INTERNATIONAL STANDARD

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Large yachts — Strength, weathertightness and watertightness of glazed openings —

Part 1: Design criteria, materials, framing and testing of independent glazed openings

Grands yachts — Résistance, imperméabilité au mauvais temps et étanchéité des ouvertures vitrées —

Partie 1: Critères de conception, matériaux, armature et essais des ouvertures vitrées indépendantes

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

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The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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ISO 11336-1 was prepared by Technical Committee ISO/TC 8, *Ships and marine technology*, Subcommittee SC 12, *Ships and marine technology — Large yachts*.

ISO 11336 consists of the following parts, under the general title *Large yachts — Strength, weathertightness and watertightness of glazed openings*:

— *Part 1: Design criteria, materials, framing and testing of independent glazed openings*

— *Part 2: Glazed opening integrated into adjacent structure (directly bonded to the bulkhead or shell), design criteria, structural support, installation and testing*

— *Part 3: Quality assurance, installation and in-service inspection*

Large yachts — Strength, weathertightness and watertightness of glazed openings —

Part 1: Design criteria, materials, framing and testing of independent glazed openings

1 Scope

This part of ISO 11336 specifies technical requirements for independent glazed openings on large yachts, taking into account navigation conditions, and the location of the opening.

Large yachts are yachts with length of the hull, L_H, higher or equal to 24 m, in use for sport or pleasure and commercial operations, with a tonnage limitation up to 3 000 gross tonnage, according to the International Tonnage Convention.

The opening and the associated closing appliances considered in this part of ISO 11336 are only those that are above the deepest waterline (dsw) and are critical for the ship integrity related to weathertightness and watertightness, i.e. those that could lead to ingress of water in the hull in case of rupture of the pane.

The scope of this part of ISO 11336 is related to and limited to independent glazed openings.

NOTE This part of ISO 11336 is based on the experience of ship window and glass manufacturers, shipbuilders and authorities who apply to ships the regulations of SOLAS, as amended, and of the International Convention of Load Lines, as amended, noting the provisions by the SOLAS Protocol of 1988, Article 8, as agreed by the appropriate Marine Administration.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 178, *Plastics — Determination of flexural properties*

ISO 1751, *Shipbuilding and marine structures — Ships' side scuttles*

ISO 3903, *Shipbuilding and marine structures — Ships' ordinary rectangular windows*

ISO 5797, *Ships and marine technology — Windows and side scuttles for fire-resistant constructions*

ISO 6345, *Shipbuilding and marine structures — Windows and side scuttles — Vocabulary*

ISO 8666, *Small craft — Principal data*

ISO 12543-1, *Glass in building — Laminated glass and laminated safety glass — Part 1: Definitions and description of component parts*

ISO/IEC 17025, *General requirements for the competence of testing and calibration laboratories*

ISO 21005, *Shipbuilding and marine technology — Thermally toughened safety-glass panes for windows and side scuttles*

EN 1288-3, *Glass in building — Determination of the bending strength of glass — Part 3: Test with specimen supported at two points (four point bending)*

EN 1990:2008, *Eurocode — Basis of structural design*

EN 12150-1:2000, *Glass in building — Thermally toughened soda lime silicate safety glass — Part 1: Definition and description*

EN 12337-1, *Glass in building — Chemically toughened soda lime silicate safety glass — Part 1: Definition and description*

EN 13195-1, *Aluminium and aluminium alloys. Specifications for wrought and cast products for marine applications (shipbuilding, marine and offshore)*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 6345 and the following apply.

3.1
glazed opening
opening in the hull, superstructure or deckhouse of a ship structure to be fitted with a transparent or translucent material

3.2
independent glazed opening
glazed opening where the mechanical behaviour of the pane can be considered independent from adjacent structure, e.g. framed appliance

3.3
glazed opening integrated into adjacent structure
glazed opening where the mechanical behaviour of the pane cannot be considered independent from adjacent structure, e.g. pane bonded directly into a seat

3.4
appliance
device made of a pane and a fixing system, used to cover an opening in the hull, superstructure or deckhouse

3.5
pane
sheet of material fixed within or to a frame

3.6
glazing
transparent or translucent pane

3.7
unsupported dimensions of a pane
clear dimensions between the supports bearing the pane

NOTE See Annex A.

3.8
deadlight
secondary watertight closure fitted to a glazed opening and which is fitted on the inside of the vessel

3.9
storm shutter
portable protective closure fitted to a glazed opening and which is fitted on the outside (weatherside) of the vessel

3.10
flag administration
government of the state whose flag the yacht flies

3.11
certifying authority
flag administration or the organization to whom the flag administration delegates certifying authority

3.12
service
description of the service limitations for which a yacht is assessed to be suitable

3.13
commercial service
yachts engaged in commercial use carrying no cargo and generally not more than 12 passengers or not needing to comply with passenger ship requirements

3.14
pleasure service
private yachts not engaged in trade

3.15
operational range and limits
description of the operation limitation for which a yacht is assessed to be suitable

3.16
operational conditions: unrestricted range yachts
extended distance from safe haven where conditions experienced can exceed wind force 8 (Beaufort scale) and significant wave heights of 4 m but limited to 6 m, excluding abnormal conditions

3.17
operational conditions: intermediate range yacht
distance of not more than 200 NM from safe haven, with significant wave height $>$ 2 m but not greater than 4 m

3.18
operational conditions: short range yacht
distance of not more than 90 NM from safe haven, with significant wave height $\leq$ 2 m

3.19
freeboard deck
uppermost complete deck exposed to weather and sea, which has permanent means of closing all openings in the weather part thereof, and below which all openings in the sides of the ship are fitted with permanent means of watertight closing

NOTE At the option of the owner and subject to the approval of the administration, a lower deck can be designated as a freeboard deck, provided it is a complete and permanent deck continuous in a fore and aft direction at least between the machinery space and peak bulkheads and continuous athwart-ships.

3.20
standard superstructure height
h_{std}
for vessels up to 75 m load line length: height to be taken as 1,8 m; for vessels over 125 m load line length: height to be taken as 2,3 m; for vessels of intermediate lengths: height to be obtained by linear interpolation

3.21
load line length
L
96 % of the total length on a waterline at 85 % of the least moulded depth measured from the top of the keel, or as the length from the fore side of the stem to the axis of the rudder stock on that waterline, if that be greater

NOTE For ships without a rudder stock, the length, L, is taken as 96 % of the waterline at 85 % of the least moulded depth.

3.22
limits in glazed openings
maximum size of glazed openings specified in this part of ISO 11336 below a line 0,05 times ship length or forward of a line drawn at the intersection of the 0,05 L waterline and the stem and below a line drawn at 0,05 $L + h_{std}$, not exceeding 0,85 m^2

NOTE See Figure 1.

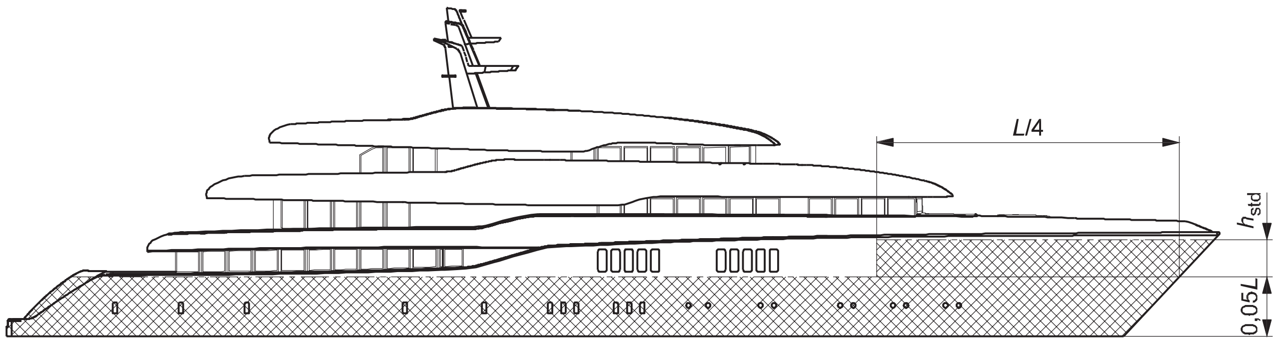


Figure 1 — Area in which glazed openings are limited to 0,85 m^2

3.23
large yacht
yachts in use for sport or pleasure and commercial operations of L_H higher or equal to 24 m, which is measured according to ISO 8666

3.24
weathertightness
capacity to prevent that, in any sea conditions, water will penetrate into the ship

NOTE Meaning of weathertight taken from Annex I, Regulation 3 (12) of International Convention of Load Lines (ICLL). This is interpreted generally as indicating that weathertightness is required from the exterior only, as opposed to watertightness indicating the ability to withstand from both inside and outside (see 3.27).

3.25
watertightness
capacity of an appliance to prevent the passage of water through the structure in any direction under a head of water for which the surrounding structure is designed

3.26
strength
capacity of a structure to maintain full structural integrity under the action of loads

3.27
design loads
external hydrostatic loads according to which glazed openings strength is assessed

3.28
hull
part of the yacht within the envelope of the side shell and decks taken into account for the assignment of freeboard and for stability evaluation

3.29
superstructure
decked structure on the freeboard deck, extending from side to side of the yacht or with side plating not being inboard of the shell plating more than 4 % of the yacht breadth

NOTE Definition adapted from Annex I, Regulation 3 (10) of International Convention of Load Lines (ICLL).

3.30
deckhouse
structure enclosing a space that is normally accessible and used for accommodation or service and that does not qualify as a superstructure and that can be positioned on the freeboard deck, and/or the tiers above

3.31
wheelhouse
control position occupied by the officer of the watch

3.32
glass and plastic materials
materials used for glazed openings, as specified in 3.35 to 3.45, and 3.49 and 3.50, with a *characteristic failure strength* (3.46)

3.33
glass ply
plate made of an inorganic non-crystalline solid exhibiting a glass transition behaviour

3.34
thermally toughened glass
glass where strength increase is obtained by a thermal treatment resulting in the introduction of permanent compression stress on both sides of its cross section

3.35
chemically toughened glass
glass where strength increase is obtained by chemical treatment resulting in the introduction of permanent compression stress on both sides of its cross section

3.36
monolithic glass
glazing consisting of one ply of glass

3.37
laminated glass
multi-layer pane made of glass plies, plastic plies or other glazing materials, which are kept together by suitable plastic adhesive films or curable resins

3.38
safety glass
monolithic thermally toughened glass, fully tempered, or laminated thermally or chemically toughened glass

3.39
insulating glazing units
IGU
glazing made of multiple panes, either monolithic or laminated, separated by sealed gaps filled with gas (air, argon, etc.)

3.40
glass case depth
l_{CD}
when a glass ply is toughened by the introduction of permanent compression stress on both sides of its cross section, depth of the compression stress layer measured from the surface to the inner cross section point where compression stress is zero

3.41
glass surface compression
S_{C}
when a glass ply is toughened by the introduction of permanent compression stress on both sides of its cross section, value of compression stress taken at the surface

3.42
plastic ply
rigid plastic plate where “rigid” means that the plastic material has a modulus of elasticity in flexure or, if not applicable, then in tension, greater than 700 MPa

3.43
interlayer
laminating adhesive material that holds together the plies of a laminated glazing

NOTE It can be a thermo plastic adhesive film or a curable resin.

3.44
characteristic failure strength
σ_C
ultimate flexural strength of *glass pane* (3.47) or *plastic material* (3.48)

3.45
glass pane
ultimate flexural strength at rupture of glass measured, on a statistical basis, in a flexural testing arrangement with a defined method of data reduction taking in account statistical dispersion

3.46
plastic material
ultimate flexural strength at rupture or flexural strength at yield, whichever is lower

NOTE The choice between the value at rupture or at yield depends on the mechanical characteristics of the plastic material; as a general indication brittle plastic material will break before yielding while non-brittle plastic material will yield before breaking.

