive test are to conform to the requirements given in Table 1V 3-4, Part 1V of the Rules for the Construction and Classification of Steel Ships. The manufacturer's certificates of material tests may be acceptable in each case if considered to be satisfactory by the Surveyor.
b. For important structural parts of diesel engines, examination of welded seams by approval methods of inspection may be required if deemed necessary by this Society.

2.8.3. For diesel engine with novel design features or those with no service records, in case of deemed necessary by this Society, tests are to be carried out to verify their endurance by the procedure as deemed appropriate by this Society.

2.8.4. For diesel engines, shop trials are to be carried out by the test procedure as deemed appropriate by this society.

2.8.5. For diesel engines, a final sea trial is to be carried out by the sea trial procedure as deemed appropriate by this society.

CHAPTER III – DECK MACHINERY AND ESSENTIAL AUXILIARIES

3.1. General

3.1.1. The requirement of this Chapter is applicable to the steering gear, windlass, mooring winch, capstan, reciprocating compressor, and essential service pumps, etc.

3.1.2. The requirements in 3.5 of this Chapter are to be complied with, as far as they are applicable, for the mooring winch and capstan.

3.2. Drawings and Data

Drawings and data to be submitted are generally to comply with the requirements specified in 4.1.4, Part IV of theRules for the Construction and Classification of Steel Ships.

3.3. Materials

Material intended for the component parts of deck machinery and essential auxiliaries are to comply with requirements specified in 4.1.5 Part IV of the Rules for the Construction and Classification of Steel Ships.

3.4. Steering Gear

3.4.1. General

a. Each ship is to be provided with a main steering gear and an auxiliary steering gear in accordance with the requirements of the Rules. The main steering gear are to be so arranged that the failure of one of them will not render the other one inoperative.
b. Consideration will be given to other cases, or to arrangements which are equivalent to those required by the Rules.

3.4.2. Main steering gear.

Main steering gear is to comply with the requirements specified in 4.2.2, and 4.2.4 to 4.2.12, Part IV of the Rules for the Construction and Classification of Steel Ships.

3.4.3. Auxiliary steering gear

a. Auxiliary steering gear is to comply with the requirements specified in 4.2.3, to 4.2.12 Part IV of the Rules for the Construction and Classification of Steel Ships.
b. Auxiliary steering gear need not be fitted when the ship is provided with:
   i. two rudders, each with its own steering gear and capable of steering the vessel with any one of the rudders out of operation, or
   ii. fitted with an approved alternative means of steering capable of steering the vessel with the rudder out of operation and provided with approved remote control from the bridge.

3.5. Windlass

3.5.1. General

A windlass of sufficient power and suitable for the size of chain is to be fitted to the ship to operate the anchors.

3.5.2. Construction

The Windlass is to comply with the requirements specified in 4.3.4, Part IV of the Rules for the Construction and Classification of Steel Ships or other recognized standard deemed appropriate by this Society.

3.6. Reciprocating compressor

The reciprocating compressor is to comply with the requirements specified in 4.4, Part IV of the Rules for the Construction and Classification of Steel Ships.

3.7. Pumps

The pump is to comply with the requirements specified in 4.5, Part IV of the Rules for the Construction and Classification of Steel Ships.

3.8. Test and Inspections

3.8.1. Hydraulic pressure test, shop trial and on-board trial are to comply with the requirements specified in 4.6.1 to 4.6.3, Part IV of the Rules for the Construction and Classification of Steel Ships.

3.8.2. Alternative proposals will be specially considered where any of tests and inspections required by 3.8.1 aboveare considered impracticable.

CHAPTER IV – GEARING AND COUPLINGS

4.1. General

4.1.1. The gearing and couplings for main propelling purpose and for driving essential service auxiliaries are to be in accordance with the requirements in Chapter 5, Part IV of the Rules for the Construction and Classification of Steel Ships.

