INTERNATIONAL STANDARD

ISO 12215-8

First edition
2009-05-15

Small craft — Hull construction and scantlings —

Part 8: **Rudders**

Petits navires — Construction de coques et échantillonnage —
Partie 8: Gouvernails

Reference number
ISO 12215-8:2009(E)

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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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

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.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 12215-8 was prepared by Technical Committee ISO/TC 188, *Small craft*.

ISO 12215 consists of the following parts, under the general title *Small craft — Hull construction and scantlings*:

— *Part 1: Materials: Thermosetting resins, glass-fibre reinforcement, reference laminate*

— *Part 2: Materials: Core materials for sandwich construction, embedded materials*

— *Part 3: Materials: Steel, aluminium alloys, wood, other materials*

— *Part 4: Workshop and manufacturing*

— *Part 5: Design pressures for monohulls, design stresses, scantlings determination*

— *Part 6: Structural arrangements and details*

— *Part 8: Rudders*

Introduction

The reason underlying the preparation of this part of ISO 12215 is that standards and recommended practices for loads on the hull and the dimensioning of small craft differ considerably, thus limiting the general worldwide acceptability of craft. This part of ISO 12215 has been set towards the lower boundary range of common practice.

The objective of this part of ISO 12215 is to achieve an overall structural strength that ensures the watertight and weathertight integrity of the craft.

The working group considers this part of ISO 12215 to have been developed applying present practice and sound engineering principles. The design loads and criteria of this part of ISO 12215 may be used with the scantling determination equations of this part of ISO 12215 or using equivalent engineering methods such as continuous beam theory, matrix-displacement method and classical lamination theory, as indicated within.

Considering future development in technology and craft types, and small craft presently outside the scope of this part of ISO 12215, provided that methods supported by appropriate technology exist, consideration may be given to their use as long as equivalent strength to this part of ISO 12215 is achieved.

The dimensioning according to this part of ISO 12215 is regarded as reflecting current practice, provided the craft is correctly handled in the sense of good seamanship and equipped and operated at a speed appropriate to the prevailing sea state.

Small craft — Hull construction and scantlings —

Part 8:
Rudders

1 Scope

This part of ISO 12215 gives requirements on the scantlings of rudders fitted to small craft with a length of hull, L_H, of up to 24 m, measured according to ISO 8666. It applies only to monohulls.

This part of ISO 12215 does not give requirements on rudder characteristics required for proper steering capabilities.

This part of ISO 12215 only considers pressure loads on the rudder due to craft manoeuvring. Loads on the rudder or its skeg, where fitted, induced by grounding or docking, where relevant, are out of scope and need to be considered separately.

NOTE Scantlings derived from this part of ISO 12215 are primarily intended to apply to recreational craft including charter craft.

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 8666, *Small craft — Principal data*

ISO 12215-5:2008, *Small craft — Hull construction and scantlings — Part 5: Design pressures for monohulls, design stresses, scantlings determination*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
design categories
sea and wind conditions for which a craft is assessed by this part of ISO 12215 to be suitable, provided the craft is correctly handled in the sense of good seamanship and operated at a speed appropriate to the prevailing sea state

3.1.1
design category A ("ocean")
category of craft considered suitable to operate in seas with significant wave heights above 4 m and wind speeds in excess of Beaufort Force 8, but excluding abnormal conditions such as hurricanes

3.1.2
design category B ("offshore")
category of craft considered suitable to operate in seas with significant wave heights up to 4 m and winds of Beaufort Force 8 or less

3.1.3
design category C ("inshore")
category of craft considered suitable to operate in seas with significant wave heights up to 2 m and a typical steady wind force of Beaufort Force 6 or less

3.1.4
design category D ("sheltered waters")
category of craft considered suitable to operate in waters with significant wave heights up to and including 0,3 m with occasional waves of 0,5 m height, for example from passing vessels, and a typical steady wind force of Beaufort Force 4 or less

3.2
loaded displacement mass
m_{LDC}
mass of the craft, including all appendages, when in the fully loaded ready-for-use condition as defined in ISO 8666

3.3
sailing craft
craft for which the primary means of propulsion is wind power, having $A_S > 0{,}07(m_{LDC})^{2/3}$ where A_S is the total profile area of all sails that may be set at one time when sailing closed hauled, as defined in ISO 8666 and expressed in square metres

NOTE 1 For the headsails, A_S is the area of the fore triangle.

NOTE 2 In the rest of this part of ISO 12215, non-sailing craft are called motor craft.

4 Symbols

For the purposes of this document, unless specifically otherwise defined, the symbols given in Table 1 apply.

