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Guidelines for Classification and Construction

Part 3 Special Ships

GUIDELINES FOR THERMOPLASTIC VESSELS

Volume 2

2023 Edition

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Part 3 Special Ships

GUIDELINES FOR THERMOPLASTIC VESSELS

Volume 2

2023 Edition

Jl. Yos Sudarso No. 38-40, Tanjung Priok
Jakarta 14320 - Indonesia
rules@bki.co.id
www.bki.co.id

The following Guidelines come into force on 1^{st} December 2023.

Foreword

This Guidelines for Thermoplastic Vessels (Pt.3, Vol.2) 2023 edition is a new Guidelines that contains requirements regarding the use of polyethylene as a structural material for hull structure of vessels.
This Guidelines consist of 5 Sections and 1 Annex namely:

Section 1 General

Section 2 Material Properties

Section 3 Structural Design

Section 4 Manufacture

Section 5 Freeboard and Stability Requirement

Annex A Stability and Buoyancy Test

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Further queries or comments concerning this Guidelines are welcomed through communication to BKI Head Office.

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Section 1 General

A. Scope and Applicability

1. These Guidelines have been developed to provide requirements regarding the use of polyethylene as a structural material for hull structure of vessels. The Guidelines cover requirements related to material properties, structural design, manufacture, and freeboard and stability of such vessels.

2. These Guidelines are intended for use in certification of vessels built to polyethylene materials like Low Density Polyethylene (LDPE), Medium Density Polyethylene (MDPE) and High Density Polyethylene (HDPE). Other types of plastics such as Linear Low Density Polyethylene (LLDPE), Cross-linked Polyethylene (XLPE), Ultra High Molecular Weight Polyethylene (UHMW) etc., may be specially considered depending upon their suitability for the intended application.

3. LDPE is flexible and tough, easy to process and has excellent chemical resistance. MDPE has better mechanical properties than LDPE as well as higher stiffness, excellent low temperature impact strength and excellent environmental stress crack resistance. HDPE is the stiffest of the polyethylene family. HPDE has excellent chemical resistance and good process ability. It is preferred that HDPE be used for vessel materials because of the high impact resistance and better longevity.

4. These Guidelines address only the hull structure, manufacture and its stability. For other aspects not covered by these Guidelines, the relevant requirements of the Rules for Small Vessels up to 24 m (Pt.3 Vol.VII) are to be complied with, as applicable.

5. The service range of thermoplastic vessel is limited up to range of service III in accordance with Rules for Small Vessels up to 24 m (Pt.3 Vol.VII) and with maximum wave height (H_{max}) refer to Table 1.1. .

6. The certification aims at providing an appropriate safety level for the vessels, their intended application and design limitations. The technical and safety standards prescribed are considered adequate for such vessels with overall lengths in the approximate range 6 to 24 m and with speeds up to 45 knots.

Certification of vessels with lengths other than those indicated above and with unusual hull form design includes but not limited to:

— canoes and kayaks;

— gondolas and pedalos;

— hydrofoils, foil stabilized boats and hovercraft when not operating in the displacement mode; and

— submersibles

will be specially considered on a case by case basis.

Table 1.1: Maximum wave height (H_{max})

Range of services *	**Maximum wave height** (H_{max}) **(m)**
III	2
IV	0.5
V	0.3
** refer to Rules for Small Vessel up to 24 m (Pt.3, Vol.VII)*	

B. Certification systematics

1. General

The certification service is performed on the basic assumption that all parties involved (designer, builder/yard, manufacturer, design owner, sub-contractor, owner, etc.) fulfil their individual obligations. The certification service is not performed in substitution of other parties' role or obligations. Nothing contained in BKI services, certificate, report or document issued in connection with or pursuant to these requirements, shall relieve any designer, engineer, builder, manufacturer, yard, seller, owner, operator or other parties from any obligations or consequences of default whatsoever. In particular, compliance with the requirements does not imply acceptance or commissioning of a vessel. This is the exclusive responsibility of the owner.

2. Certification procedures

2.1 The certification procedures are based on schemes. These procedures (schemes) cover the design phase, the manufacturing phase or both. This subsection also contains information about what procedures to choose and give detailed requirements for each scheme.

2.2 An application for certification shall be sent to the BKI office and include:

- Name and address of the applicant
- Name and address of the owner of the design
- Name and address of the builder (yard, manufacturer)
- Vessel specification and type designation
- Chosen procedure(s)
- Technical documentation.

2.3 The applicant has to be authorised by the owner of the design to act on his behalf. If the applicant subcontract design or production, the applicant remains responsible for the execution of conformity assessment for all technical documentation, sub-supplies and the finished vessel.

3. Technical documentation

3.1 The applicant shall submit technical documentation for approval irrespective of certification procedure. Technical documentation shall enable understanding of the design and construction of the vessel, and shall confirm compliance with the requirements given in this Guidelines.

3.2 The following technical documentation shall be submitted as applicable:

1) Materials:

   — Material specification (specification of thermoplastic granulate/ powder and sheets)
   — Material data sheet
   — Test procedure at manufacturer (Qualification testing)

2) Structures:

   — General arrangement plan
   — Midships section
   — Shell expansion
   — Transverse section
   — Longitudinal section
   — Decks
   — Transverse bulkheads
   — Longitudinal bulkheads
   — Forepeak Construction
   — Afterpeak Construction
   — Bottom
   — Cross structure, for catamarans/multihulls
   — Superstructure and deck houses

3) Stability:

   — Stability booklet
   — Lines plan
   — External watertight and weathertight integrity plan
   — Inclining test or light weight survey procedure
   — Inclining test or lightweight survey report
   — Freeboard plan

4) System:

   — Ventilation system (Ducting diagram)
   — Exhaust gas system (Piping diagram)
   — Conventional steering arrangements (Arrangement plan)
   — Propeller shaft
   — Propeller shaft bracket
   — Bilge handling systems
   — Fuel oil system
   — Sea water system
   — Fresh water and grey water systems
   — Engine room arrangement
   — Electric power system, general
   — Electrical load balance

— Battery spaces
— Electric power system

5) Safety:

— Accommodation plan
— Safety plan
— Field of vision (Vertical and horizontal field of vision)
— Fire control plan
— Structural fire protection drawing
— Control and monitoring system documentation
— Fixed fire extinguishing system documentation
— Navigation lights and shapes, and sound signal appliances (Arrangement plan)

6) Sea Trial:

— Test procedure for quay and sea trial

3.3 BKI has the right to request related documents and/or drawings, if deemed necessary.

3.4 Any deviation from the approved drawings shall be reported and re-approved before work is carried out.

C. Certification

1. General

1.1 The type of certificates to be issued by BKI will be:

— Product Certificate
— Type Approval Certificate
— Quality System Production Certificate

1.2 The certificates shall contain the following information as applicable:

— the name and address of the builder (yard, manufacturer)
— the identification of the product (boat/vessel) type designation and reference to Owner of the design
— reference to the standard and regulations applied
— any restrictions/limitations in the use of the vessel
— validity
— date of issue and signatures.

2. Certification Schemes

2.1 One-off Vessel (Scheme 1)

2.1.1 General

2.1.1.1 The procedure (scheme) is applicable for one-off certification, i.e. a design on which only one vessel is built.

2.1.2 Procedure

2.1.2.1 BKI will verify that the technical documentation complies with the requirements.

2.1.2.2 BKI will carry out surveys during production, examine the complete vessel and carry out the appropriate tests as set out in the relevant requirements to ensure its conformity.

2.1.2.3 Upon successful completion of the certification procedure, BKI will issue a Product Certificate.

2.2 Series of vessel (Scheme 2 and 3A or 3B)

2.2.1 General

2.2.1.1 The procedures (schemes) described in 2.2.2, 2.2.3 and 2.2.4 are applicable to one design on which a series of vessel is manufactured. 2.2.2 covers the design phase and shall always be followed by a procedure covering the production phase, 2.2.3 or 2.2.4.

2.2.2 Type Approval (Scheme 2)

2.2.2.1 The procedure (scheme) shall normally be used for approval of a design produced in series and shall be followed by a procedure (scheme) covering the production phase.

2.2.2.2 The procedure shall be according to Guidance for Approval and Type Approval of Materials & Equipment for Marine Use (Pt.1, Vol. W), Section 3.

Note:

Overall principles for Type Approval (TA):

- *Application for TA*
- *Quotation*
- *Approval of the design*
- *Initial assessment*
- *Type testing*
- *Issuance of TA certificate*

2.2.2.3 BKI verifies that the technical documentation complies with the requirements.

2.2.2.4 BKI verifies, by performing examinations and tests that a prototype complies with the applicable requirements and is built in accordance with the technical documentation.

2.2.2.5 Upon successful completion with the certification procedure, BKI will issue a Type Approval Certificate with validity of 5 years.

2.2.3 Product verification (Scheme 3A)

2.2.3.1 The procedure (scheme 3A) covers the production phase and follows procedure for Type Approval (Scheme 2).

2.2.3.2 The builder shall take necessary actions to ensure that the manufacturing process ensures conformity of the products with the type as described in the approved technical documentation.

2.2.3.3 Normally all products will be individually examined and appropriate tests carried out in order to verify their conformity with the type as described in the type approval certificate and the approved technical documentation.

2.2.3.4 If statistical verification is agreed, the method shall be according to ISO 2859-1:

- Each relevant section shall be considered as an inspection item
- Sample size shall be based on Table 1, General inspection level “I”
- Sampling plan shall be according to Table 2-A
- Acceptance Quality Limit (AQL) shall be 1.0

If a lot is found not acceptable, all items shall be re-examined until BKI is satisfied that all non-conforming items have been rectified/replaced. BKI will determine whether the re-examination shall include all inspection items, or only the particular types of non-conformities which caused initial non-acceptance.

2.2.3.5 BKI verifies that the technical documentation complies with the requirements.

2.2.3.6 Upon successful completion of the certification procedure, BKI will issue a Product Certificate covering either each unit or a defined lot.

2.2.4 Production verification (Scheme 3B)

2.2.4.1 The procedure (scheme 3B) covers the production phase and follows procedure for Type Approval (scheme 2).

2.2.4.2 Production verification will only be considered used for small vessel of simple design.

2.2.4.3 The builder shall operate an approved Quality Assurance system (QA system) for manufacturing, final product inspection and testing. The QA system shall be subject to monitoring as specified below.

2.2.4.4 The procedure may cover several designs with valid Type Approval Certificate.

2.2.4.5 The builder shall submit the documentation concerning the QA system. The QA system shall ensure compliance of the products with the type(s) as described in the Type Approval Certificate(s) and the approved technical documentation.

2.2.4.6 All the elements, requirements and provisions adopted by the manufacturer shall be documented in a systematic and orderly manner in the form of written policies, procedures and instructions.

2.2.4.7 The QA system documentation shall permit a consistent interpretation of the quality programmes, plan, manuals and records.

2.2.4.8 The QA system shall contain in particular an adequate description of:

- the quality objectives and the organizational structure, responsibilities and powers of the management with regard to product quality
- the manufacturing, quality control and quality assurance techniques, processes and systematic actions that will be used
- the examinations and tests that will be carried out before, during and after manufacture, and the frequency with which they will be carried out
- the quality records, such as inspection reports and test data, calibration data, qualification reports of personnel concerned, etc.
- the means to monitor the achievements of required product quality and the effective operation of the quality system.