3.47
main structural section
monolithic or laminated pane construction that meets the strength requirements according to 5.2

3.48
additional functional plies
additional glass or plastic plies or panes not included in the frame that can be coupled to the main structural section and that do not have structural functionalities and do not affect structural functionality of the main structural section

NOTE The flexural modulus/flexural strength, E/σ_C, is substantially less (50 %) than that of the main structural section.

3.49
deepest seagoing waterline
dsw
either the assigned waterline for commercial yachts or the deepest seagoing waterline for private yachts

3.50
forward perpendicular
perpendicular taken at the forward end of the length, L, and which coincides with the foreside of the stem on the waterline on which the length is measured

4 Symbols and abbreviated terms

p_D design pressure

a factor relating to location and vessel length

b factor based on longitudinal location

f factor based on vessel length

c	factor based on width of superstructure or deckhouse
h	height of centre of pane from dsw
h_{std}	standard superstructure height
k_{s}	service factor
L_{H}	length of the hull
L	load line length
L_{p}	length between perpendiculars on summer load waterline
x	distance of centre of pane or storm shutter from aft perpendicular
t_{O}	basic pane thickness
a_{P}	unsupported long side of a rectangular pane or “equivalent long side” of a pane
b_{P}	unsupported short side of a rectangular pane or “equivalent short side” of a pane
β_{S}	pane aspect-ratio coefficient for stress
β_{D}	pane aspect-ratio coefficient for deflection
σ_{A}	allowable design flexural stress of the material
d	diameter of a circular glazed opening
σ_{C}	characteristic breaking strength of a material or laminate
γ	design factor
t_{a}	actual pane thickness
t_{min}	minimum pane thickness
$t_{\text{p1}}, t_{\text{p2}}, \ldots, t_{\text{p}n}$	ply thicknesses of a laminated pane
$t_{\text{eq},j}$	equivalent thickness of each ply of the laminate
t_{eq}	equivalent thickness of laminated construction
t_{L}	physical thickness of a laminate
δ_{max}	maximum pane deflection
M	pane stiffness
l_{CD}	depth of compression layer
S_{C}	surface compression
N	number of test specimens
n	number of independent plies
σ_i	breaking stress for each test specimen when tested according to EN 1288-3 for glass or ISO 178 for brittle plastic materials; stress at yield for each test specimen when tested according to ISO 178 for non-brittle plastic materials
σ_{av}	average breaking stress or yield stress, whichever is applicable
s_x	standard deviation

C_V	coefficient of variation
Kn	statistic coefficient corresponding to 95 % confidence limit
kN	kilonewtons
E	Young's modulus
ν	Poisson's ratio
SM	Section Modulus
NM	nautical miles
ICLL 1966	International Convention on Load Line 1966, as amended
IACS	International Association of Class Societies
TTG	Thermally Toughened Safety Glass
CTG	Chemically Toughened Glass
IGU	Insulated Glass Units
MSS	Main Structural Section
PMMA	PolyMethylMethAcrylate
PC	Polycarbonate
dsw	deepest seagoing waterline
FRP	Fibre Reinforced Plastics

5 Design criteria

5.1 General

Other International Standards, e.g. dealing with stability, buoyancy, weathertight or watertight integrity, may have restrictions on the position of appliances which are outside the scope of this part of ISO 11336 and which are therefore not considered here. However it is necessary for the builder or user to ensure that the appliances comply with other relevant International Standards.

It is also possible that national authorities can have additional requirements differing from those of this part of ISO 11336. It is necessary that individual statutory regulations of flag administrations for commercial yachts be observed. For example, where yachts are complying with the published "Conditions of Assignment" of the International Convention on Load Line, 1966, as amended[6], the maximum size of a glazed opening below the freeboard deck is 0,16 m^2.

5.2 Strength

The strength of glazed openings and associated appliances shall meet the requirements of this part of ISO 11336 and of the applicable International Standard cited in Clause 2, which covers their type. For the scope of this part of ISO 11336, strength is considered only with reference to local loads, that is, external hydrostatic loads coming from weather and sea conditions. Strength requirements are fulfilled according to any of the following criteria:

— where the glazed opening type is covered by an existing relevant International Standard, such as ISO 3903 or ISO 1751, respectively;

— where the pane thickness is calculated according to the method outlined in 5.6, and the glass is flat or convex towards the load action direction and strength requirements of the frame are according to an existing relevant International Standard;

— when the pane has been tested according to the hydrostatic test procedure outlined in 7.3.

External hydrostatic loads (design loads) shall be the only loads considered for strength requirement fulfilment according to this part of ISO 11336. For a particular application, other requirements and criteria can be relevant and may apply.

Strength requirements for monolithic and laminated constructions shall be fulfilled only for the main structural section. Additional functional plies or panes are, normally, not intended to fulfil strength requirements or to take part in the structural validation of the appliance in the hydrostatic test outlined in 7.3. Such plies or panes shall not adversely affect the strength of the main structural section.

According to qualification by hydrostatic test, any changes to the glazing materials or any change to the cross section or larger dimensions of the glazing shall require re-testing. For tolerances, see 7.3.2.

5.3 Watertightness

The appliance shall be designed and mounted to prevent ingress of water into the yacht according to any of the following criteria:

— where the appliance type is covered by an existing relevant International Standard;

— where the pane thickness is calculated according to the method outlined in 5.6 and the pane is clamped with rubber gasket (bonding may be used alternatively) or bonded in the frame with the bonding joint in compression and the strength requirements of the frame are according to an existing relevant International Standard;

— when tested according to the hydrostatic test procedure outlined in 7.3.

Any changes to the glazing materials or any change to the cross section or larger dimensions of the glazing shall require re-testing. For tolerances, see 7.3.2.

5.4 Weathertightness

The weathertightness requirements shall be fulfilled by performing a hose test in the final installation on board. The hose test consists of hosing the appliance along its perimeter (width 100 mm) by means of at least 12,0 mm nominal size hose held at a distance of not more than 1,5 m from the appliance and with a static water pressure (with no water flow) of 200 kPa and the free height of water from the hose with stream directed upwards of not less than 10 m.

The hosing shall last at least three minutes uniformly applied around the periphery for each appliance and no water shall be detected on the inner side of the appliance.

5.5 Design loads

5.5.1 Design pressure for glazed openings in end bulkheads of superstructures and deckhouses on or above the freeboard deck

This design pressure shall also be applied to storm shutters and deadlights in the exposed bulkheads of superstructures and deckhouses on and above the freeboard deck.

The design pressure equation in IACS UR S 3[9], is adapted to the following equation to give design pressures p_D (kN/m²) for glazed openings and storm shutters in the end bulkheads of superstructures and in the end and side bulkheads of deckhouses on or above the freeboard deck.

Design pressure, p_D (kN/m²), shall be not less than given by the equation:

$$p_\mathrm{D} = 10{,}05 \cdot a \cdot k_\mathrm{s} \cdot \left(b \cdot f - h\right) \cdot c \qquad (1)$$

The design pressures given in IACS UR S 3[9] are also included in ISO 5779[2] and BS MA 25[10].

Definition of symbols introduced in Equation (1):

a = factor relating to location and vessel length, given in Table 1;

k_S = service factor

= 1,00 for unrestricted range yacht,

= 0,85 for intermediate range yacht,

= 0,75 for short range yacht;

b = factor based on longitudinal location, given in Table 3;

f = factor based on vessel length, given in Table 2;

h = height of centre of window from dsw, in m;

c = 0,85;

but in no case is the design pressure p_D (kN/m^2) to be less than

— for $L \leq 50$ m

— front positions on the uppermost continuous deck and superstructure/side shell (A) (see Table 1):

p_D = 30 kN/m^2;

— elsewhere:

p_D = 15 kN/m^2;

— for $L > 50$ m

— front positions on the uppermost continuous deck and superstructure/side shell (A) (see Table 1):

$$p_D = 25 + L/10 \;; \qquad (2)$$

— for all other locations:

$$p_D = 12{,}5 + L/20 \;; \qquad (3)$$

where L is the load line length (m).

For a definition of the limiting significant wave heights for the above operational ranges, see 3.15 to 3.18.

Table 1 — Values of a

	Location		L m							
			24	**30**	**40**	**50**	**60**	**70**	**80**	**90**
a	Fronts	Superstructure or deckhouse at more than 0,02 L [m] above dsw	2,20	2,25	2,33	2,42	2,58	2,62	2,67	2,75
		Superstructure or deckhouse at more than 0,02 $L + h_{std}$ [m] above dsw	1,20	1,25	1,33	1,42	1,50	1,58	1,67	1,75
		Superstructure or deckhouse at more than 0,02 $L + 2\ h_{std}$ [m] above dsw	0,67	0,70	0,77	0,83	0,90	0,97	1,03	1,10
	Sides	Superstructures /Side Shell (A)	Refer to Fronts in this Table							
		Superstructures /Side Shell (B)	See Table 4							
		Deckhouses	0,67	0,70	0,77	0,83	0,90	0,97	1,03	1,10
	Aft end	$x/L_p < 0{,}45$	0,64	0,65	0,66	0,67	0,68	0,69	0,70	0,71
		$x/L_p > 0{,}45$	0,32	0,33	0,34	0,35	0,36	0,37	0,38	0,39

NOTE Type (A) and Type (B) Sides/superstructures are identified as

(A), not included in the assessment of the vessel’s stability and buoyancy, and

(B), included in the assessment of the vessel’s stability and buoyancy.

See also Figure 2.

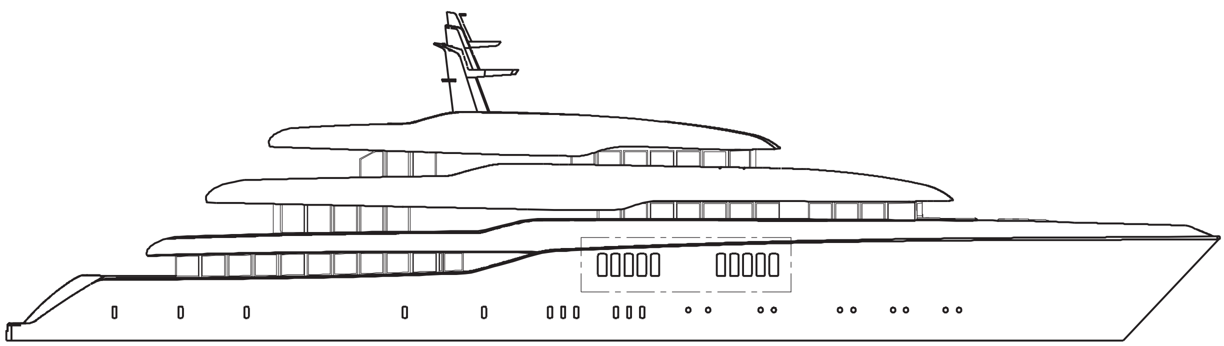


Figure 2 — Superstructure/side shell windows

Table 2 — Values of f

Length L m	24	30	40	50	60	70	80	90
Factor f	1,24	1,74	2,27	3,32	4,07	4,71	5,41	6,00

Table 3 — Values of b

x/L_p	b	x/L_p	b
0,00	1,57	0,50	1,01
0,10	1,34	0,60	1,09
0,20	1,17	0,70	1,26
0,30	1,06	0,80	1,51
0,40	1,01	0,90	1,84
0,45	1,00	1,00	2,25

5.5.2 Design pressure for glazed openings and deadlights in the side shell

Glazed openings and deadlight design pressures shall be as given in Table 4. Design of glazed openings shall include consideration of the strength of the deadlights and their means of attachment to the hull structure.

Table 4 — Design pressures for glazed openings and deadlights between the dsw and uppermost continuous deck

L m	**Motor yachts** kN/m^2	**Cruising sailing yachts** (kN/m^2)
24	70	70
30	70	70
40	70	70
50	70	83
60	76	96
70	84	109
80	91	121
90	98	133

5.6 Scantling determination of panes

Scantling equations given in 5.6.1.1 and 5.6.1.2 are for panes supported on their full perimeter mechanically independent from the adjacent structure.

The equation given in 5.6.1.1 is valid for rectangular panes; for circular panes see 5.6.1.2.