NOTE The symbols used in the annexes are not listed in Table 1.

Table 1 — Symbols, coefficients, parameters

Symbol	Unit	Designation/meaning of symbol	(Sub)clause/table concerned
A	m^2	Total area of the moving part of the rudder	6.2.1, 6.2.3
A_0	m^2	Rudder effective area (Types II to IV)	6.2.3
A_1	m^2	Rudder blade area (Types II to IV) or top blade area (Type V)	6.2.3
A_2	m^2	Bottom rudder blade area (Type V)	6.2.3
A_3	m^2	Rudder skeg area [only used to determine type (see Figure 3)]	6.2.3
c	m	Rudder chord length at centre of area level	6.2.1, 6.2.2
c_1	m	Length of the top chord (Type I)	6.2.1
c_2	m	Length of the bottom chord (Type I)	6.2.1
co_1	m	Compensation at top chord (distance from LE to rotation axis) (Type I)	6.2.2
co_2	m	Compensation at bottom chord (distance from LE to stock CL) (Type I)	6.2.2
d	mm	Required solid stock diameter	10.4
d_i	mm	Inner diameter of tubular stock	10.6
d_o	mm	Outer diameter of tubular stock	10.6
F	N	Final side force on rudder	7.1
F_1	N	Side force on rudder in design category sea state	7.2
F_2	N	Side force on rudder during a turn at speed in slight sea	7.3
h_b	m	Height between rudder top and centre of hull bearing	6.2.1
h_c	m	Height between rudder top and centre of area	6.2.1
h_d	m	Height between rudder top and centre of skeg bearing (Type V)	6.2.3
h_e	m	Height between rudder bottom and centre of skeg bearing (Type V)	6.2.3
h_{in}	m	Height between centre of upper bearing and a point inside the hull (Type I)	6.2.1
h_{ou}	m	Height between bottom of spade and a point outside the hull (Type I)	6.2.1
h_r	m	Average height of rudder blade (see Figure 1)	6.2.1
h_s	m	Height of skeg from hull attachment to skeg bearing (Types II to V)	6.2.3
h_u	m	Height between centres of hull (lower) bearing and upper bearing	6.2.1
k_b	1	Rudder bending coefficient	6.2.1
k_{FLAT}	1	Coefficient lowering force for flat or wedge rudder blade shape	7.3
k_{GAP}	1	Coefficient lowering force due to gap hull/rudder top	7.2
k_{LD}	1	Length displacement coefficient	7.2
k_S	1	Coefficient for skeg deflection	8.3.4
k_{SEA}	1	Coefficient considering extra load due to sea in design categories A and B	7.2
k_{SERV}	1	Coefficient considering lower required service in design categories C and D	7.3
k_{SIG}	1	Coefficient lowering design stress for F_2	7.3
k_{USE}	1	Coefficient considering lower usage of craft with damage survey	7.2
k_5	1	Fibre type factor	13.3.1.2
L_S	m	Effective length of the skeg	8.3.4

Table 1 (*continued*)

Symbol	Unit	Designation/meaning of symbol	(Sub)clause/table concerned
L_{WL}	m	Length at waterline, according to ISO 8666 in m_{LDC} conditions	7.2
M	Nm	Bending moments on the rudder stock or skeg	8
M_S, M_H	Nm	Bending moments at skeg or hull	8.3.4
m_{LDC}	kg	Loaded displacement mass	3.2, 7.2
r	m	Horizontal distance from rudder force to stock axis	6.2.1
r_{min}	m	Minimum value of r	9
R_U, R_H, R_S	N	Reaction force at upper bearing, hull bearing, skeg bearing, respectively	8
t	mm	Skin thickness of tubular or hollowed closed section	Table 6
T	Nm	Torque (twisting moment) on the rudder stock	9
u	m	Longitudinal distance from leading edge to stock axis at centroid chord	6.2.1
V_{MAX}	knots	Maximum speed of craft in calm water, m_{LDC} conditions	7.3
w	kg/m^2	Minimum fibre mass per area of rudder blade	13.3.1.2
z_b	m	Effective bending moment lever $z_b = k_b \cdot h_r + h_c$	8.2.1
z_{eq}	m	Equivalent bending moment lever	10.4
α	1	Tip chord to root chord ratio (c_2/c_1)	6.2.2
Λ	1	Geometric aspect ratio of the rudder	6.2.1, 6.2.3
σ	N/mm^2	Direct stress (ultimate, yield, design)	5
τ	N/mm^2	Shear stress (ultimate, yield, design)	5
χ	1	Ratio between reaction at skeg and rudder force	8.3.2