2.2.4.9 Upon successful approval of the QA system BKI will issue a Quality System Production Certificate valid for 5 years.

2.2.4.10 BKI will carry out audits annually to make sure that the builder maintains and applies the quality system. The audit will include spot checks on vessel under building and review of quality records of built vessel.

2.2.4.11 Additionally BKI may pay unannounced visits.

D. Testing and sea trials

All equipment shall be function tested after installation to demonstrate compliance with the requirements in this Guidelines. The testing shall include sea trial(s) with all equipment installed. All testing shall be carried out according to a plan approved by BKI. BKI may require witnessing of all or part of the testing and/or sea trials.

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Section 2 Material Properties

A. General Requirements

1. The approval is given to the manufacturer who produces the raw material at the final stage before vessel production:

1.1 For rotational moulding, the approval is granted to the granulate/ powder manufacturer.

1.2 For thermoforming of sheets the approval is granted to the sheet manufacturer.

2. Ageing properties are to be verified on sheet material with pigments etc. which is to be used in the production.

3. The content of pigments is not to exceed 4% and is to be evenly distributed in the material. Any detrimental effect on the strength of the material is to be recorded.

4. The impact strength of the material at low temperatures is to be approved in relation to the fracture character at pendulum notch impact testing.

4.1 Brittle fracture at temperatures above 0° C is not acceptable.

4.2 If the transition between tough and brittle fracture occurs between 0 °C and -20 °C, the following statement is entered on the vessel's certificate:

> "The impact strength of the plastic material is reduced at low temperatures. The vessel is not recommended to be used in cold temperatures."

5. The ability of the material to withstand heating by sunlight is subject to approval on the basis of the reduction in the material stiffness between 20 °C and 65 °C.

6. A reduction in the shear modulus of the material greater than 80% due to heating is not acceptable.

6.1 If the reduction is between 30% and 80%, the following statement is entered on the vessel's certificate:

> "The material softens at high temperatures and may be permanently deformed by long term loading at high temperatures."

7. It is recommended that flame resistance of polyethylene plastics may be increased by adding flame retardants. Commercially available flame retardants contain mainly bromine, chlorine, phosphorus and nitrogen or aluminum and magnesium hydroxides which are incorporated into the polymers during their processing. Aluminium tri-hydroxide may be used when the processing temperature is below 200 °C. When processing temperatures are above 200 °C. Magnesium dihydroxide may be used. The fire retardant additives used are to be indicated by the manufacturer.

8. Engines spaces, if arranged, are to be provided with fire protection of minimum 15 minutes rating, Arrangement and materials for structural fire protection are to be approved. The fire protection is to cover the entire boundary of the engine space above lowest waterline.

9. For small vessels (normally **L** < 15 m) arrangements other than those specified in 8. would be specially considered (e.g. intumescing paint, fire retarding resin on interior surface of laminates).

B. Documentation

1. The material properties and documentation requirements for LDPE and MDPE are indicated in Table 2.1 and 2.2. Similarly Table 2.3 specifies the requirements for HDPE.

2. The test specimens are to be taken from the material which is used in production, but the material is not to be weakened due to the manufacturing process.

3. The approval is to state the manufacturing process for which the material is approved.

Table 2.1: Properties and documentation for LDPE and MDPE

Properties	**Test method**	**Results to be given for information except where noted.**
Tensile properties	ISO 527-2:2012 (Test specimen type 2, 5 - 50 mm/min.)	Curve at 20 °C and 65 °C
Shear modulus	ISO 6721-2:2019 (torsion pendulum)	Curve for temperature range 20 °C to 65 °C
Shear strength	ASTM D792-20	
Creep	ISO 899-1:2017 (carried out on at least 3 stress levels and 2 test pieces per level)	Isochronous stress-deformation diagram for 1000,100, 10, 1 and 0,1 hours at 20 °C and 65 °C
Fatigue	Fatigue test carried out with constant stress or deformation amplitude	Curves up to at least 100.000 loading cycles at 20 °C
Hardness	ISO 868:2003 (Shore D)	Given at 20 °C, read after 15 seconds
Falling weight impact	ASTM D5628-18 (method A). The radius of the drop hammer's striking surface is to be 12,5 mm	Fracture energy by visible crack as fracture criterion, given at 0 °C and at 20 °C and with relevant material thickness
Pendulum impact	With V-notch 45° in accordance with ISO 180:2019. For particularly flexible materials an alternative test method (tensile impact strength) may be used.	Fracture energy at 0°C as well as a description of fracture type. The notch impact strength is only stated for non-aged
Ageing	ISO 179-1:2010 (Charpy) without notch: - Natural ageing DIN 53386, item 6.1. - Accelerated ageing: DIN 53387	Plotted fracture energy for aged materials as a function of logarithmic time. The time is normally to cover 48 months natural ageing or 5 000 hours accelerated ageing. A shorter time can be approved if the ageing process is clarified at an earlier stage
Fuel resistance	Stressed material submerged in normal engine fuel	Description of surface cracking
Melt index	ISO 1133-1:2011	
Chemical resistance	ISO 175:2010	List of chemicals which may damage the material
Density	ISO 1183-2:2019	*
Oxygen index	ASTM D2863-19/ ISO 4589-2:2017	Value *
Flexural Properties	ASTM D790-17/ ISO 178:2019	
Compressive strength	ASTM D695-15/ ISO 604:2002	
Note: * Also required by delivery		