Unsupported clear dimensions for panes are defined in Annex A. For panes having shapes different from a rectangle or a circle, the approximations of Annex A shall be used to determine the “equivalent” unsupported dimensions.

5.6.1 Basic pane thickness — t_O

5.6.1.1 Basic pane thickness — t_O — for rectangular or rectangular equivalent glazed openings

Basic pane thickness t_O is calculated as

$$t_O = b_P \cdot \sqrt{\frac{\beta \cdot p_D}{1\,000 \cdot \sigma_A}} \tag{4}$$

where

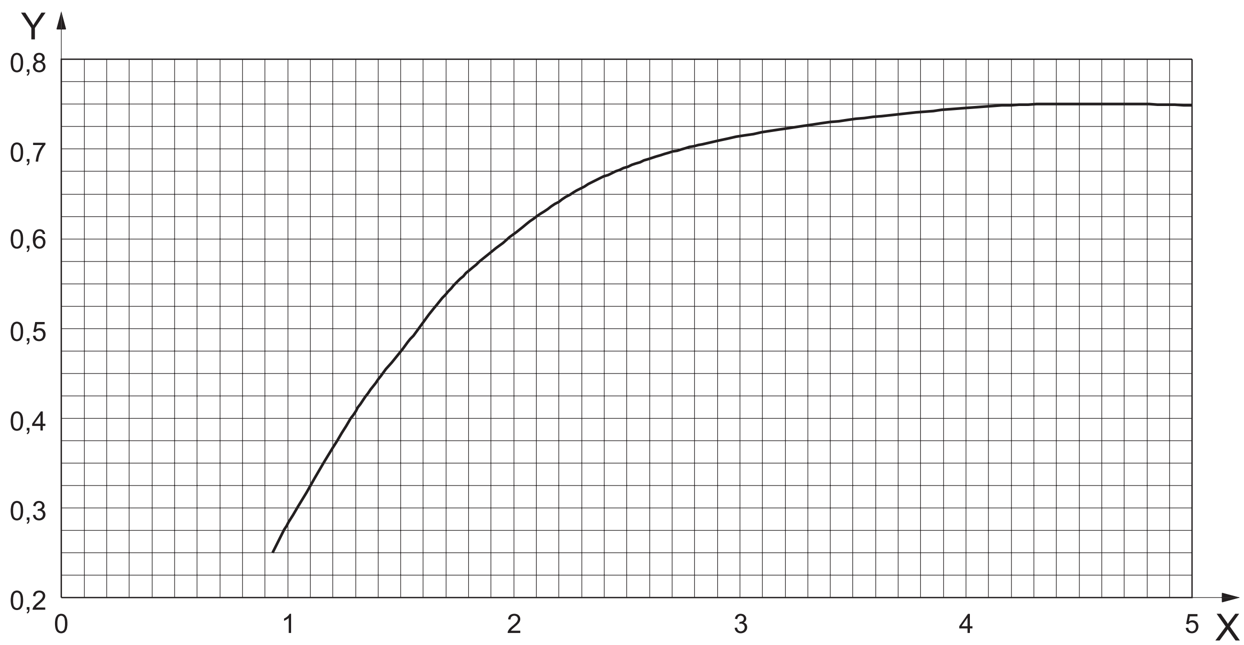
t_O is the basic pane thickness (mm);

b_P is the clear opening short side of a rectangular pane or “equivalent short side” of a pane (mm);

β is the pane aspect-ratio coefficient (see Figure 3 and Table 6);

p_D is the design pressure (see 5.5) (kN/m^2);

σ_A is the allowable design flexural stress of the material (see 5.6.1.3) (N/mm^2).



Key

X aspect ratio, AR, equal to ap/bp

Y pane aspect ratio coefficient, β

Figure 3 — Pane aspect ratio coefficient — β (X = AR)

5.6.1.2 Basic pane thickness — t_O — for circular or circular equivalent glazed openings

Basic pane thickness t_O is calculated as

$$t_O = 0{,}5 \cdot d \cdot \sqrt{\frac{1{,}21 \cdot p_D}{1\,000 \cdot \sigma_A}} \tag{5}$$

where

t_O is the basic pane thickness (mm);

d is the diameter or the equivalent diameter of the glazed opening (mm);

p_D is the basic design pressure (see 5.5) (kN/m^2);

σ_A is the allowable design flexural stress of the material (N/mm^2).

See Annex C for further information.

5.6.1.3 Design flexural stress of material — σ_A

Design flexural stress of material, σ_A, is evaluated from the values of the characteristic failure strength, σ_C, of the material and the relevant design factor, γ, according to

$$\sigma_A = \frac{\sigma_C}{\gamma} \tag{6}$$

The values of characteristic failure strength of the pane material are the manufacturer's stated values. Values shall be used for glass when tested according to EN 1288-3. The accepted value is the one corresponding to the lower confidence interval value evaluated by the t_Student distribution at 90 % probability. Values shall be used for plastic when tested according to ISO 178. The accepted value is the one corresponding to the lower confidence interval value evaluated by the t_Student distribution at 90 % probability Table 5 indicates minimum characteristic failure strength values to be achieved to qualify glazing materials, materials with lower characteristic failure strength are not allowed.

Table 5 — Minimum mechanical properties of materials

Material	Acronym	Characteristic failure strength σ_C N/mm^2	Design factor [a] γ	Design flexural stress σ_A N/mm^2
Polymethylmethacrilate	PMMA	100	3,5	28,6
Polycarbonate	PC	90	3,5	25,7
Thermally toughened safety glass	TTG	160	4,0	40,0
Chemically toughened glass	CTG	160	4,0	40,0

[a] For mixed constructions the higher design factor shall be used.

5.6.2 Selection of monolithic pane thickness

The value of the pane thickness, t_a, expressed in millimetres, to be used in case of monolithic construction, shall be the higher of the following:

— the basic pane thickness, t_O, calculated in 5.6.1;

— the minimum pane thickness, t_{min}, according to the relevant International Standard, ISO 1751, ISO 3903, ISO 21005, when applicable.

With commercially available panes, the actual thickness will be selected as the first upper integer.

5.6.3 Selection of laminated pane thickness

Laminated constructions can be considered

a) laminates with plies of the same material (type A), and

EXAMPLE 1 Glass ply/interlayer/glass ply.

EXAMPLE 2 Plastic ply/interlayer/plastic ply.

NOTE In Example 2, the “plastic” layer always consists of the same material. Examples of type (A) are: Acrylic/interlayer/acrylic or Polycarbonate/interlayer/polycarbonate. It is not type (A) if the construction is: Acrylic/interlayer/polycarbonate.

b) laminates with plies of different materials (type B).

EXAMPLE 1 Glass ply/interlayer/plastic ply.

EXAMPLE 2 Glass ply/interlayer/plastic ply/interlayer/glass ply.

EXAMPLE 3 Acrylic ply/interlayer/polycarbonate ply.

5.6.3.1 Type (A) laminates — Laminates with plies of the same material

5.6.3.1.1 Independent plies

When the mechanical properties of the interlayer material (the laminating adhesive material) are not known, the plies of the laminated glazing have to be considered as mechanically independent.

The equivalent thickness of type (A) laminates made of n independent plies of thicknesses: t_{p1}, t_{p2}, …, $t_{\mathrm{p}n}$, shall be calculated and compared with the basic thickness, t_{O}, calculated according to 5.6.1.

The equivalent thickness of n independent plies shall be calculated as follows. The thickness of one ply of the laminate is indicated generically as, t_j, where the index j is ranging from 1 to n.

For each ply of the laminate a partial equivalent thickness, $t_{\mathrm{eq},j}$, is calculated as

$$t_{\mathrm{eq},j} = \sqrt{\frac{\sum_{i=1}^{n} t_i^3}{t_j}} \qquad j = 1,n \tag{7}$$

and the equivalent thickness of the laminate t_{eq} shall be the minimum of the n $t_{\mathrm{eq},j}$ values:

$$t_{\mathrm{eq}} = \min\left[t_{\mathrm{eq},j}\right]; \qquad j = 1,n \tag{8}$$

The laminate construction is accepted when it results $t_{\mathrm{eq}} \geq t_{\mathrm{O}}$.

5.6.3.1.2 Collaborating plies

When the mechanical properties of the interlayer are known in terms of shear modulus, G (N/mm^2), at 25 °C for 60 s duration load the equivalent thickness shall be calculated as follows.

Definitions:

t_1 ply thickness (mm);

t_2 ply thickness (mm);

t_I interlayer thickness (mm);

a shortest clear opening dimension of the glazing laminate (mm);

E Young's modulus of the ply (N/mm^2);

G shear modulus of the interlayer at 25 °C (N/mm^2).

Acceptable value for polyvinyl butyral (PVB) is: $G = 1{,}6$ N/mm^2. For other interlayer materials the shear modulus value at 25 °C for short time duration load (60 s) shall be declared by the interlayer material manufacturer. In case this value is not known the plies shall be considered independent and 5.6.3.1.1 shall be used.

Preliminary calculations:

$$hs = 0{,}5 \cdot (t_1 + t_2) + t_I$$

$$t_{s;2} = \frac{hs \cdot t_2}{t_1 + t_2} \quad ; \quad t_{s;1} = \frac{hs \cdot t_1}{t_1 + t_2}$$

$$Is = t_1 \cdot t_{s;2}^2 + t_2 \cdot t_{s;1}^2$$

Shear transfer coefficient evaluation (for independent plies $\Gamma = 0$, for full collaborating plies as "monolithic" behaviour $\Gamma = 1$):

$$\Gamma = \frac{1}{1 + 9{,}6 \cdot \frac{E}{G} \cdot \frac{Is}{hs^2} \cdot \frac{t_I}{a^2}} \quad (9)$$

Equivalent thicknesses evaluation:

For deflection:

$$t_{\text{eq;W}} = \sqrt[3]{t_1^3 + t_2^3 + 12 \cdot \Gamma \cdot Is} \quad (10)$$

For strength:

$$t_{\text{1ef;}\sigma} = \sqrt{\frac{t_{\text{eq;W}}^3}{t_1 + 2 \cdot \Gamma \cdot t_{\text{s;2}}}} \quad t_{2ef;\sigma} = \sqrt{\frac{t_{\text{eq;W}}^3}{t_2 + 2 \cdot \Gamma \cdot t_{\text{s;1}}}} \quad (11)$$

Equivalent thickness shall be selected as

$$t_{\text{eq}} = \min\left[t_{1ef;\sigma}, t_{2ef;\sigma}\right] \quad (12)$$

In case of multiple (more than two plies) laminates the calculation shall be iterated. The iteration shall start from the outer ply (the one directly loaded by water pressure) and end with the inner ply. See Annex E for examples.

The laminate construction is accepted when it results $t_{\text{eq}} \geq t_{\text{O}}$.

5.6.3.2 Type (B) laminates — Laminates with plies of different materials

When the laminate construction is of type (B), the plies of the laminated glazing shall be considered as mechanically independent and the equivalent thickness of n independent plies of different materials shall be calculated as follows. The thickness of one ply of the laminate is indicated generically as t_j and its Young's modulus as E_j where the index j is ranging from 1 to n.

For each ply of the laminate a partial equivalent thickness, $t_{eq,j}$, is calculated as

$$t_{eq,j} = \sqrt{\frac{\sum_{i=1}^{n} E_i t_i^3}{E_j t_j}} \qquad j = 1,n \tag{13}$$

and the equivalent thickness of the laminate, t_{eq}, shall be the minimum of the n $t_{eq,j}$ values:

$$t_{eq} = \min\left[t_{eq,j}\right]; \qquad j = 1,n \tag{14}$$

See Annex F for examples.

The laminate construction is accepted when it results $t_{eq} \geq t_O$.

t_O shall be calculated for the same material type corresponding to the material for which minimum value of $t_{eq,j}$ is selected.

5.6.3.3 Selection of laminates thickness by flexural testing

The flexural strength of a multiply laminate of physical thickness, t_{Lam}, can be determined as characteristic flexural strength by a four point bending strength test according to the method described in EN 1288-3 as outlined in 7.2.1.