5 Design stresses

5.1 Rudder material

Values of design stresses shall be taken from Table 2

Table 2 — Values of design stresses

Stresses in newtons per square millimetre

Material	Direct stresses			Combined stresses
	Tensile/compressive σ_d	Shear τ_d	Bearing σ_{db}	
Metals[a]	$\min(\sigma_y ; 0{,}5\, \sigma_u)$	0,58 τ_d	1,8 σ_d	$\sqrt{\sigma^2 + 3\tau^2} \leqslant \sigma_d$
Wood and fibre-reinforced plastics (FRP)	0,5 × σ_u	0,5 τ_u	1,8 σ_d	$\left(\frac{\sigma}{\sigma_u}\right)^2 + \left(\frac{\tau}{\tau_u}\right)^2 < 0{,}25$

[a] Steel, stainless steel, aluminium alloys, titanium alloys, copper alloys (see Annex A). In welded condition for welded metals.

In Table 2,

- σ_d is the design tensile, compressive, or flexural strength (as relevant);
- σ_u is the ultimate tensile, compressive, or flexural strength (as relevant);
- σ_y is the yield tensile, compressive, or flexural strength (as relevant);
- σ_{db} is the design bearing strength;
- τ_d is the design shear strength;
- τ_u is the ultimate shear strength.

Additional requirements are given in Annex A (metals) and Annex B (composites)

For wood and composites, the strength values of the relevant annexes of ISO 12215-5 shall be used.

6 Rudder and steering arrangement, rudder types

6.1 General

6.1.1 General definition

The rudder and steering arrangement comprises all components necessary for manoeuvring the craft, from the rudder and the rudder operating gear to the steering position.

Rudder and steering equipment shall be arranged so as to permit inspection.

NOTE It is good practice that the rudder keeps the steering effect after grounding (for example, a spade rudder with the stock not going down to the bottom enables the rudder blade to break without bending the stock).

6.1.2 Multi-rudder arrangement

If the craft has several rudders, the following requirements apply to each one of the rudders.

NOTE On sailing craft, twin rudders, frequently canted outwards, are not usually protected from contact with floating objects by the keel, a skeg, the hull canoe body at centreline, etc. This is particularly the case for the windward rudder, close to the waterline, that can also be hit by breaking waves and can therefore support a part of the craft's weight. It is therefore current practice to have twin rudders installed on sailing craft that are significantly stronger than required in this part of ISO 12215, which only considers loads from normal lift forces. This enhanced strength is not quantified here.

6.1.3 Vertical support

The rudder stock or blade shall be supported vertically with limited axial upwards movement.

6.1.4 Hard over stops

Rudder stocks that are, or can be, actuated by a remote steering system (i.e. not directly by the tiller) shall be fitted with hard over stops, angled at 30° to 45° from zero lift position (usually at centreline). This also applies to rudders only actuated by a tiller of design category A and B.

Hard over stops can act on the rudder, the tiller, the quadrant, or any device directly connected to the rudder.

NOTE The need for stops is both to avoid excessive angle of attack and lift when running backwards and to avoid excessive range of movement of the steering system.

6.1.5 Actuating system of the rudder

The following devices shall be able to transmit the rudder torque, T, defined in Clause 9, without exceeding their design stress, as defined in Clause 5:

- the actuating device that turns the rudder including the tiller, rudder arm and quadrant;
- the connection between the rudder stock and the actuating device (cone, square, key, etc.);
- the stops provided at either end of the tiller, rudder arm or quadrant stroke.

The connection between the rudder stock and the actuating device shall be designed to ensure alignment between the rudder blade and the tiller, actuating arm, etc. and allow a visual instant checking of this alignment.

6.1.6 Emergency tiller

Any component of the emergency tiller, where fitted, shall be able to transmit a rudder torque of 0,5 T, where T is defined in Clause 9, without exceeding its design stress defined in Clause 5.

6.2 Rudder types

This part of ISO 12215 is applicable to five types of rudder configuration: Type I to Type V, as shown in Figures 2 and 3. In all cases except case I c, the rudder blade is taken as rectangular or trapezoidal.