Table 2.2: Properties of LDPE and MDPE

Property	**Requirement LDPE**	**Requirement MDPE**	**Unit**	**Comments**
Density	< 0,930	0,930 - 0,945	g/cm^3	
Melt index	Stated value ±1.0 Though max. 3,5	Same as LDPE	g/10 min.	
Tensile yield stress	min. 7,5 min. 4,5	min 13,0 min 8,0	N/mm^2 N/mm^2	At 20 °C At 65 °C
Elasticity modulus in tensile yield	min. 180	min. 350	N/mm^2	At 20 °C
Tensile creep strength	max. 2,5 at stress 2,0	2,0 at stress 3,0	% N/mm^2	Deformation after 100 hours at 20 °C
Flexural Strength	8-15	20	N/mm^2	
Flexural Modulus	250	500	N/mm^2	
Compressive Strength	9,6	15	N/mm^2	
Shear Strength	8	12	N/mm^2	
Hardness	Stated value ±3	Same as LDPE	Shore D	Tested at 20 °C and read after 15 sec.
Impact strength (drop test without notch)	min. 15	min. 15	J/mm thickness	Freely supported test piece 0 °C
Notch impact strength (pendulum test with notch)	No brittle fracture	No brittle fracture	Visual	Required only for vessels with single skins 0 °C
Pore contents	max. 15 max. 20	Same as LDPE Same as LDPE	% of thickness % of thickness	In structural parts In the vessel elsewhere
Impact tensile strength of aged material	No brittle fracture min. fracture energy 1,0 J/cm^2	Same as LDPE J/cm^2	Visual	Aged material corresponding to 4 years of natural ageing, tested at 0 °C and with a test speed $2x10^5$ %/mm

Table 2.3: Properties of HDPE

Property	Properties of HDPE	Unit	Test Method
Density	0,946 to 0,972	g/cm^3	ASTM D792-20
Melt Mass Flow Rate	0,030 to 10 (190 °C/2,16 kg)	g/10 min	ISO 1133-1:2011
Tensile Yield Stress	min 17	N/mm^2	ASTM D638-14
Ultimate Tensile Stress	min 24	N/mm^2	ASTM D638-14
Tensile Elongation at Yield	1,0 to 27	%	ASTM D638-14
Tensile Elongation at Break	10 to 1500	%	ASTM D638-14
Tensile Creep Modulus	292 (After 1000 hrs)	N/mm^2	ISO 899-1:2017
Compressive Stress	20	N/mm^2	ASTM D695-15/ ISO 604:2002
Shear Strength	18	N/mm^2	ASTM D792-20
Flexural Strength	40	N/mm^2	ASTM D790-17/ ISO 178:2019
Flexural Modulus	750	N/mm^2	ASTM D790-17/ ISO 178:2019
Hardness	as LDPE (1)	Shore D	
Impact strength (drop test without notch)	as LDPE (1)	J/mm thickness	
Notch impact strength (pendulum test with notch)	as LDPE (1)	Visual	
Pore contents	as LDPE (1)	% of thickness	
Impact tensile strength of aged material	as LDPE (1)	Visual	
Viscosity Number (Reduced Viscosity)	157,8 to 398,3	ml/g	ISO 1628-3:2010
Water Absorption	0,010 to 0,017 (24 hrs)	%	ASTM D570-98/ ISO 62:2008

(1) Test method, results and comments of referred material are to be applied as indicated in Table 2.1 and Table 2.2.

Note:
1. The information contained at the table above stated at 23 °C are typical values intended for reference and comparison purposes only.
2. The values mention above, intended to be used for design calculations, shall be agreed with BKI in advance

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Section 3 Structural Design

A. General

1. Material properties are given in the tables for scantling calculation purposes as a reference. Those properties are to be validated by material test results.

2. The design of the vessel is to be suitable for the manufacturing process and the raw material being used.

3. When forming vessels of polyethylene, it is to be taken into consideration that the mechanical properties of the material vary with the temperature and the duration of the loading.

4. Hard points in the structure are as far as practicable to be avoided. Stiffening is to be evenly distributed over the hull, to the extent this is practicable.

5. The design is to be such that sufficient hull stiffness is obtained. Large flat surfaces are to be avoided as far as practicable.

6. In general, the polyethylene structures are not suitable for the carriage of vehicles (concentrated loads).

7. Pillars in polyethylene vessels are in general not allowed. Specific cases may be considered by BKI based on strength and stiffness under compression.

B. Rule thickness

1. Rule thickness is the value stated in C.2.

2. A measured thickness is regarded as satisfactory when the average of the values measured at 20 points is not less than the rule thickness and if none of the values measured at the individual points is more than 15% below rule thickness.

3. Local reinforcements that are welded or glued to the hull, may be specially considered as part of the skin thickness.

4. Rounding-off

Values for thickness as obtained from formula are to be rounded off to the nearest standard value, without such a reduction exceeding 3 per cent.

C. Scantlings

1. Scantling values obtained by direct calculation methods are not to be less than 80% of those stated in relevant empirical formula given below.

2. Hull Thickness

2.1 Hull Scantlings - Simplified Method

2.1.1 The thickness of the outer hull bottom and side is not to be less than:

$$t = k \cdot s \sqrt{\frac{P_F}{6,7L}(14 + 3,6L)}$$

Where:

	LDPE	MDPE	HDPE
k	1	0,85	0,72

s = stiffener spacing in metres
P_F = Pressure factor for bottom or side (P_{Fb} or P_{FS}), as taken from the Table 3.1 and 3.2 below:

Table 3.1: Values for P_{Fb}

V [Knot]	**Length [m]**							
	3	**6**	**9**	**12**	**15**	**18**	**21**	**24**
10	18	28	40	54	70	85	98	110
15	25	38	50	65	80	95	109	120
20	37	51	66	82	97	112	125	138
25	52	69	87	104	120	134	150	163
30	70	91	112	131	150	165	182	197
35	93	119	142	166	185	202	220	238
40	120	150	179	205	227	248	268	287
45	150	185	219	251	275	298	320	342