4.1.2. Flexible shaft couplings.

Details of the various components of flexible couplings for main propelling purpose and for driving essential service auxiliaries are to be submitted for approval. Flexible couplings with elastomer or spring type flexible members and which represent the sole source of transmitting propulsive power in a line shaft on a single screw vessel are to be provided with torsional limit capacity (coupling will locks beyond its limit) or positive means of locking the coupling. Operation of the vessel with a locked coupling may be at reduced power provided warning notices are posted at the control station.

4.1.3. Alternative proposals will be specially considered where any requirements specified in 4.1.1 and 4.1.2 above are considered impracticable.

CHAPTER V – SHAFTINGS, PROPELLERS, WATERJET PROPULSION SYSTEM AND TORSIONAL VIBRATION OF SHAFTING

5.1. Shaftings

5.1.1. Scope

The requirements of this section apply to propulsion shafting and power transmission system which transmit power from prime mover driving generators and essential service auxiliaries. The torsional vibration of shaftings are to comply with the requirements specified in 5.4 of this Chapter.

5.1.2. Drawings and data

Drawings and data to be submitted are generally as follows:

a. Drawings for approval (including specifications of material)
    i. Shafting arrangement
    ii. Thrust shaft
    iii. Intermediate shaft
    iv. Stern tube shaft
    v. Propeller shaft
    vi. Stern tube and stern tube bearing
    vii. Stern tube sealing device
    viii. Shaft bracket bearing
    ix. Shaft couplings and coupling bolts
    x. Shafts which transmit power to generators or essential service auxiliaries.

b. Data for reference
    i. Data necessary for the calculations of shafting strength specified in this section.
    ii. Data deemed necessary by this Society.

5.1.3. Materials, construction, and strength

a. Material intended for the principal components of shafting are to confirm to the requirements specified in 1.4 and 6.1.3, Part IV of the Rules for the Construction and Classification of Steel Ships in addition to the following:
    i. The specified minimum tensile strength of forgings for propeller shaft and other shafts is to be selected within the following general limits:
       Carbon and carbon manganese steel: 400 to 600 N/mm^2
       Alloy steel (Age-hardened martensitic stainless steels or other high strength alloy materials): not exceeding 800 N/mm^2
    ii. Where it is proposed to use alloy steel, details of the chemical composition, heat treatment and mechanical properties are to be submitted for approval.
    iii. Ultrasonic tests are only required on shaft forgings of which the diameter is 250 mm or greater.

b. The dimensions of shafts are to comply with the requirements specified in 6.2, 6.3, 6.4 and 6.5, Part IV of the Rules for the Construction and Classification of Steel Ships.

c. The dimension and construction of shafting accessories are to comply with the requirements specified in 6.6, Part IV of the Rules for the Construction and Classification of Steel Ships.

5.1.4. Fitting of propellers

a. Where propellers are force fitted on the propeller shafts, the fixing part is to be of sufficient strength against torque to be transmitted. The edge at the fore end of the tapered hole of the propeller boss is to be appropriately rounded off.

b. Where a key is designed at fixing part, ample fillets are to be provided at the corners of the keyway and the key is to fit tightly in the keyway and be of sufficient size to transmit the full torque of the shaft. The fore end of keyway on the propeller shaft is to be rounded smoothly for avoiding an excessive stress concentration.

c. Where a propeller is force fitted on the propeller shaft without a key, the minimum and maximum limits of pull-up length are to comply with the requirements specified in 7.3.1, Part IV of the Rules for the Construction and Classification of Steel Ships. Calculation sheet of propeller pull-up length is to be submitted for approval.

d. Where the propeller and propeller shaft flange are connected with bolts, the following (i) and (ii) are to comply with:

   i. The bolts and pins are to be of sufficient strength.

   ii. The thickness of the aft propeller shaft flange at the pitch circle is to be submitted for approval.

e. The propeller hub is not to be fitted or removed by means of local heating.

5.1.5. Protection for propeller shaft against corrosion.

Protection for propeller shaft against corrosion is to comply with the requirements specified in 6.7.3, Part IV of the Rules for the Construction and Classification of Steel Ships.

5.2. Propellers

5.2.1. Scope

The requirements of this Chapter are applicable to the screw propellers. Where a design is proposed to which the following cannot be applied, special strength calculations are to be submitted for consideration.