6.2.1 Type I (spade) rudders (see Figures 1 and 2)

The main variables are as follows:

- A is the rudder (spade) area;

- $\Lambda = \frac{h_r^2}{A}$ is the rudder geometric aspect ratio (1)

  where h_r is the average height of the rudder;

- h_b is the height between rudder top and centre of hull bearing;
- c_1 and c_2 are, respectively, the top and bottom chords or their natural extension;
- co_1 and co_2 are the top and bottom compensation, respectively, i.e. the distance, measured from fore to aft, between the leading edge and the rotation axis;
- c is the chord length at the height of the centroid of rudder area;
- h_c is the height between rudder top and centroid of rudder area (this is the position where the rudder force is considered to act);
- h_{ou} and h_{in} are, respectively, any local height outside and inside the centre of hull bearing to be used in Figure 5;
- k_b is the rudder bending coefficient with $k_b = h_c/h_r$;
- r is the horizontal distance between the position of the resultant of the rudder force (taken at rudder centroid) and the rudder's rotational axis, as defined in Table 6, and shall not be taken less than r_{min};

— u is, for Type I (spade) rudders, the horizontal distance from fore to aft, from the leading edge to the rudder rotational axis at the height of centroid of rudder area (i.e. the geometric centre of the profile area); u is positive if the leading edge is forward of the axis (see Figure 2 Types I a, I b, or I c) or negative in the opposite case (see Type I d).

6.2.2 Rudder spade with trapezoidal shape

For spade rudders with a trapezoidal (or close to) shape some values are easily calculated as follows:

$$A = h_r \frac{c_1 + c_2}{2}$$ is the area of a trapezoidal spade; (2)

$$k_b = \frac{h_c}{h_r} = \frac{1 + 2\,\alpha}{3\,(1 + \alpha)}$$ for a trapezoidal spade; (3)

where $\alpha = \frac{c_2}{c_1}$ is the taper coefficient.

See Table 3.

Table 3 — Calculated values of k_b for a trapezoidal spade as a function of c_2/c_1

$c_2/c_1 = \alpha$	1,00	0,90	0,80	0,70	0,60	0,50	0,40	0,30	0,20
k_b	0,50	0,49	0,48	0,47	0,46	0,44	0,43	0,41	0,39

$$h_c = k_b \times h_r$$ (4)

$$c = c_1 - k_b(c_1 - c_2)$$ for a trapezoidal spade (5)

$$u = co_1 - k_b(co_1 - co_2)$$ for a trapezoidal spade (6)

The value of h_c can also be determined graphically, as shown in Figure 1.

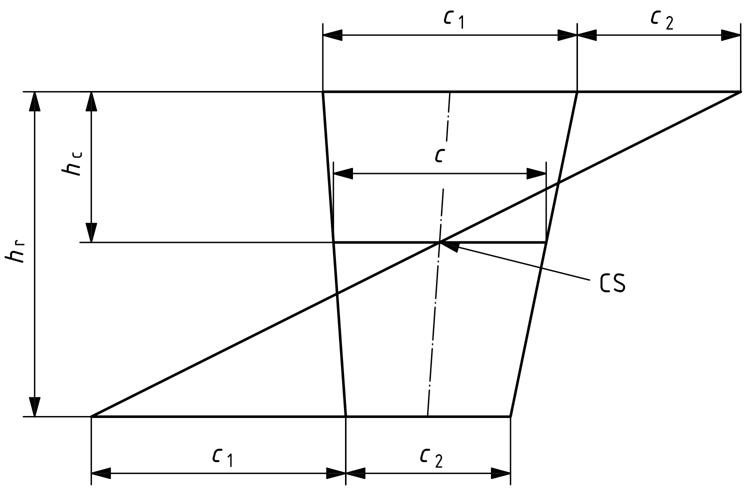
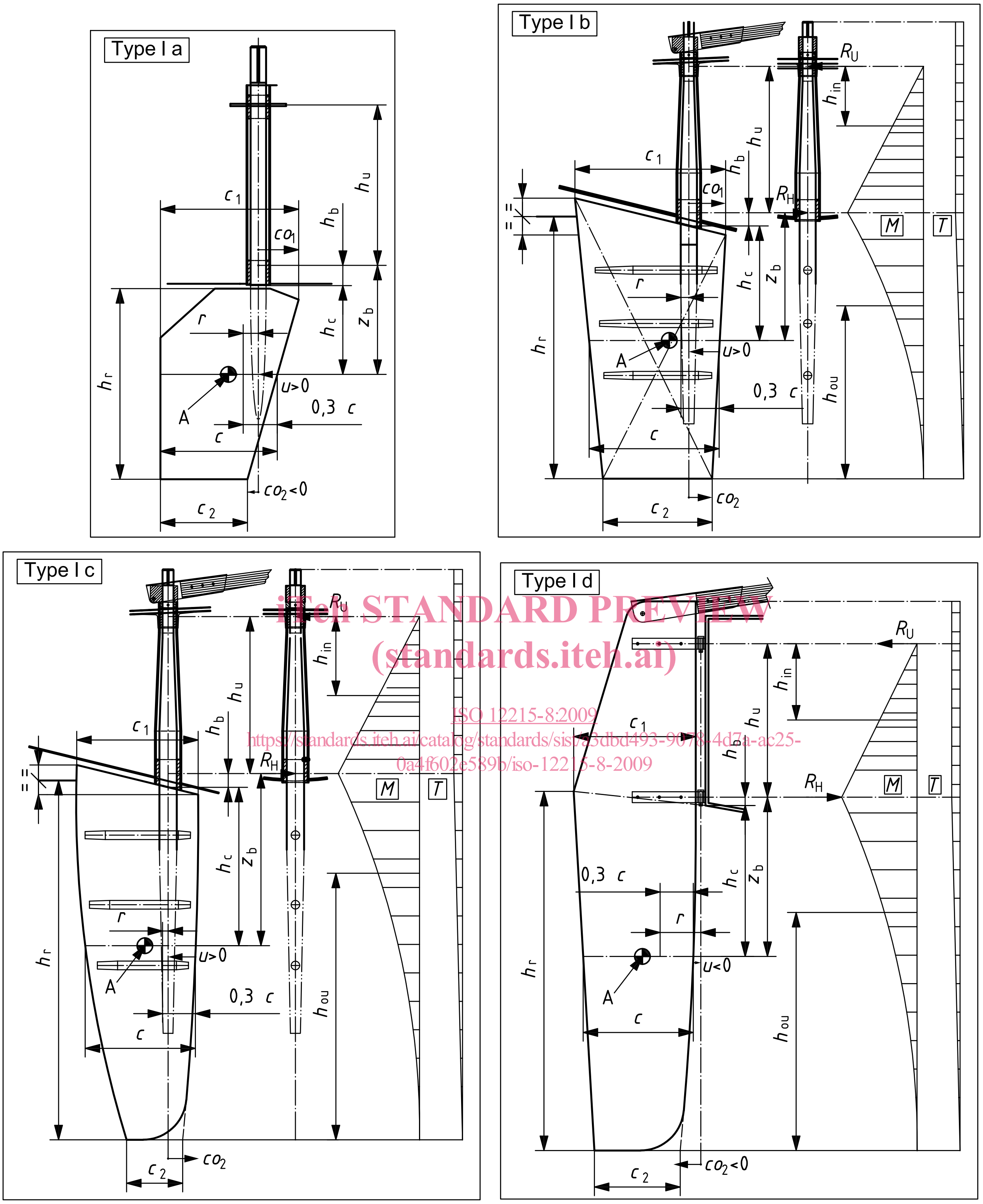