The measured characteristic flexural strength value is strictly to be referred to the actual cross section of the tested laminated pane.

The characteristic flexural strength of the laminate divided by the design factor of glass shall be considered as the allowable design flexural stress of the laminate.

Scantling equation in 5.6.1 may be used to calculate the basic pane thickness, t_O, resulting from design pressure, geometry of the laminated pane and its allowable flexural strength.

The physical thickness of the laminate, t_{Lam}, shall be compared with the calculated t_O and it is accepted when

$$t_{Lam} \geq t_O$$

5.6.4 IGU panes determination

5.6.4.1 Stepped IGU

In stepped IGU one of the panes is fixed to the framing while the other pane is not supported by the framing structure. In this case the framed pane of the IGU shall be selected according to 5.6.2 if monolithic or 5.6.3 if laminated using the relevant design pressure loads from 5.5.

5.6.4.2 Unstepped IGU

In unstepped IGU both panes are supported by the framing structure. These IGU types shall be qualified by the hydrostatic pressure test according to 7.3 performed on the complete appliance.

5.6.5 Strength requirements of fire resistant glazing

The strength requirement for fire-resistant glazing shall be fulfilled by evaluating the construction according to ISO 5797.

5.6.6 Maximum deflection limitation

The maximum deflection of the structural pane either monolithic, laminated or stepped IGU shall be calculated as

$$\delta_{max} = \alpha \cdot \frac{p_D \cdot b_P^4}{1000 \cdot M} \qquad (15)$$

where

δ_{max} is the maximum pane deflection (mm);

α is the pane aspect-ratio deflection coefficient (see Table 6);

p_D is the design pressure (see 5.5) (kN/m^2);

b_P is the unsupported short side of a rectangular pane or “equivalent short side” of a pane (mm);

M is the pane stiffness calculated according to Annex B where t_W is the physical thickness in case of monolithic glazing (Nmm) and is

$$t_W = \sqrt[3]{t_1^3 + t_2^3 + .. + t_n^3}$$

in case of Type (A) laminated glazing with independent plies, and

$$t_W = t_{eq;W}$$

in case of Type (A) laminated glazing with collaborating plies, and

$$t_W = t_{eq;}$$

in case of Type (B) laminates.

The structural glazing will be accepted if

$$\delta_{max} \leq \frac{a_P}{50}$$

where a_P (mm) is the clear opening long side of a rectangular pane or “equivalent long side” of a pane.

Table 6 — Coefficients α and β versus aspect ratio

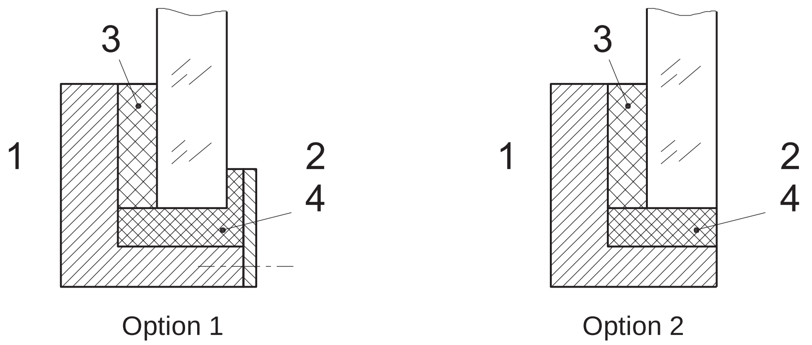
Aspect ratio AR = a_P/b_P	α	β
1,0	0,004 06	0,287 4
1,1	0,004 85	0,332 4
1,2	0,005 64	0,376 2
1,3	0,006 38	0,416 4
1,4	0,007 05	0,453 0
1,5	0,007 72	0,487 2
1,6	0,008 30	0,517 2
1,7	0,008 83	0,544 8
1,8	0,009 31	0,568 8
1,9	0,009 74	0,591 0
2,0	0,010 13	0,610 2
3,0	0,012 23	0,713 4
4,0	0,012 82	0,741 0
5,0	0,012 97	0,747 6
∞	0,013 02	0,750 0

6 Framing

Glazed openings are generally framed if the glazed openings are designed to be independent from loads of the adjacent structure. The framing shall provide a safe and secure fixing of the glazing. The glazing shall either be clamped with elastomer gaskets or bonded and additionally secured with an elastomer gasket between glazing and retaining frame, or bonded at both sides. Framing concept types are represented in Figures 4, 5 and 6. The sketches are not to scale and shall be considered as a concept arrangement.

Bonding requirements are defined in ISO 11336-2.

6.1 Framing types



Key

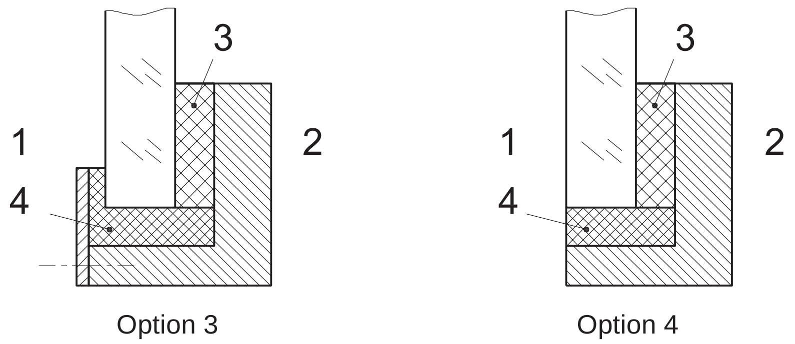
1 inside

2 outside

3 bonding

4 seal

Figure 4 — Framing types 1 and 2



Key

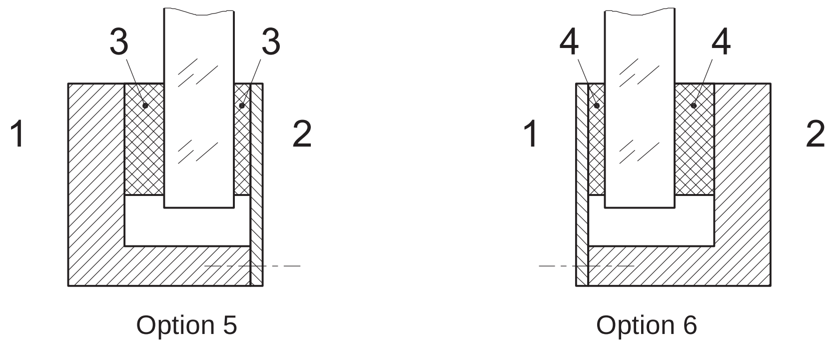
1 inside

2 outside

3 bonding

4 seal

Figure 5 — Framing types 3 and 4



Key

1 inside

2 outside

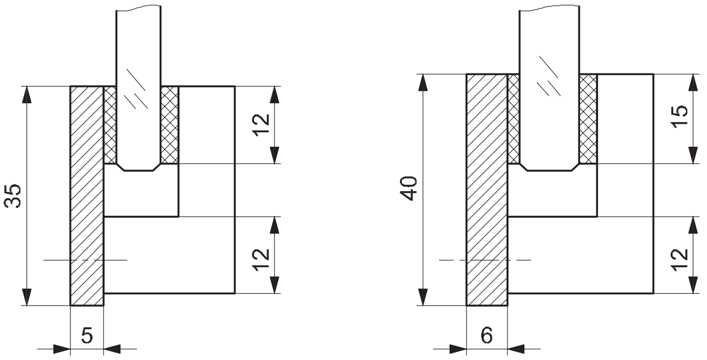
3 rubber gasket

4 rubber gasket

Figure 6 — Framing types 5 and 6

6.2 Framing dimensions

The dimensions indicated in Figure 7 shall be considered as minimum dimensions. Chamfered edge or other preparations (i.e. bullnose) of the glass edge shall not be included in the width of overlap indicated in Figure 7. The direct contact between frame and glazing shall be avoided.



Glazed opening clear view ≤ 1,00 m^2 Glazed opening clear view ≤ 2,50 m^2

Figure 7 — Minimum dimensions (mm)

6.2.1 Clear view: > 0,45 m^2 up to 1 m^2

Glazed openings with smaller dimensions are covered by existing International Standards, e.g. ISO 3903. Elastomer gaskets shall have the following characteristics: Shore A 50-70, width ≥ 12 mm, thickness outside 2 mm to 6 mm (not in compression) thickness inside 2 mm to 4 mm (not in compression). The gaskets shall be properly secured against dislocation (i.e. gluing, positive fit). The distance between frame and glass shall not be less than 5 mm.

6.2.2 Clear view: > 1 m^2 up to 2,5 m^2

For glazed openings with clear view > 1 m^2 up to 2,5 m^2 elastomer gaskets shall have the following characteristics: Shore A 55-70, width ≥ 15 mm, thickness outside 4 mm to 6 mm (not in compression), thickness inside 2 mm to 4 mm (not in compression). The distance between frame and glass shall not be less than 7 mm.

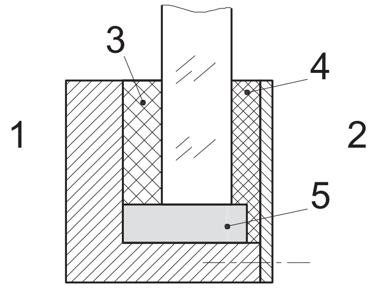
Glazed openings with a clear view exceeding the 2,50 m^2 shall be considered on case by case basis.

Windows which are fitted in such a way that the adhesive is under tension load are not permitted in or below areas 1, 2, and 3 (see Figure 9 and Figure 10).

All load transmitting elements in the load path between the glazing and the adjacent bulkhead structure shall generally be metal and are to be based on the glazing design pressure and a design factor of 1 on the yield strength of the material.

6.3 Support pads

Support of the glass mass and secure positioning within the frame shall be achieved by support pads with comparable elastic properties as the elastomeric gasket or the bonding material. Support pad arrangement is shown in Figure 8. The compatibility of materials between support pad and bonding shall be assured.



Key

1 inside

2 outside

3 bonding

4 elastomer gasket

5 support pad

Figure 8 — Support pads

6.4 Material requirements for the framing

All materials used shall be in compliance with or equivalent to existing International Standards ISO 3903 or ISO 1751. The strength of metal frames shall ensure under the window design pressures that the yield strength of the material is not exceeded. Non-metallic frames are outside the scope of this part of ISO 11336.

Bolts generally should be of stainless steel with a minimum grade 50. The bolt material shall be compatible both in terms of strength and corrosion with the frame. The supplier shall ensure that the mechanical properties are achieved and valid documentation shall be provided.

Bolts shall have at least M6 and shall fulfil the general requirements for the thread/screwed-in depth for the used frame material. The maximum allowable pitch of the bolts shall not exceed 75 mm (according to ISO 3903 Heavy type E).

Deviating materials i.e. larger bolts or bolts with a higher grade and smaller screw pitch can be used to meet the respective requirements. They shall be specified by the manufacturer and approved by the certifying authority.