Table 3.2: Values for P_{Fs}

V [Knot]	**Length [m]**							
	3	**6**	**9**	**12**	**15**	**18**	**21**	**24**
10	17	25	37	54	71	89	109	129
15	17	26	38	55	72	90	110	130
20	19	28	40	57	74	92	113	133
25	21	30	43	60	77	97	118	138
30	26	36	48	66	83	102	124	144
35	32	42	56	72	90	109	131	151
40	40	51	63	80	98	118	140	160
45	50	61	73	90	108	128	150	171

2.1.2 The thickness of the inner hull is not to be less than:

$$t_i = 0,8\,t \quad [mm]$$

2.2 Hull Scantling - Alternative Method

If the thickness obtained from the scantling calculation in 2.1 cannot be met, the following calculation may be used as an alternative.

2.2.1 Hull structure scantling analysis

The hull structure scantling analysis is to be carried out according to the requirements for aluminum in Rules for Small Vessel up to 24 m (Pt.3, Vol.VII), Sec.1, F.5 to F.11 as applicable, with the material factor modified as described in 2.2.2.

2.2.2 Modifications for material factor (k)

For the purposes of scantling calculations, the stress components used are taken from the minimum values determined by the manufacturer or by following table below.

	HDPE	MDPE	LDPE
R_{eH}	22	17,0	10,0
R_m	30	17,0	10,0

Material factor (k) for aluminium in Rules for Small Vessel up to 24 m (Pt.3, Vol.VII), Sec.1, F.3.3.3 is to be modified as follows:

$$k = \frac{635}{(R_{eH} + R_m)/S_f}$$

where S_f is the Safety factor for **PE** (see 2.2.3 to 2.2.4)

2.2.3 Safety factor for plating

For the plate formula, in case of impact pressure or of plating of subdivision bulkheads:

$$S_f = 1,45$$

while in case of quasi-static pressure (external or internal):

$$S_f = 1,60$$

2.2.4 Safety factor for ordinary stiffeners and primary supporting

For the ordinary stiffeners/primary supporting:

S_f = 1,95 in general
= 1,60 for ordinary stiffeners/primary supporting of cross-deck bottom and internal sides of twin-hull craft, when subject to impact pressure
= 1,45 for ordinary stiffeners/primary supporting of subdivision bulkheads

2.2.5 Minimum ordinary stiffener section modulus

As a rule, the minimum section modulus of hull and deck ordinary stiffeners is not to be less than 15 cm^3.

2.3 Equivalence

Structural checks of the hull scantlings may be also carried out in compliance with the provisions of ISO 12215-5 for metallic materials. The design category is not to be greater than C and the safety coefficient to be adopted for the definition of the design stresses is 1,5.

2.4 It is recommended that rotation moulded vessels are to have a hull weight of at least k x 45 kg. The vessel is to be stiffened in such a manner that keel, bottom or side shell is not deformed by normal load.

2.5 Proper stiffness is to be provided and demonstrated to BKI. For this purpose direct calculation methods may be utilized.

2.6 Scantlings of stiffeners are to be adequate with intended service of the vessel and to withstand loads to which the vessel may encounter. For this purpose direct calculations are to be submitted to BKI along with plans. The scantlings of primary and secondary stiffening members are to be determined by direct calculation where the vessel is of unusual design, form or proportions.

2.7 Transom for engine mounting is normally to be stiffened over its full breadth. Scantlings based on practical testing with simulated loads from the engine may be accepted.

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Section 4 Manufacture

A. General

1. Premises

1.1 Premises for manufacturing of vessels of polyethylene are to be suitable for the production process applied.

1.2 Such vessels can be manufactured either by rotational moulding or welding.

1.3 Uncontrollable draughts are to be avoided in the vicinity of the production machinery and in cooling rooms.

1.4 Premises and production machinery are to be arranged to avoid risk of pollution by oil spill, dust etc.

2. Marking of produced vessels

2.1 The vessel is to have a durably fitted plate or similar which clearly states the structural material of the vessel.

2.2 The vessel manufacturer is to supply the following with each vessel:

— information on the vessel's presupposed use,

— directions for maintenance and repair as well as information on substances which may have detrimental effects on the vessel's structural material.

B. Rotation Moulding

1. General

1.1 In rotational moulding, rigid, resilient hollow bodies are formed by powdered plastic material in heated molds, which are rotated simultaneously in two planes perpendicular to each other. The plastic particles make contact and melt on the inner surfaces of the hot molds and fuse in layers until all the powder is fused and the desired end product and wall thickness is obtained. The wall thickness is controlled by the amount of powder placed in the mold. Rotationally molded pieces are stress-free except for slight shrinkage forces because the pieces are produced without any external pressure. Additionally, there is practically no scrap in rotational molding.

1.2 Raw materials may be approved in accordance with Section 2. No materials built into the vessel are to have detrimental effects on the other materials applied.

1.3 Material moulded in accordance with the vessel manufacturer's procedure is to at least have properties as given in Table 2.1 and Table 2.2 or Table 2.3.

1.4 The skins in double hulled constructions and in sandwich constructions are to be watertight. Screws or bushings in the skins are also to be watertight.

1.5 Where exposed, the connection between inner and outer skin is to be watertight.

1.6 Requirements to moulding time, temperatures and cooling time are to be determined based on quantity of powder used and the rotation speed, on the background of inspection of complete moulded vessels.

2. Moulding condition

2.1 Release compositions applied to the mould are not to have any detrimental effects on the vessel material, e.g. stress cracking.