5.2.2. Drawings and data.

Drawings and data to be submitted are generally to comply with the requirements specified in 7.1.2, Part IV of the Rules for the Construction and Classification of Steel Ships.

5.2.3. Materials.

Materials of propeller are generally to comply with the requirements specified in 7.1.3, Part IV of the Rules for the Construction and Classification of Steel Ships.

5.2.4. Strength calculations and construction

a. The strength calculations and construction of propeller blades and blade attaching studs are generally to comply with the requirements specified in 7.2.1 and 7.2.2, Part IV of the Rules for the Construction and Classification of Steel Ships.

b. Where the blade thickness for propellers fitted onto propeller shafts with a propeller blade rake of 5° or more and for rudder propellers may be reduced to the value given by the following formula:

$$t = K\sqrt{\frac{K_1 H}{K_2 NBZ}}$$

Where:

t = Required propeller blade thickness (excluding the fillet of blade root), in mm

H = Maximum continuous output of the engine driving the propeller, in kW.

N = Revolution of the propeller, in rpm.

Z = Number of blades.

B = Width of blade at radius in consideration, in mm.

K = 447.5

K_1 = Coefficient given by the following formula at radius in consideration

$$K_1 = \frac{30.3}{\sqrt{1 + a\left(\frac{P'}{D}\right)^2}}\left(b\frac{D}{P} + c\frac{P'}{D}\right)$$

D = Diameter of propeller, in mm.

P = Pitch at radius of 0.7R, in mm. (R = Radius of propeller, in mm)

P' = Pitch at radius in consideration, in mm.

a.b.c = Values given in Table IV 5-1

K2 = Coefficient given by the following formula:

$$K_2 = K_3 - \left(d\frac{E}{t_0} + e\right)\frac{(0.001D)^2(0.01N)^2}{1000}$$

K_3 = Value given in Table IV 5-2

d,e = Values given in Table IV 5-1

E = Blade rake of aft, measured as the distance between the tip of the blade and a perpendicular where the line of the blade face intersects with the axis of the propeller, in mm.

to = Imaginary thickness of blade at propeller shaft centreline, in mm.

Note: t^0 is projection thickness obtained by connecting from the blade tip thickness via 0.25R (or 0.35R for controllable pitch propeller) maximum thickness then intersecting the propeller shaft centreline.

Table IV 5-1
Values of a, b, c, d, and e

Radial position	a	b	c	d	e
0.25R	1.62	0.386	0.239	1.92	1.71
0.35R	0.827	0.308	0.131	1.79	1.56
0.6R	0.281	0.113	0.022	1.24	1.09

Table IV 5-2
Values of K_3

Material		K_3
Copper alloy casting	NF1A	1.15
	NF1B	1.15
	NF2A	1.3
	NF2B	1.15

Notes:

1. For the materials of blades different from those specified in the above Table IV 5 -2, the value of K3 is to be determined in each case.
2. For propellers having a diameter of 2500 mm or less, the value of K3 may be taken as the value in the above Table IV 5-2 multiplied by the following factor:

$$2 - 0.4\frac{D}{1000} \qquad \text{for } 2500 \text{ mm} \geq D > 2000 \text{ mm}$$

$$1.2 \qquad \text{for } D \leq 2000 \text{ mm}$$

5.2.5. Controllable pitch propeller.

The Controllable pitch propeller is generally to comply with the requirements specified in 7.3.3, Part IV of the Rules for the Construction and Classification of Steel Ships.

5.3. Waterjet Propulsion Systems

5.3.1. Scope

Waterjet propulsion systems are to conform to requirements in this section, according to their design, in additional to the applicable requirements in this Chapter.