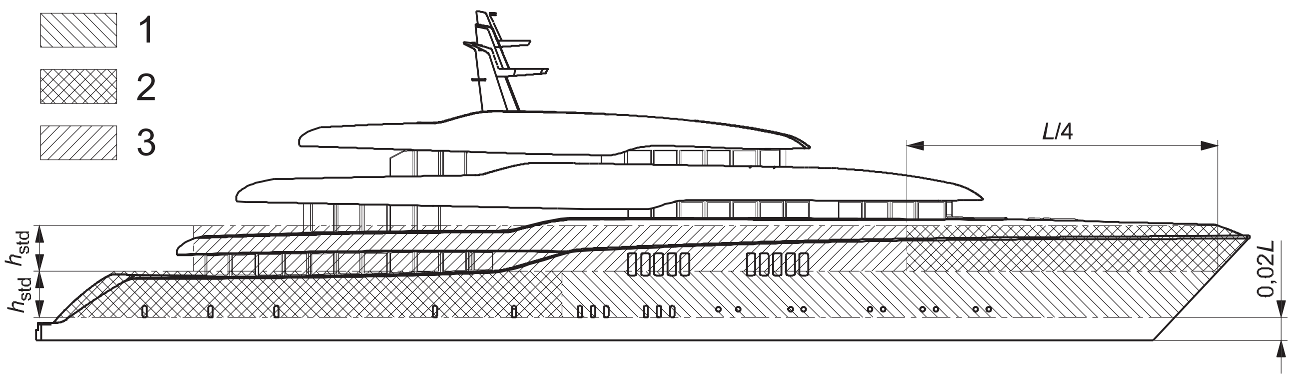


Figure 9 — Areas of typical motor yacht

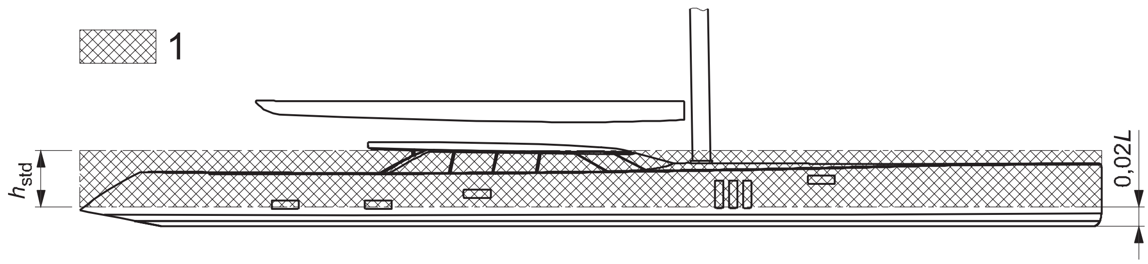


Figure 10 — Areas of typical sailing yacht

7 Materials

In Clause 7 are identified the glazing materials that can be used within the scope of this part of ISO 11336. Testing methods for the qualification of these materials for use with this part of ISO 11336 are also shown.

NOTE The testing methods for the characteristic failure strength of pane materials and the selection of laminates by flexural testing are shown in Clause 5.

7.1 Materials selection

Panes shall be made of glazing materials, such as toughened glass (thermally - TTG or chemically - CTG), polycarbonate (PC) or polymetylmetacrilate (PMMA).

Other materials of comparable strength and stiffness to those cited above, may be considered.

7.1.1 Glass

7.1.1.1 Restrictions of usage

— For laminated constructions only thermally or chemically toughened glass shall be used.

— For monolithic construction only toughened safety glass meeting the requirements of the fragmentation test outlined in EN 12150-1:2000, Clause 8 shall be used.

— Thermally toughened glass used both in monolithic or laminated construction shall meet the requirements of EN 12150-1.

— For laminated construction the glazing shall meet the requirements outlined in ISO 12543-1.

— In wheelhouse glazing, for both front and sides positions, laminated safety glass shall be used.

— Coating (hard or soft) shall not influence the strength of the glass.

7.1.1.2 Chemically toughened glass

Chemically toughened glass (CTG) shall meet the requirements outlined in EN 12337-1. For marine applications, CTG is not covered by existing International Standards. For this reason, it shall be qualified as a structural material. The qualification of chemically toughened glass as structural material shall be performed according to 7.1.1.2.1 and 7.1.1.2.2.

7.1.1.2.1 Chemically toughened glass strengthening characteristics

The following characteristics shall be declared by the glass ply manufacturer for structural qualification:

— depth of compression layer, l_{CD} (µm);

— surface compression, s_C (N/mm^2);

— characteristic breaking strength, σ_C (N/mm^2).

The glass ply manufacturer is also responsible for the production conformity to the declared values.

7.1.1.2.2 Qualification by the characteristic breaking strength

CTG shall be qualified by its Characteristic breaking strength, σ_C, value. For this purpose, the glass ply manufacturer shall declare its characteristic breaking strength, σ_C (N/mm^2), as defined in EN 1990:2008, Annex D, and determined by mechanical tests according to 7.2.1.

Acceptable values to comply with this part of ISO 11336 are at minimum

$$\sigma_C \geq 160 \text{ N/mm}^2$$

Quality production control is introduced in ISO 11336-3.

This structural qualification does not take into consideration the effects coming from surface abrasion resulting during pane service life. These effects can introduce additional requirements on the strengthening characteristics. Such additional requirements may be considered and introduced by recognized organizations and authorities.

7.1.2 Materials other than glass

7.1.2.1 Rigid plastic materials

7.1.2.1.1 Restrictions of usage

For monolithic construction only rigid plastic panes with a minimum characteristic failure strength of 90 MPa shall be used.

Plastic panes (monolithic) or plies (laminated) shall be used according to indications of material manufacturers both in terms of chemical compatibility with other materials (adhesives, sealants, gaskets) and application conditions (with special attention to exposure to outdoor environment).

7.1.2.2 Interlayers

In laminated glazing, thermo plastic adhesive films or thermo setting curable resins may be used as adhesive materials to keep together glass or plastic plies.

Interlayer materials shall be used according to indications of the material manufacturer both in terms of chemical compatibility with other materials (glass, plastic plies, sealants, gaskets) and application conditions (with special attention to exposure to outdoor environment) and in terms of laminated glazing manufacturing. The glazing manufacturer is responsible of following indications, precautions and manufacturing methods approved by the interlayer material manufacturer.

Where, for collaborating plies of a laminated glazing, the contribution of the interlayer shall be taken into account, the shear modulus G (MPa) at 25 °C for short duration load (60 s) shall be declared by the interlayer manufacturer. In cases where there is no declaration, the plies shall be considered as mechanically independent.

If a value is available only for Young’s modulus, E (MPa), a shear modulus may be assumed as $G = E/3$.

Where the interlayer is made of polyvinyl butyral (PVB) a shear modulus value may be assumed as $G = 1{,}6$ MPa.

7.2 Testing of materials

This is limited only to tests for structural qualification of glazing materials. Other qualification tests are not included here and shall be performed according to International Standards relevant to the specific material.

7.2.1 Glass

Characteristic flexural strength of glass materials shall be determined by flexural four point bending test according to EN 1288-3.

The characteristic failure strength, σ_C, shall be determined by mechanical tests as follows:

N number of test specimens (at least 10);

σ_i breaking stress (MPa) for each test specimen tested according to EN 1288-3;

σ_{av} average value;

$$\sigma_{av} = \frac{1}{N} \cdot \sum_{i=1}^{N} \sigma_i \tag{16}$$

s_x standard deviation;

$$s_x = \sqrt{\frac{\sum_{i=1}^{N} (\sigma_i - \sigma_{av})^2}{N-1}} \tag{17}$$

C_V coefficient of variation;

$$C_V = \frac{s_x}{\sigma_{av}}$$

Kn statistic coefficient corresponding to 90 % confidence limit. This value depends on the number of test specimens, N, according to the *t*-Student statistical distribution, see Annex D.

With the above definitions, σ_C, characteristic failure strength is

$$\sigma_C = \sigma_{av} \cdot (1 - Kn \cdot C_V) \tag{18}$$

7.2.2 Rigid plastic materials

Characteristic failure strength, σ_C, for rigid plastic materials shall be determined by the flexural three point bending test according to ISO 178 as follows:

N number of test specimens (at least 10);

σ_i breaking stress (MPa) or, when not applicable, yield stress for each test specimen;

σ_{av} average value;

$$\sigma_{av} = \frac{1}{N} \cdot \sum_{i=1}^{N} \sigma_i \tag{19}$$

S_x standard deviation;

$$s_x = \sqrt{\frac{\sum_{i=1}^{N} (\sigma_i - \sigma_{av})^2}{N-1}} \tag{20}$$

C_V coefficient of variation;

$$C_V = \frac{s_x}{\sigma_{av}}$$

Kn statistic coefficient corresponding to 90 % confidence limit. This value depends on the number of test specimens, N, according to the t-Student statistical distribution, see Annex D.

With the above definitions, σ_C, characteristic failure strength is

$$\sigma_C = \sigma_{av} \cdot \left(1 - Kn \cdot C_V\right) \tag{21}$$

7.3 Testing of appliances

7.3.1 Test procedure for hydrostatic structural testing of marine windows system

7.3.1.1 Scope

This procedure establishes an experimental method for proof testing of marine glazed openings system to assess their strength and watertightness characteristics. The test shall be performed on the complete glazed opening assembly including the fixing system. The glazed opening system has two main components:

— glazing;

— edge fixing system (clamping, framing, bonding or any mechanical/chemical method to fix the glazing on the ship structures).

When the glazing cross section is already qualified according to 5.6, the hydrostatic test shall be understood to be a qualification test of the fixing system and the hydrostatic test shall be performed on one sample.

When the glazing cross section cannot be qualified, the hydrostatic test shall be understood to be a qualification test on the complete system (glazing and fixing) and the test shall be performed on three samples.

7.3.1.2 Motivations

Motivations for testing glazed opening systems are

— innovative materials or construction systems which are introduced and are not considered in existing International Standards,

— edge fixing which is performed by bonding or by any method not included in existing International Standards, and

— strength and watertightness characteristics of the glazed opening systems which cannot be predicted according to the International Standards above reported or to 5.6 calculations.

7.3.1.3 Apparatus

7.3.1.3.1 Testing assembly

The test shall be carried out using a testing basin which ensures the watertightness up to the requested test pressure. The basin shall show the real assembly situation on board, using identical or equivalent materials and dimensions.

The filling water piping and the basin pressure measuring piping shall be separated.

During filling the basin with water, ensure that air trapping is eliminated or at least minimized.

The supporting structure of the tested window system shall be stiff enough to prevent edge deflection which will influence the test results.

7.3.1.3.2 Measuring instruments

It is a technical responsibility of test operators to run tests with calibrated measuring instruments meeting metrological criteria in terms of reference to international measuring unit system, accuracy and repeatability.

7.3.1.3.3 Sample

The tested sample shall be representative of the glazed opening construction and installation on board. A drawing of sample construction and fixing shall be provided and included in the test documentation.

7.3.1.3.4 Test procedure

The test shall be carried out by laboratories or institutions meeting, in general, the requirements of ISO/IEC 17025. Alternatively, window manufacturers fulfilling the equivalent minimum standard may perform such tests.

The test shall be carried out as follows.

Procedure (A):

a) Dimensions of all main components (basin and glazed opening) shall be checked and recorded.

b) Measuring instruments gauges shall be calibrated.

c) Design test pressure, p_D (kN/m^2), shall be established according to 5.5.

Chamber pressure shall be raised up to p_D and maintained for at least 300 s. The pressure in the test chamber shall be raised up to design factor times (Table 5) the design load pressure (γ x p_D).

Three unloading/loading cycles shall be performed within the pressure range from 1 x p_D to γ x p_D starting at below 1/2 γ x p_D and going to γ x p_D.

d) Central deflection shall be measured and recorded up to the design pressure. The basin pressure shall be measured and recorded continuously during the test.

e) Any event such as loss of watertightness (from the glazing or from the fixing system) or glass plies breakage shall be recorded by the test operators with the relevant test pressure.

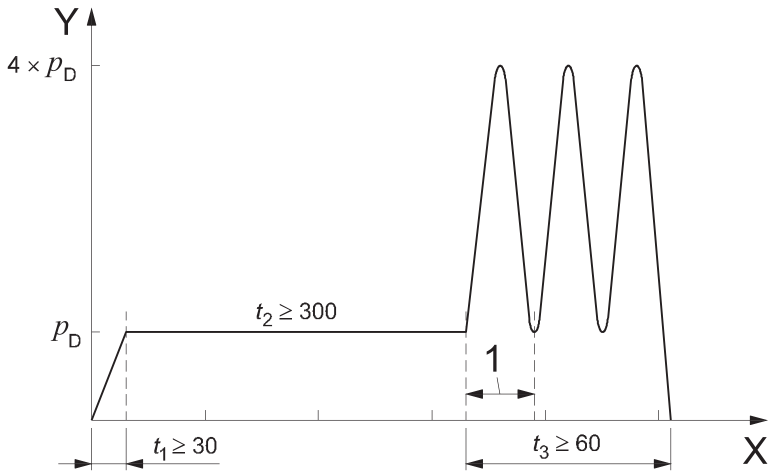
f) Unless otherwise specified and if possible, the sample shall be taken to final collapse.