2.2 Regenerated raw material will not be accepted for use in hulls manufactured by rotation moulding.

2.3 The rotation procedure is to be the same for moulding of all vessels of the same type.

2.4 The weight quantity of powder in the mould is not to be less than 1% below the specified value.

2.5 The temperature is to be automatically controlled. The temperature and its specified permissible variations will be subject to approval in each case, on the basis of the limitations of the raw material properties. The temperature at each measuring point is not to vary by more than +5 °C for each moulding process.

2.6 The sintering time and the after-sintering time is stipulated on the basis of thickness measurements on the vessel type in question to ensure that an even distribution of material in the mould is obtained. The process time is not to vary by more than + 1 minute from the approved time. Any welding together of inner and outer mould is to be approved in each separate case.

2.7 The cooling-down process is to be the same for each vessel of the same type, and is to be stipulated on the basis of the sintering temperature, vessel type and raw material, so that deformations in the material are avoided.

2.8 If alterations are made in the manufacturing method, BKI is to be informed for considering whether special tests will be required to check the material quality.

3. Moulded vessels

3.1 The material in the finished moulded vessels is to be without any visible surface flaws which might be of significance to the vessel's service. Surfaces and cross sections are not to show any sign of either insufficient fusion of the powder particles or thermal degradation of the material.

3.2 Pores or air bubbles must not be so numerous or of such size that the material properties are significantly reduced. The amount and size allowed are to be stipulated for each type of material.

3.3 The material in the moulded vessels is to comply with the requirements to minimum mechanical properties specified for the raw material in question.

3.4 Completed vessels are not to have significant deformations, and all welded joints are to be tight.

4. Internal quality control

4.1 The raw material is to be stored in accordance with the manufacturer's instructions. The vessel manufacturer is to keep a verifiable record of the raw material supplier's certificate data, and store samples from each material delivery.

4.2 The vessel manufacturer is to record the following process data for each individual vessel:

- weighed quantity of powder
- temperature
- sintering and after-sintering time
- cooling-down time

— moulding time

— density

— melt index.

4.3 Each vessel is also to be visually checked for surface flaws and tightness of welded joints.

4.4 Each vessel is to be marked with its production number, which is to identify the mould in which the vessel has been manufactured. The marking is to be made in a durable manner.

4.5 Thickness measurements are normally to be carried out on vessels that are cut into several sections. Such measurements are to be carried out on one out of 200 vessels manufactured in each mould.

C. Welding

1. General

There are various methods by which plastics can be welded for fabrication of different items. Among others, these include extrusion welding and hot gas welding, which are generally used for manufacture of vessels.

2. Definitions

2.1 Extrusion welding – A process in which a welding rod is drawn into a miniature hand held plastic extruder, plasticized, and forced out of the extruder against the parts being joined, which are softened with a jet of hot air to allow bonding to take place. It is the preferred technique for joining material over 6 mm thick.

2.2 Hot gas welding, also known as hot air welding, is a plastic welding technique, which is analogous to metals, though the specific techniques are different. A specially designed heat gun, called a hot air welder, produces a jet of hot air that softens both the parts to be joined and a plastic filler rod, all of which must be of the same or a very similar plastic. Two sheets of plastic are heated via a hot gas or a heating element and then rolled together. This is a quick welding process and can be performed continuously.

3. Equipment

Equipment used for hot gas welding and extrusion welding are generally in accordance with national / international standards such as EN 13705:2004.

4. Internal quality control

4.1 Raw materials may be approved in accordance with Section 2. No materials built into the vessel are to have detrimental effects on the other materials applied.

4.2 The vessel manufacturer is to keep a verifiable record of the raw material supplier's certificate data, and store samples from each material delivery. The raw material is to be stored in accordance with the manufacturer's instructions.

4.3 Vessels manufactured by welding processes are to also comply with the requirements in B.4.3 to 4.5.

4.4 The welding procedure specification (WPS) is to be prepared and non-destructive testing (NDT) of weld joints is to be carried out in accordance with recognized national/ international standards. Similarly, welders for thermoplastics are also to be trained and qualified as per recognized national/ international standards. An indicative list of standards for welding of thermoplastics is provided in Table 4.1.

Table 4.1: Standards related to thermoplastics

S No	Standard No	Standard
1	ISO 472:2013 Amd 1 - 2018	Plastics – Vocabulary
2	ISO 17855-1:2014	Plastics – Polyethylene (PE) Moulding and Extrusion Materials Part 1: Designation System and basis for specifications.
3	ISO 17855-2:2016	Plastics – Polyethylene (PE) Moulding and Extrusion Materials Part 2: Preparation of test specimens and determination of properties
4	ISO 14632:1998	Extruded sheets of polyethylene (PE-HD) - Requirements and test methods
5	ISO 15527:2018	Plastics - Compression-moulded sheets of polyethylene (PE-UHMW, PE-HD) - Requirements and test methods.
6	ISO 20753:2018	Plastics – Test Specimens
7	ISO 11469:2016	Plastics - Generic identification and marking of plastics products
8	ISO 11501:1995	Plastics - Film and sheeting - Determination of dimensional change on heating
9	EN 13705: 2004	Machines and equipment for hot gas welding (including extrusion welding)
10	EN 13067:2013-01	Plastics Welding Personnel – Qualification testing of Welders – Thermoplastic welded assemblies
11	PD CEN/TS 16892:2015	Plastics – Welding of thermoplastics – specifications of welding procedures.
12	EN 12943:1999	Filler Materials for Thermoplastics
13	ISO 16012:2015	Plastics - Determination of linear dimensions of test specimens
14	EN 12814-1:1999	Testing of Welded Joints of Thermoplastics Semi-finished Products Part 1 – Bend Test
15	EN 12814-2:2000	Testing of Welded Joints of Thermoplastics Semi-finished Products Part 2 – Tensile Test
16	EN 12814-3:2014	Testing of welded joints in thermoplastics semi-finished products - Part 3: Tensile creep test
17	EN 12814-4:2018	Testing of welded joints of thermoplastics semi-finished products - Part 4: Peel test
18	EN 12814-5:2000	Testing of Welded Joints of Thermoplastics Semi-finished Products Part 5 – Macroscopic Examination
19	EN 12814-6:2000	Testing of welded joints of thermoplastics semi-finished products - Part 6: Low temperature tensile test
20	EN 12814-7:2002	Testing of welded joints of thermoplastics semi-finished products - Part 7: Tensile test with waisted test specimens
21	EN 12814-8:2001	Testing of Welded Joints of Thermoplastics Semi-finished Products Part 8 – Requirements
22	EN 13100-1:2017	Non-destructive Testing of Welded Joints of Thermoplastics semi-finished products – Part 1: Visual Examination
23	EN 13100-2:2017	Non-destructive Testing of Welded Joints of Thermoplastics semi-finished products – Part 2: X Ray Radiographic Testing
24	EN 13100-3:2005	Non-destructive Testing of Welded Joints of Thermoplastics semi-finished products – Part 3: Ultrasonic Testing
25	EN 13100-4:2012	Non-destructive testing of welded joints of thermoplastics semi-finished products - Part 4: High voltage test
26	EN 14728:2019	Imperfections in Thermoplastic Welds- Classification
27	EN 16296:2012	Imperfections in thermoplastics welded joints - Quality levels