5.3.2. Drawings and data.

Drawings and data to be submitted are generally as follows:

a. Drawings and data for approval
    i. General arrangement and sectional assembly (showing the materials, and dimensions of the principal components including the water intake duct).

ii. Shafting arrangement (showing the arrangements, shapes and constructions of the main propulsion machineries, reduction gears, clutches, couplings, main shafts, bearings. thrust bearings, sealing devices and impellers).
iii. Details of water intake duct.
iv. Construction of impeller (showing the detailed blade profiles, the maximum radius of the impeller from the center of the main shaft, number of blades and material specifications).
v. Details of bearings, thrust bearings and forward sealing devices of the main shaft.
vi. Details of deflectors.
vii. Details of reversers.
viii. Diagram of hydraulic piping system.
ix. Calculation sheets of torsional vibration of main shaft.

b. Drawings and data for reference
   i. Calculation sheets of bending natural frequency when bending vibration due to self-weight is expected.
   ii. Strength calculation sheets for deflectors and reversors.
   iii. Others deemed necessary by this Society.

5.3.3. Materials.

The materials of parts of the waterjet propulsion system are suitable for respective uses intended, and the following essential components are to comply with the requirements in the Rules for the Construction and Classification of Steel Ships:

a. Main shaft.
b. Shaft coupling and coupling bolts.
c. Impeller.
d. Water intake duct, nozzle and impeller casing which are composing a part of shell plating.

5.3.4. Construction

a. The following design load conditions are to be considered:
   i. Maximum thrust force ahead.
   ii. maximum side force and moment,
   iii. maximum reversing force and moment.

b. The supporting area of the stern is to be adequately strengthened to withstand the above design load.
c. Support for shaft bearing in way of duct penetration is to be adequately strengthened against primary structure.
d. Others deemed necessary by this Society.

5.4. Torsional Vibration of Shafting

5.4.1. Scope

a. The requirements of this Chapter are applicable to the torsional vibration of main propulsion shafting system (excluding a part of waterjet propulsion system) and auxiliary diesel engines for essential service.
b. The torsional vibration of novel designed engine or some parts of the installation such as gear, chain, cam mechanism or elastic coupling etc. is to be submitted for special approval.

5.4.2. General.

The torsional vibration of main propulsion shafting system and auxiliary diesel engines for essential service is to comply with the requirements specified in the Rules for the Construction and Classification of Steel Ships.

5.5. Test Inspections

5.5.1. Test and inspections of shaftings are generally to comply with the requirements specified in the Rules for the Construction and Classification of Steel Ships.

5.5.2. Tests and inspections of propellers are generally to comply with the requirements specified in the Rules for the Construction and Classification of Steel Ships.

5.5.3. Alternative proposals of tests and inspections will be specially considered where any requirements specified in 5.5.1 and 5.5.2 above are considered impracticable.

CHAPTER VI – PIPING AND PUMPING SYSTEM

6.1. General

6.1.1. Classed Ships are to be provided with necessary piping and pumping facilities for acquiring safe and efficient operation in the services for which they are intended.

6.1.2. The following items are generally to comply with the requirements specified in the Rules for the Construction and Classification of Steel Ships:

a. Design pressure and temperature.
b. Classes of pipes.
c. Materials
d. Strength of pipes.
e. Application of pipes, valves, and other fittings.
f. Pipe welding
g. Construction of pumps.
h. General requirements of piping arrangements.
i. Plans are to be submitted for consideration and approval.

6.2. Ship’s Side fittings

Ship's side fittings are to be in accordance with the requirements of the Rules for the Construction and Classification of Steel Ships in addition to the following:

6.2.1. Where valves or cocks are fitted to the shell plating, the fitting method is to be such that deemed appropriate by this society.

6.2.2. The locations of overboard discharges subjected to pressure by the pump are not to be such that water can be discharged into life rafts at fixed launching positions, unless special provision is made for preventing any discharge of water into them.

6.3. Air Pipes and Overflow Pipes

Air pipes and overflow pipes are to be in accordance with the requirements of 3.2, Part VI of the Rules for the construction and Classification of Steel Ships in addition to the following:

6.3.1. The overflow pipes are to be provided under either one of the following categories:

a. Where total sectional area of air pipes to tanks which can be pump up is less than 1.25 times total sectional area of filling pipes.
b. Where there is any opening below the open ends of air pipes fitted; and
c. Fuel oil settling tanks and fuel oil service tanks.