Procedure (B):

Preliminary operations included in procedure (A) [namely a), b) and c)] shall be completed.

Pressure cycle shall be as in Figure 12 (cyclic phase, hold phase and final rise to test pressure).

Operations requested for procedure (A) [namely d), e) and f)] shall be completed.



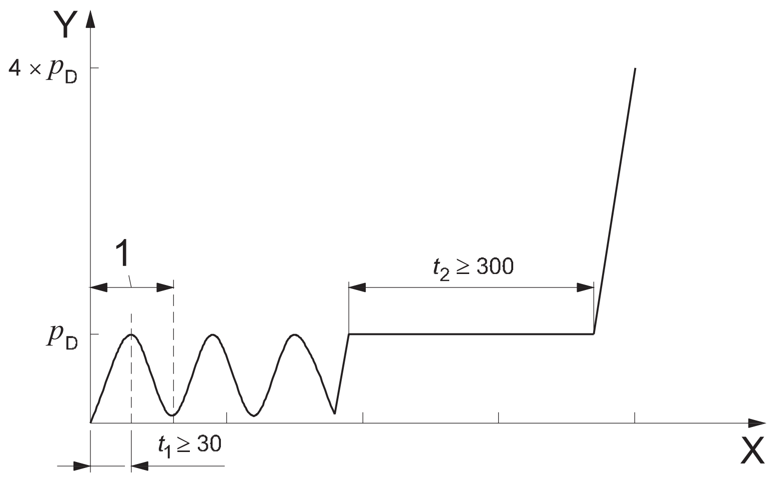
Key

X time

Y pressure

1 loading/unloading cycle

Figure 11 — Water pressure vs. time for test procedure (A)



Key

X time

Y pressure

1 loading/unloading cycle

Figure 12 — Water pressure vs. time for test procedure (B)

Chamber pressure shall be raised up to p_D and three unloading/loading cycles shall be performed within the pressure range from unloaded to p_D. Then the pressure should be maintained for at least 300 s. Finally the water pressure shall be raised up to γ times (see Table 5) the design load pressure.

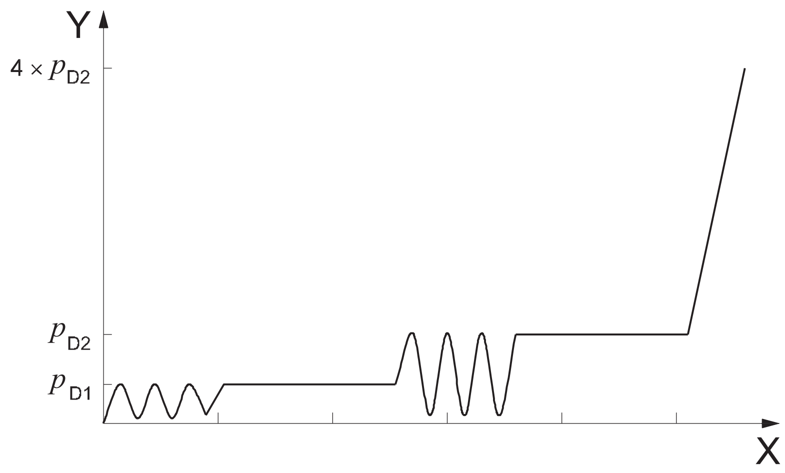
Procedure (C):

This is a procedure for a stepped test, in which one glass construction is tested for two (or more) different design loads.

Preliminary operations included in procedure (A) [namely a),b) and c)] shall be completed.

Pressure cycle shall be as in Figure 13 (cyclic phase at pressure p_{D1}, cyclic phase at pressure p_{D2}, hold phase and final rise to test pressure).

Operations requested for procedure (A) [namely d), e) and f)] shall be completed.



Key

X time

Y pressure

Figure 13 — Water pressure vs. time for test procedure (C)

7.3.2 Acceptance criteria

The test is passed if the system withstands the design factor times p_D load pressure without failure of any part of the system and the watertightness is maintained. Design pressure shall be reached in not less than 30 s for both procedure (A) and (B) and first design pressure for procedure (C) and the three unloading/loading cycles for procedure (A) shall be performed in not less than 60 s. Providing that the fixing system is maintained in terms of construction details, geometrical dimensions and materials, and the pane cross section is identical, test acceptance may be extended to any glazed opening with lower requirements regarding strength (design pressure p_D) and size.

Tolerances for size extension are limited to a maximum of 5 % of each individual clear length of the glazing.

In case of earlier breakage of the sample the maximum achieved pressure value can be divided by design factor in order to define the maximum load capacity for the tested glass construction.

EXAMPLE For glass:

Required: $p_D = 20$ kPa.

4 x $p_D = 80$ kPa should be achieved.

The sample breaks at 60 kPa.

60 kPa/4 = 15 kPa means that this glass construction can be applied for locations with defined $p_D = 15$ kPa.

7.3.2.1 Glazing equivalent to storm shutters

For qualification through calculation (5.6), where windows are requested with storm shutters, to waive them, the glass thickness and equivalent thickness (in case of laminated construction) shall be calculated using a design pressure increased by a factor 1,5 (see also Annex G for discussion about this factor) in respect to design pressure calculated according to 5.5.

For qualification through hydrostatic test (7.3), where windows are requested with storm shutters, to waive them, the glass thickness and equivalent thickness (in case of laminated construction) shall be tested at a design pressure increased by a factor 1,5 in respect to design pressure calculated according to 5.5. Final test pressure shall be kept at 4 times design pressure calculated according to 5.5.

7.3.3 Test report

The test report shall contain at least the following information:

— date and location of the test;

— window sample engineering documentation (drawings and description of glazing and fixing system);

— when the test is a type approval test, production documents are provided identifying the production controls performed during sample manufacturing;

— measuring instruments description;

— test conditions description: design pressure test, p_D, description of testing chamber and of hydraulic circuits;

— test procedure selection;

— test results: pressure rate to reach design pressure from beginning of the test, waiting time at design pressure, pressure rate to reach test pressure, watertightness failures and locations, glazing plies breakage events, other relevant events related to strength, watertightness of the window;

— name and institution of people witnessing the test;

— test operators and their qualification in terms of test responsibilities and institution responsibilities;

— bonding methods and qualification of the bonding personnel.

8 Storm shutters and deadlights

The purpose of storm shutters is to protect the glass against impact by debris or other objects and to provide resistance against extreme green sea loads and limit the ingress of water in case of breakage of the glazed openings.

The purpose of deadlights is to provide a means to maintain the watertight integrity of the buoyancy volume in case of breakage of the glass or leakage of the glass mounting.

As a minimum, storm shutters shall be provided for openings located in side bulkheads at a height (h) above the waterline less than $(0{,}05L + 1{,}80)$ m, and in front bulkheads at a height above the waterline less than $(0{,}05L + 3{,}6)$ m.

Deadlights shall be provided to glazed openings in the side shell.

Alternative arrangements to waive storm shutters are generally subject to the approval of the certifying authority. See G.2.

Waiving deadlights to glazed openings in the side shell is not permitted.

8.1 Storm shutters

8.1.1 General practice

Storm shutters shall be fitted externally on the bulkhead.

8.1.2 Material

Storm shutters shall be constructed of a material acceptable for hull construction and for the bulkheads in which the windows are located.

Metal storm shutters are generally an aluminium plate, suitably stiffened or extruded panels bolted to the bulkhead. Aluminium alloys shall be of the 5 000 series (wrought alloy plating and stiffeners) or 6 000 series (extruded alloy sections). Alloy of the 2 000 series may be used, if suitable for marine applications.

Fibre reinforced plastics (FRP) storm shutters may be single skin or sandwich laminate, as can be used for bulkhead construction.

8.1.3 Construction

The construction shall be to the quality standards and material testing as required for the structure of the bulkhead in which the storm shutter is located.

8.1.4 Design pressures and design flexural stresses

Design pressures shall be the same as required for windows in accordance with 5.5.

Design flexural stress for aluminium constructions shall be taken as the yield strength of 0,2 % proof stress.

Design flexural stresses shall take into account the un-welded or as-welded yield strength depending on whether the construction is welded or extruded as specified in EN 13195-1.

For FRP a factor of safety to failure of 3 shall be achieved.

8.1.5 Structural model

Plating shall be considered simply supported at the edges of the window and between stiffeners.

Stiffeners shall be considered simply supported.

Stiffeners shall be checked for bending strength, shear strength, and tripping.

Support from mullions shall be considered using a grillage approach provided the EI of the mullions and the bulkhead supporting structure are considered in the grillage calculation.

8.1.6 Scantlings

Scantlings of storm shutters may be determined by direct calculation or through simple expressions as shown below.

8.1.6.1 Plating

Thickness of plating shall be calculated according to Equation (22) in case of aluminium material and according to Equation (23) in case of FRP material.

$$t_{\text{Aluminium}} = s \cdot 1\,000 \cdot \left[\left(\frac{p_{\text{D}}}{8} \right) \cdot \left(\frac{4}{1\,000 \cdot \sigma_{\text{y}}} \right) \right]^{0,5} \qquad (22)$$

$$t_{\mathrm{FRP}} = s \cdot 1\,000 \cdot \left[\left(\frac{p_{\mathrm{D}}}{8} \right) \cdot \left(\frac{6}{1\,000 \cdot 0{,}28 \cdot \sigma_{\mathrm{fu}}} \right) \right]^{0{,}5} \tag{23}$$

Sandwich laminates shall have strength not less than required for a single skin laminate storm shutter, with each skin not less than 3 plies

where

- t is the required thickness of plating or single skin laminate, generally not less than 5 mm (mm);
- s is the spacing of stiffeners (mm);
- p_{D} is the design pressure (kN/m^2);
- σ_{y} is the tensile yield strength (for welded aluminium this shall be in the as-welded condition) (N/mm^2);
- σ_{fu} is the flexural strength of single skin laminate (N/mm^2).

8.1.6.2 Sandwich laminate

Section modulus, SM (cm^3) for a width of sandwich of 1 cm

$$SM = \left(\frac{t^2}{600} \right) \cdot \left(\frac{\sigma_{\mathrm{uave}}}{\sigma_{\mathrm{uc}}} \right) \tag{24}$$

where

- SM is the section modulus of width of sandwich of 1 cm (cm^3);
- t is the required thickness in accordance with Equation (22) (aluminium) (mm), or Equation (23) (FRP) (mm);
- σ_{uc} is the ultimate compression strength of sandwich skin (N/mm^2);
- σ_{ut} is the ultimate tensile strength of sandwich skin (N/mm^2);
- σ_{uave} is the $(\sigma_{\mathrm{uc}} + \sigma_{\mathrm{ut}})/2$ (N/mm^2).

Core thickness, t_{c} (mm)

$$t_{\mathrm{c}} = \frac{0{,}50 \cdot p_{\mathrm{D}} \cdot s}{1\,000 \cdot 0{,}40 \cdot \tau_{\mathrm{u}}} \tag{25}$$

where

- t_{c} is the required thickness of core = core thickness + 0,50 combined thickness of the skins (mm);
- τ_{u} is the minimum shear strength of core material (N/mm^2).

8.1.6.3 Stiffeners

Aluminium

$$SM = 125 \cdot \frac{p_D \cdot s \cdot l^2}{\sigma_y} \tag{26}$$

where

SM is the required section modulus of stiffener including the attached plating, cm^3;

p_D is the design pressure (kN/m^2);

s is the spacing of stiffeners (m);

l is the unsupported length of stiffener (m);

σ_y is the tensile yield strength (for welded aluminium this shall be in the as-welded condition) (N/mm^2).

$$A = 1\,000 \cdot \frac{p_D \cdot s \cdot l}{2 \cdot \tau_y} \tag{27}$$

where

A is the required web area of stiffener (mm^2);

p_D is the design pressure (N/mm^2);

s is the spacing of stiffeners (m);

l is the unsupported length of stiffener (m);

τ_y is the shear yield strength (for welded aluminium this shall be in the as-welded condition (N/mm^2);

web thickness shall be not less than

t_w depth/*k* mm;

$k = 6$ for aluminium flat bar,

$= 11$ for aluminium angle bars and “T” section.