Table 4.1: Standards related to thermoplastics
(continued)

S No	Standard No	Standard
28	DVS Technical Code 2207-1	Welding of Thermoplastic Heated Tools Welding of Pipes, Pipeline Components and Sheets Made of PE – HD
29	ASTM E3044	Standard Practice for Ultrasonic Testing of Polyethylene Butt Fusion Joints

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Section 5 Freeboard and Stability Requirement

A. Freeboard

All vessels shall meet minimum required freeboard in accordance with Rules for Small Vessel up to 24 m (Pt.3, Vol.VII), Annex H .

Note:

Freeboard is smallest height above the waterline to any downflooding opening or gunwale (whichever is less) when the vessel is upright in calm water in the maximum load condition.

B. Stability Requirements

1. For vessel of length from 6 to 24 m shall meet stability requirement in Rules for Small Vessel up to 24 m (Pt.3, Vol.VII), Section 5.

2. For vessel of length less than 6 m may be comply with requirement in Annex A.

C. Removal of water

The internal arrangement of a vessel shall facilitate the drainage of water, either:

— bilge pump or equivalent means,

— directly overboard with non return system

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Annex A Stability and Buoyancy Test

A. Scope

These Annex address only the stability and buoyancy tests for vessels with length less than 6 m.

B. Flotation Tests

1. General

1.1 This test is to demonstrate that the vessel has sufficient flotation and stability during emergency.

1.2 Swamped stability shall be proven using method given in 2. and 3.

1.3 Swamped buoyancy shall either be proven using the physical test method given in 2. and 4. or the calculation method of C. for the same condition and loading.

1.4 Where flotation elements are used, they shall comply with D.

1.5 In addition, for the purpose of the test, the vessel may be fitted with some means, such as handholds..

2. Test Condition

2.1 During the tests, the vessel shall be in calm water in the light vessel condition and then equipped as follows:

— A mass equal to 25% of the dry mass of stores and equipment included in the maximum total load shall be added on the interior deck, on the centreline at $L_H/2$,

— Vulnerable items, such as engines, may be replaced with an appropriate mass at the appropriate location.

— For outboard engines, the vessel manufactures's maximum recommended power shall be used. Table A.1 and A.2, columns 2 and 4 give the appropriate replacement mass to be used with respect to engine power for petrol engines. A heavier mass may be used if it is recorded in the owner's manual. A mass of 86 % of the engine dry mass shall be used for diesel, jet-propulsor or electric outboards, if these are supplied as the standard outfit. vessels equipped for use both with and without an outboard engine shall be tested in both conditions.

— For inboard engines, the replacement mass shall be lead, steel or iron of a mass equal to 75 % of the installed dry mass of the engine and stern-drive.

— Replacement masses shall, as far as practicable, have the same position of centre of gravity as the actual engine.

— Portable fuel tanks shall be removed. Fixed tanks shall either be removed, or shall be full with either fuel or water.

— All cockpit and similar drains normally open during operation of the vessel shall be left open. The plugs of drains for emptying the vessel of residual water when ashore shall be fulfilled.

— Care shall be taken throughout the testing to eliminate entrapped air other than in air tanks or air containers.

— Void compartments integral with the vessel structure and not complying with the requirements for air tanks in D. shall be opened so that they become swamped with water.

— Vessels intended to be fitted with engines of more than 3 kW and which are fitted with integral air tanks which have laminated, glued, welded or bolted seams in their construction, and which air tanks do not comply with the enhanced pressure test of D., shall have a number of air tanks opened to atmosphere during testing, according to Table A.3.