6.4. Sounding Pipes

Sounding pipes are to be in accordance with the requirements of the Rules for the Construction and Classification of Steel Ships in addition to the following:

6.4.1. Name plates of sounding pipes are to be affixed to the upper ends of sounding pipes.

6.5. Hull Piping System

Hull Piping system is to be in accordance with the requirements of the Construction and Classification of Steel Ships.

6.6. Drainage of Cargo Holds

6.6.1. Drainage of cargo holds are to be in accordance with the requirements of the Rules for the Construction and Classification of Steel Ships.

6.6.2. Alternative proposals will be specially considered where any requirements specified in 6.6.1 above are considered impracticable.

6.7. Drainage of Machinery and Tunnel Spaces

6.7.1. Drainage of Machinery and Tunnel spaces are to be in accordance with the requirements of the Rules for the Construction of Steel Ships.

6.7.2. Alternative proposals will be specially considered where any requirements specified in 6.7.1 above are considered impracticable.

6.8. Drainage from Refrigerated and Cargo Holds

Drainage from refrigerated cargo holds are to be in accordance with the requirements of 3.8, Part VI of the Rules for the Construction and Classification of Steel Ships.

6.9. Drainage from Spaces in Other Decks

6.9.1. Drainage from spaces in other decks are to be in accordance with the requirements of the Rules for the Construction and Classification of Steel Ships.

6.9.2. Alternative proposals will be specially considered where any requirements specified in 6.9.1 above are considered impracticable.

6.10. Drainage of Tanks

6.10.1. Drainage of tanks are to be in accordance with the requirements of the Rules for the Construction and Classification of Steel Ship.

6.10.2. Alternative proposals will be specially considered where any requirements specified in 6.10.1 above are considered impracticable.

6.11. Sizes of Bilge Suction Pipes

6.11.1. The internal diameter of main bilge line is to be not less than that required by the following formula.

$$d_1 = 25 + 1.68\sqrt{L(B+D)}$$

Where:

d_2 = Internal diameter of branch bilge suction pipe, in mm

l = Length of the compartment, in m

B and D = are as defined in 6.11.1

The actual internal diameter of branch bilge suction pipes may be rounded off to the nearest pipe size of a recognized standard, but d_2 is in no case to be less than 25 mm.

6.12. Bilge Pumps

6.12.1. Number of pumps.

Every ship 20 m in length or greater is to be provided with two power driven bilge pumps, one of which may be attached to the propulsion unit. Ships under 20m in length are to be provided with one fixed power-driven pump, which may be an attached unit, and one portable hand pump.

6.12.2. Capacity

The capacity of each bilge pump is to be in accordance with the following:

Ship Length	Minimum Capacity per Pump (m^3/hr)
L< 20	5.5 (hand pump 1.13 m^3/hr)
20≦L < 30	11
30≦L≦35	14.75

6.12.3. Where centrifugal pumps are installed, suitable means for priming are to be provided.

6.12.4. Sanitary, ballast and general service pump may be accepted as independent power bilge pumps, provided they are of the required capacity and are fitted with the necessary control valves for pumping bilges.

6.12.5. Connections at the bilge pumps are to be so arranged that one can be worked while the other is being overhauled.

6.13. Ballast System

6.13.1. The arrangement of ballast piping and number of suctions are to be such that any ballast tank can be filled or emptied under normal service condition whether the ship is upright or listed.

6.13.2. The arrangement of ballast piping is to be such as to prevent the possibility of water passing from the sea or from ballast tanks into dry cargo and machinery spaces or other dry compartments.

6.13.3. Ballast water pipes are not to pass through drinking water, feed water or lubricating oil tanks. Where it is unavoidable, the ballast water pipes are to be of steel and extra heavy and welded joints are to be adopted.

6.13.4. Where a hold is intended for carrying ballast water and cargo alternately, adequate provisions such as blank flange or spool piece are to be made in the ballast piping system to prevent inadvertent ingress of sea water through ballast pipes when carrying cargo and in the bilge piping system to prevent inadvertent ingress of ballast water through the bilge pipes when carrying ballast water.