FRP

Stiffeners where fitted shall be single skin laminate

$$SM = 125 \cdot \frac{p_D \cdot s \cdot l^2}{0{,}28 \cdot \sigma_u} \tag{28}$$

where

SM is the required section modulus of stiffener (cm^3);

p_D is the design pressure (kN/m^2);

s is the spacing of stiffeners (m);

l is the unsupported length of stiffener (m);

σ_u is the tensile strength of stiffener laminate (N/mm^2);

t_w is the depth/3 (m).

Effective width of plating shall be as specified in Annex H.

8.1.6.3.1 Structural detail

Stiffeners shall be arranged such that they can take the design loads and adequately transmit them to the surrounding yacht structure.

Storm shutter shall suitably overlap all around.

8.1.6.3.2 Metal construction

Stiffeners shall be sniped at their ends and stopped 15 mm from the storm shutter plate edge. The snipe shall be not less than 1 in 3 and shall start at 50 mm overlap of the stiffener onto the bulkhead structure.

Welding of stiffener to plating may be intermittent. Welding shall be full return at the end of stiffeners of not less than 100 mm.

8.1.6.3.3 FRP construction

FRP stiffeners, where fitted, shall be laminated or bonded to the storm shutter plate.

An important thing is that the spacing between the glass pane and the storm shutter shall be bigger than the maximum deflection of the storm shutter under design load.

8.1.7 Attachment to bulkhead

The storm shutters shall be effectively attached to the bulkhead e.g. by bolted connections or by fitting into retaining bars.

In selecting the materials for the means of securing, the effects of corrosion between dissimilar metals shall be considered.

Bolt diameter shall be at least M12 spacing maximum 500 mm; alternative arrangements shall be approved by the certifying authority.

Bolts shall be permanently attached to the storm shutter.

Where bolts and plate are of different materials, shear stress and bearing stress shall be designed to consider the different material mechanical properties.

8.2 Deadlights

8.2.1 General practice

Deadlights shall generally be permanently attached if located in the areas indicated in Figure 1. Where portable deadlights are allowed they shall be stored in an easily accessible location and readily and safely mounted in any sea condition.

8.2.2 Material

Materials shall be either in accordance with ISO 1751, marine grade aluminium alloy, or composite material as used for hull construction. Cast aluminium alloy shall be of a ductile type with elongation to breakage not less than 6 %.

Other materials shall be ductile, acceptable for hull construction and approved by the certifying authority.

8.2.3 Design pressure and design flexural stresses

Deadlights shall be dimensioned such that when loaded by the design pressure the yield stress is not exceeded.

For portlights up to 450 mm diameter, the deadlight and all associated hinge pins, securing devices and fittings, can be taken in accordance with ISO 1751.

For openings larger than 450 mm diameter, the deadlight shall be designed considering the same design pressure as required for the glazing. Subject to this pressure the stress in deadlight and all load carrying fittings is not to exceed the yield strength.

8.2.4 Testing

The deadlights in the mounted position shall be tested for watertightness using a design pressure of 42% of the design pressure.

When equivalent strength is not shown by calculations, the deadlights in the mounted position shall be tested for strength at a test pressure according to ISO 1751. After the test, any permanent deformation shall not be more than 1 % (0,01 times) the smaller dimension of the clear opening.

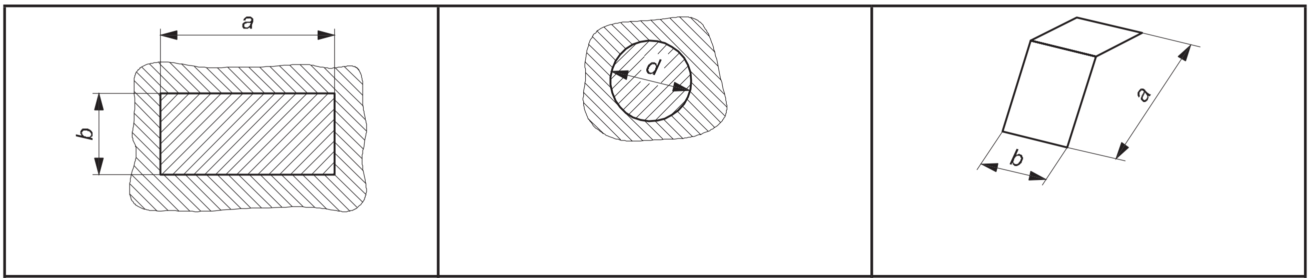
8.3 Owner’s manual

Guidance shall be included in the Operating Manual on the sea state at which storm shutters and deadlights shall be fitted and on maintenance and inspection of the storm shutters and deadlights and their means of securing.

Annex A
(normative)

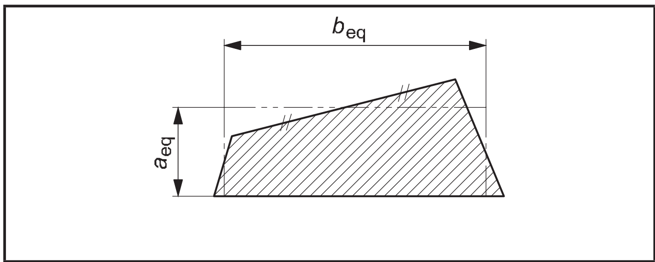
Unsupported pane dimensions

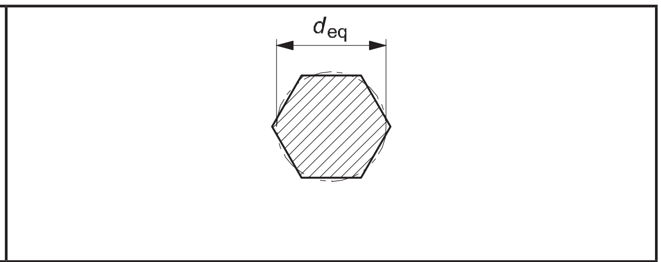
For rectangular pane, the small and large unsupported dimensions are b_P and a_P respectively, as shown in Figure A.1 a). For a folded pane, the small and large unsupported dimensions are b_P and a_P respectively, as shown in Figure A.1 c). For a circular plate, the unsupported diameter is d, as shown in Figure A.1 b). For non-rectangular or non-circular plate shapes, use “equivalent” dimensions of a rectangular or circular plate having an area equal to the plate being considered (see Figure A.2).



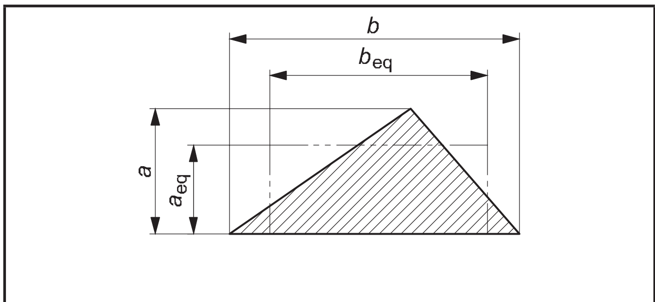
a)	b)	c)

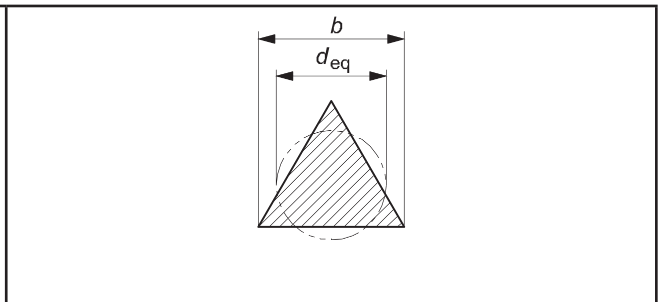
Figure A.1 — Unsupported pane dimensions





The rectangle has the same area	The circle has the same area
a) Quadrangle	**b) Polygon**





$a_{eq} = 2a/3$ $b_{eq} = 3b/4$	$d_{eq} = 3b/4$
c) Triangle	**d) Equilateral triangle**

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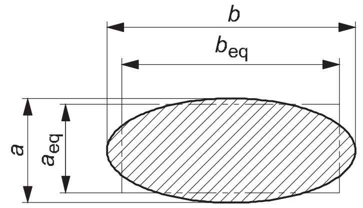
<tr>
<td>
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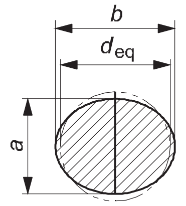
<td>
</td>
</tr>
<tr>
<td>$a_{eq} = 0{,}87a \quad b_{eq} = 0{,}87b$</td>
<td>$d_{eq} = \sqrt{ab}$</td>
</tr>
<tr>
<td>e) Flat ellipse</td>
<td>d) Round ellipse</td>
</tr>
</table>

Figure A.2 — Equivalent dimensions

Annex B
(normative)

Calculation of the stiffness of a pane

B.1 Monolithic pane

For a monolithic pane of physical or equivalent thickness t_W(mm) the calculation of its stiffness, M (Nmm), shall be performed on the basis of the knowledge of its mechanical characteristics:

E (N/mm²) Young's modulus;

ν Poisson's ratio;

as

$$M = \frac{E \cdot t_W^3}{12 \cdot \left(1 - \nu^2\right)} \tag{B.1}$$

Values of E and ν can be found in Table B.1. Other values may be used for Young's modulus and Poisson's ratio if declared by the material manufacturer.

Table B.1 — Mechanical properties of materials

Material	Acronym	Young's modulus E N/mm²	Poisson's ratio ν
Polymethylmethacrilate	PMMA	3 300	0,37
Polycarbonate	PC	2 300	0,38
Glass	TTG/CTG	70 000	0,23

Annex C
(informative)

Scantling equation

The scantling equation given in 5.6.1.2 comes from the equation

$$t_O = b \cdot \sqrt{\frac{\beta \cdot p_D}{\sigma_A}} \qquad (C.1)$$

where

t_O is the basic pane thickness (mm);

b is the unsupported short side of a rectangular pane or “equivalent short side” of a pane (mm);

β is the pane aspect-ratio coefficient;

p_D is the basic design pressure (kN/m^2);

σ_A is the allowable design flexural stress of the material (N/mm^2).

This equation has been rearranged to be expressed in more practical units p_D in kN/m^2 and σ_A in N/mm^2 as given in 5.6.1.2.

This equation is coming from linear plate theory and it is strictly valid for small deflection of the pane (less than $t_O/2$). A more accurate structural analysis may be based on non-linear FEM calculation. Nevertheless this simplified linear approach has been found to be consistent and conservative for scantling determination of plates when comparing results of hydrostatic tests with the more accurate non-linear FEM calculations.

Annex D
(informative)

Statistical coefficient Kn and worked example

The statistic coefficient introduced in 6.2.1 corresponding to 90 % confidence limit depends from the number of test specimens, N, according to the t-Student statistical distribution. In Table D.1 the Kn is reported as a function of the number of test specimens for a confidence limit of 90 %.