Figure 1 — Graphical determination of centroid, CS, of a trapeze



Type I a: Typical fast motor craft spade rudder with low aspect ratio and cut out top aft to avoid ventilation

Type I b: Near-rectangular shape

Type I c: Semi-elliptical shape typical on performance sailing craft

Type I d: Transom-hung spade rudder

NOTE The marking with a shaded circle shows the geometric centre of surface. The rudder force is located at the same height, but at a distance 0,3 c aft of the chord's leading edge.

Figure 2 — Spade rudders: Type I

6.2.3 **Rudder types II to V** (see Figure 3)

The dimensions are the same as for spade rudders, except that:

— A is the total area of the moving part of the rudder, divided into A_1 and A_2 in Type V;

— A_3 is the skeg area (only used to determine the type in Figure 3);

— h_r is the average height of the rudder;

— $\Lambda = \frac{h_r^2}{A_0}$ is the effective rudder geometric aspect ratio (7)

where A_0 is the rudder effective area (moving part plus effective part of the skeg, see Table 4);

— $c = A_0/h_r$ is the mean chord;

— h_s is the height of the skeg/horn between hull and mid-skeg bearing for Type V and the lower bearing for Types III and IV.

Table 4 gives values of A and A_0 according to rudder type.

Table 4 — Rudder types and effective areas

Type	Value	
	A	A_0
II	A	
III	A_1	$A_1 + A_3$
IV	A_1	A_1
V	$A_1 + A_2$	$A_1 + A_2 + A_3$

For Type V, h_d and h_e are the portions of h_r above and below the skeg bearing, respectively.

For Types II to V:

— u is, for rudder Types II and IV, the horizontal distance, fore to aft, from the leading edge of the rudder to the stock vertical axis at the height of centroid of rudder area. For rudder Types III and V, u is measured aft of the leading edge of the partial or full narrow skeg (see Figure 3);

— r is the horizontal distance between the position of the centroid of rudder area and the rudder's rotational axis, as defined in Table 6, and shall not be taken less than r_{min}.

The rudders of Types II to V are considered to be held by three bearings (two bearings inside the hull and one skeg bearing, see 8.3.1)