6.13.5. Where a tank is intended to be used both for fuel oil and ballast water, adequate provision such as blank flange or spool piece are to be made to prevent mixing of fuel oil and ballast water in the ballast pipe when carrying fuel oil and in the fuel oil pipe when carrying ballast water.

6.14. Cooling Water System

6.14.1. Cooling water pumps

a. Number and capacity of cooling water pumps for the main propulsion machinery are to comply with the following requirements:
    i. Two sets of main cooling water pumps are to be provided with sufficient total capacity enough to maintain the supply of cooling water at the maximum continuous output of the main propulsion machinery, and each of which has sufficient capacity to obtain navigable speed of the ship.
    ii. Where two or more main propulsion machineries are provided, such system that each of them has an exclusive cooling water pump may be accepted providing that it is possible to give a navigable speed even if one of them is out of use.
b. Number and capacity of cooling pump for essential auxiliary engine are to comply with the following requirements:
    i. Where each essential auxiliary engine is fitted with a built-in cooling water pump, the standby pump may be dispensed with.
    ii. If two or more auxiliary engines are supplied with cooling water from a common system, a standby cooling water pump is needed. The standby cooling water pump may be substituted by other pumps of sufficient capacity.
c. Where fresh water coolings is employed for main and/or auxiliary engines, a standby freshwater pump need not be fitted if there are suitable emergency connections from a saltwater system.
d. In the ship of 24 m and under in length with main engine provided main cooling water pump driven by main engine, standby cooling water pump may be omitted.

6.14.2. Sea inlets and strainers

a. Not less than two sea inlets are to be provided for the cooling water pumps of sea water cooling system. The suction of any cooling water pump under normal service conditions is to be supplied from either one of the sea inlets.
b. Strainers are to be provided to the suction pipes between the sea inlets and the suctions of sea water cooling pumps. The strainers are to be so arranged that they can be cleaned without interrupting the cooling water supply.

6.15. Fuel Oil System

6.15.1. Fuel oil system is to be in accordance with the requirements specified in the Rules for the Construction and Classification of Steel Ships.

6.15.2. The limitation in the use of fuel oil is to be in accordance with the requirements specified in 1.4.10 of this Part.

6.16. Lubricating Oil and Hydraulic system

6.16.1. Lubricating oil and hydraulic system are to be in accordance with the requirements specified in the Rules for the Construction and Classification of Steel Ships.

6.16.2. Where each essential auxiliary engine is fitted with a built-in lubricating oil pump, the standby pump may be dispensed with. If two or more auxiliary engines are connected to a common lubricating oil system, a standby pump is needed.

6.17. Starting Air System

Starting air system is to be in accordance with the requirements of 4.6, Part VI of the Rules for the Construction and Classification of Steel Ships.

6.18. Exhaust Gas Piping Arrangement for Diesel Engine

Exhaust gas piping arrangement for diesel engine is to be in accordance with the requirement of 2.6.2 of this Part.

6.19. Test and Inspections

6.19.1. Test and inspections before installation onboard.

Test and inspections of pipes before installation on board are to be in accordance with the requirements of the Rules for the Construction and Classification of Steel Ships.

6.19.2. Tests and inspections after assembly on board.

Tests and inspection of all piping systems after assembly on board are to be in accordance with the requirements of the Rules for the Construction and Classification of Steel Ships.

6.19.3. Hydrostatic tests of valves and fittings.

Hydrostatic tests of values and fittings are to be in accordance with the requirements of the Rules for the Construction and Classification of Steel Ships.

HISTORY

REV. No.	DATE	COMMENTS
00	DEC/11/2013	New Rule
01	NOV/12/2014	Annual revision of the class rule
02	DEC/07/2015	Annual revision of the class rule
03	DEC/14/2016	Annual revision of the class rule
04	OCT/22/2017	Annual revision of the class rule
05	DEC/28/2018	Annual revision of the class rule
06	DEC/16/2019	Annual revision of the class rule
07	DEC/05/2020	Annual revision of the class rule
08	MAY/23/2022	Total revision of the document

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