Table D.1 — Kn vs. number of tested specimens at 90 % confidence limit

Number of tested specimens	Kn
10	1,833
11	1,812
12	1,796
13	1,782
14	1,771
15	1,761
20	1,729
25	1,711
30	1,699
40	1,685
60	1,671
100	1,660
∞	1,645

Worked example:

Consider 12 strength tests sampling 12 individuals from a production lot, average value, standard deviation are: $\sigma_{\text{av}} = 210$ MPa; $s_x = 20$ MPa; setting a probability level of 90 % it results from Table D.1: $Kn = 1{,}796$.

$$C_V = \frac{s_x}{\sigma_{\text{av}}} = \frac{20}{210} = 0{,}095\ 2$$

With the above definitions, σ_{C}, characteristic failure strength is

$$\sigma_{\text{c}} = \sigma_{\text{av}} \cdot (1 - Kn \cdot C_V) = 210 \cdot (1 - 1{,}796 \cdot 0{,}095\ 2) = 174 \text{ MPa}$$

Annex E
(informative)

Worked examples of equivalent thickness calculation for Type A laminates

Example 1 — Independent plies case

Construction cross section:

Glass 8 mm / 1,5 mm interlayer / glass 10 mm / 1,5 mm interlayer / glass 8 mm

Table E.1 — Example of calculation for independent plies case

t mm	t^3 mm^3	$t_{eq,j} = [\Sigma(t^3)/t]^{1/2}$
8	512	15,9
10	1 000	14,2
8	512	15,9

t_{eq} = 14,2 mm

Example 2 — Collaborating plies case (symmetrical construction)

Construction cross section:

Glass 8 mm / 1,52 mm PVB interlayer / glass 8 mm

Glazing short dimension: 1 000 mm

E(Glass) = 70 000 MPa

G(PVB) = 1,6 MPa

Table E.2 — Example of calculation for collaborating plies case (symmetric construction)

Shear transfer coeff. Γ	**Equivalent thickness deflection** $t_{eq;W}$	**Equivalent thickness stress — Ply 1** $t_{1ef;\sigma}$	**Equivalent thickness stress — Ply 2** $t_{2ef;\sigma}$
0,281	13,1	14,5	14,5

t_{eq} = 14,5 mm

Example 3 — Collaborating plies case (asymmetrical construction)

Construction cross section:

Glass 12 mm / 1,52 mm PVB interlayer / glass 8 mm

Glazing short dimension: 1 000 mm

E(Glass) = 70 000 MPa

G(PVB) = 1,6 MPa

Table E.3 — Example of calculation for collaborating plies case (asymmetrical construction)

Shear transfer coeff. Γ	**Equivalent thickness deflection** $t_{eq;W}$	**Equivalent thickness stress — Ply 1** $t_{1ef;\sigma}$	**Equivalent thickness stress — Ply 2** $t_{2ef;\sigma}$
0,246	16,0	17,0	19,0

t_{eq} = 17,0 mm

Example 4 — Collaborating plies case (three plies iteration case)

Construction cross section:

Glass 8 mm / 1,52 mm PVB interlayer / glass 10 mm / 1,52 mm PVB interlayer / glass 10 mm

Glazing short dimension: 1 000 mm

E(Glass) = 70 000 MPa

G(PVB) = 1,6 MPa

First iteration

Glass 8 mm / 1,52 mm PVB interlayer / glass 10 mm

Table E.4 — Example of calculation for collaborating plies case (three plies iteration case) – First iteration

Shear transfer coeff. Γ	**Equivalent thickness deflection** $t_{eq;W}$	**Equivalent thickness stress — Ply 1** $t_{1ef;\sigma}$	**Equivalent thickness stress — Ply 2** $t_{2ef;\sigma}$
0,261	14,5	16,6	15,7

t_{eq} (first iteration) = 15,7 mm

Second iteration

Glass 15,7 mm / 1,52 mm PVB interlayer / glass 10 mm

Table E.5 — Example of calculation for collaborating plies case (three plies iteration case) – Second iteration

Shear Transfer Coeff. Γ	**Equivalent thickness Deflection** $t_{eq;W}$	**Equivalent thickness stress — Ply 1** $t_{1ef;\sigma}$	**Equivalent thickness stress — Ply 2** $t_{2ef;\sigma}$
0,204	20,0	21,0	24,2

t_{eq} (final) = 21,0 mm

Annex F
(informative)

Worked examples of equivalent thickness calculation for Type B laminates

Example 1 — Glass/plastic laminates

Construction cross section:

Glass 8 mm / interlayer 1,5 mm / 9 mm polycarbonate / 1,5 mm interlayer/ glass 8 mm

Table F.1 — Example calculation for Glass/Plastic laminates

t mm	E MPa	E_t mm^3	E_t^3 mm^3	$t_{eq,j} = [\Sigma(E_t^3/E_t)]^{1/2}$
8	70 000	560 000	35 840 000	11,5
9	2 500	22 500	1 822 500	57,2
8	70 000	560 000	35 840 000	11,5

t_{eq} = 11,5 mm (glass material)

Example 2 — Plastic 1/plastic 2 laminates

Construction cross section:

Acrylic 8 mm / interlayer 1,5 mm / 9 mm polycarbonate / 1,5 mm interlayer / acrylic 8 mm

Table F.2 — Example calculation for Plastic1/Plastic2 laminates

t mm	E MPa	E_t mm^3	E_t^3 mm^3	$t_{eq,j} = [\Sigma(E_t^3/E_t)]^{1/2}$
8	3 000	24 000	1 536 000	14,3
9	2 500	22 500	1 822 500	14,7
8	3 000	24 000	1 536 000	14,3

t_{eq} = 14,3 mm (acrylic material)

Annex G
(informative)

Design pressure in lieu of storm shutters

G.1 Background of design pressures

Yachts are typically built with excess freeboard. Where the geometric minimum freeboard required by the International Convention on Load Lines, 1966, as amended, for a vessel with zero sheer for yachts in the size range considered in this International Standard is about 0,02L, the height of the main deck above the deepest load waterline of yachts, as built, is typically 0,05L. On the basis of this greater freeboard, the MCA and other flag Administrations in their Commercial Yacht Codes relaxed a number of the requirements of the International Convention on Load Lines.

Therefore, for a 60 m yacht, the excess freeboard can be as large as one standard superstructure height; 1,80 m. As a consequence, openings in deckhouses on the main deck of the vessel are at a height above the waterline corresponding to a location on a superstructure on a ship built for maximum displacement. For this reason, existing regulations are difficult to apply for yachts featuring split level deck constructions etc.

It was considered that there is no technical reason to relate design pressures to presence or position of inner decks, and a more rational approach was looked for, defining pressures on the basis of height above the waterline and position along the ship only, while keeping consistency with the existing regulations.

An investigation into the freeboard requirements in ICLL 1966 (as amended), revealed that for the size range of yachts this International Standard applies to, the basic geometric minimum freeboard for a yacht without sheer (Fb) could be approximated with sufficient accuracy for application in this International Standard as: Fb = 0,02L.

The requirement for bow height is not included because in the range where there is a bow height requirement, the forward 0,07L, in general no glazed openings are fitted.

From that basic freeboard, the traditional tiers are translated into ranges with a height equal to one standard superstructure height.

It is noted this approach relates to design pressures on vertical or largely vertical bulkheads only, and refers to deckhouse bulkheads and raked deckhouse front bulkheads.

G.2 Enhanced strength requirements for glazing in lieu of storm shutters and, where permitted, in lieu of deadlights

Based on investigation reports of damages to front bulkheads of offshore service vessels operating in the North Sea, an estimation was made of the loads that can occur in extreme sea states. The damages and the weather conditions in which they occurred, featuring significant wave heights of up to 9,0 m, were reported, and can be used as a basis for deriving the pressures.

The length of the offshore service vessels was about 50 m. The deformations found in plating in the front bulkhead were investigated presuming a deformation of 1x thickness. The bulkheads were located approximately 10 % of length after the fore perpendicular. At a position between 2 and 3 standard superstructure heights above the freeboard deck the pressure was calculated at 88 kPa. This was taken as the reference pressure.

Pressures for positions between 1 and 2 superstructure heights above the freeboard deck were then derived using the coefficients in Table 1. This resulted in a prediction of a pressure of 255 kPa for positions in the first standard superstructure height above the freeboard deck and 150 kPa for positions over one standard superstructure height higher.

Subsequent correction for typical front bulkhead positions on a yacht, at 0,60L, on the basis of Table 3 resulted in 175 kPa for positions up to one standard superstructure height, 102 kPa for positions up to two standard superstructure heights, and 60 kPa above this.

In view of the operation of yachts, a typical significant wave height of not more than 6 m was chosen, and a linear correction was applied, leading to 117 kPa and 68 kPa for positions up to one and two standard superstructure heights above the freeboard deck, respectively.

For yachts of length less than 50 m, the values of design pressure from IACS UR S 3[9] and ISO and BS MA standards for windows can be negative.

As the windows should have a strength equivalent to the bulkhead in which they are located, it was necessary to refer to the minimum bulkhead plate thickness in IACS UR S 3[9], which is the standard used in this International Standard and in other BS MA and International Standards for windows.

The minimum required thickness of 5 mm steel plating gives a minimum design pressure associated with deformation of about 1x thickness of 58 kPa. This should be taken as the minimum design pressure from 5.5.1 for windows for which storm shutters should be waived to which the 1,5 factor should be applied.

This establishes a factor of 1,5 over the design pressures given in 5.5.1, and it was concluded that this would be an appropriate factor to apply in lieu of storm-shutters.

It is noted that this factor is in line with standing industry practice.

Annex H
(normative)

Effective width of plating

With reference to 8.1.6.3, stiffeners, the following approach provides an indication about the effective width of plating. This is based on the assumption that the associated plating has quasi-isotropic in-plane properties. It may be adopted for reasonably balanced in-plane stiffness laminates. The effective width of plating w_{eff} is taken as being dependant on the ratio L_1/w solely. The width of plating to account for when determining the beams stiffness can be taken from Figure H.1 as a fraction of w.

L_1 is the length between zero bending moments of a beam between supports and is determined as follows:

L_1 = unsupported span for beams with hinged end supports

= 0,4 times the unsupported span for beams with ends fixed;

w = width of plating supported, measured from centre to centre of the adjacent unsupported fields.

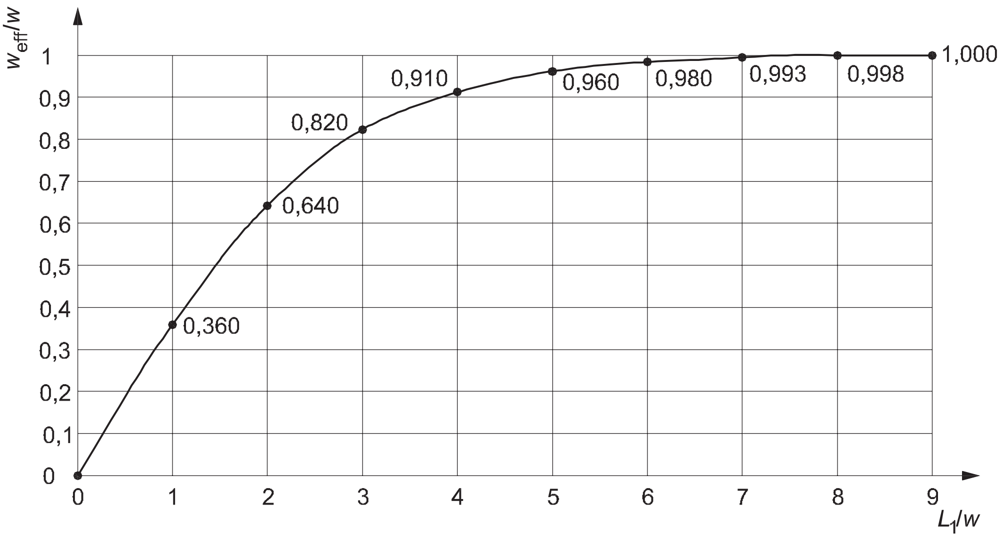


Figure H.1 — Effective width of plating

Additionally, the beam's foot width, w_f, can be added to w_{eff}, see Figure H.2.

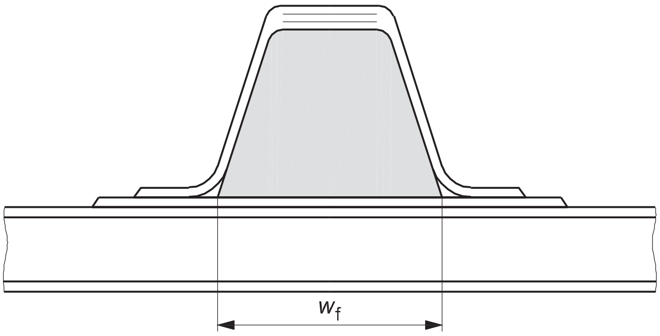


Figure H.2 — Typical top hat stiffner

The calculated effective width should not be taken as greater than the load width.

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