Table A.1: Mass of single-engine installations

Engine power kW	Engine + controls kg		Battery kg	
	Column 1 Dry	Column 2 Swamp	Column 3 Dry	Column 4 Swamp
0 to 1,5	13,7	11,7	-	-
1,6 to 2,9	18,2	15,5	-	-
3,0 to 5,2	40,9	34,8	-	-
5,3 to 11,2	60,0	51,0	9,1	5,0
11,30 to 18,7	104,5	88,9	20,5	11,4
18,8 to 33,6	124,1	106,2	20,5	11,4
33,7 to 44,8	161,7	138,2	20,5	11,4
44,9 to 56,0	188,5	161,0	20,5	11,4
56,1 to 74,6	207,6	177,2	20,5	11,4
74,7 to 108,2	258,6	220,5	20,5	11,4
108,3 to 164,1	260,7	222,3	20,5	11,4
164,2 and over	312,5	266,3	20,5	11,4

Table A.2: Mass of twin-engine installations

Engine power kW	Engine + controls kg		Battery kg	
	Column 1 Dry	Column 2 Swamp	Column 3 Dry	Column 4 Swamp
37,6 to 67,2	247,9	212,2	40,9	22,7
67,3 to 89,6	323,3	276,2	40,9	22,7
89,7 to 112,0	376,8	321,8	40,9	22,7
112,1 to 149,2	415,0	354,2	40,9	22,7
149,3 to 216,4	517,1	440,9	40,9	22,7
216,5 to 328,2	521,2	444,5	40,9	22,7
328,3 and over	624,9	532,5	40,9	22,7

Table A.3: Number of air tanks to be opened

Total number of air tanks	Number to be opened
≤ 4	Single largest
>4 but ≤ 8	Two largest
>8	Three largest

3. Swamped Stability Test

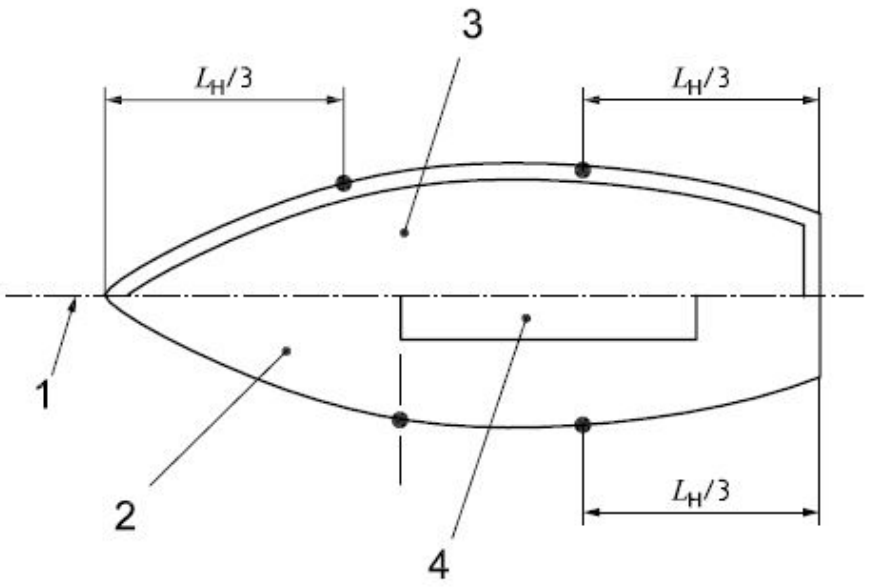
3.1 A metallic test weight with a dry mass of 6dP kg (P is maximum number of person to carry) but not less than 15d kg shall be suspended over the side of the vessel at each of four positions in turn. These positions shall be at LH/3 from the ends of the vessel (as shown in Figure A.1) or at the ends of the cockpit, if this is nearer amidships. There shall be no other test weights in the vessel during this test, apart from those required by B.2.

3.2 d is a coefficient to account for the buoyancy of the test weight, as given in Table A.4. Where test weights are not all of the same material, the calculation should be similar to:

$$\frac{m_{LD}}{1,099} + \frac{m_{CI}}{1,163} + \frac{m_{AL}}{1,612} = 6P$$

Where:

m_{LD} = mass of lead weights [kg];
m_{CL} = mass of cast-iron weights [kg];
m_{AL} = mass of aluminium weights [kg].



Key

1 centreline
2 deck
3 open boat
4 cockpit

Figure A.1: Positioning test weights

Table A.4: Material coefficient

Property	Material				
	Lead	65/35 brass	Steel	Cast iron	Aluminium
Value of d	1,099	1,138	1,151	1,163	1,612

3.3 As an alternative to suspending a test weight over the side, an equivalent heeling moment (calculated when the vessel is upright) may be applied using weights or persons positioned inside the vessel at seat level. Persons may only be used if they are not immersed when the vessel is heeled.

3.4 With the test weight in each position in turn, swamp the vessel by applying a downwards force at a position on the gunwale at approximately mid-L_H until the deepest point of the gunwale or coaming is 0,2 m below the water surface. Hold the vessel in this position until the water level has equalized, or for 5 min, whichever is less, and then release the vessel.

Note:

It is often helpful to partially fill the vessel with water before swamping in this manner.

3.5 For each position of the test weights, after a further 5 min have elapsed, the vessel shall not heel more than 45°.

4. Swamped Buoyancy Test

4.1 General

4.1.1 Vessels of L_H < 4,8 m shall satisfy both the tests described in 4.2 and 4.3. Vessels of L_H ≥ 4,8 m shall satisfy the test described in 4.3.

4.2 One-person Test

4.2.1 Load metallic test weights with a dry mass of 75d on the inner bottom of the vessel. Alternatively, provided they are not immersed above the knee, a person may be used instead of test weights, provided that they have a total dry mass of not less than 82,5 kg. This mass may be located at any longitudinal position needed to satisfy 4.2.3.

4.2.2 Swamp the vessel by applying a downwards force at a position on the gunwale at approximately mid-L_H until the deepest point of the gunwale or coaming is 0,2 m below the water surface. Hold the vessel in this position until the water level has equalized, or for 5 min, whichever is less, and then release the vessel.

Note:

It is often helpful to partially fill the vessel with water before swamping in this manner.

4.2.3 After a further 5 min have elapsed, it shall be demonstrated that the swamped vessel floats such that the residual freeboard and the corresponding position of the one person allow the latter to pump or bail the vessel dry.

4.3 Load Test

4.3.1 Load metallic test weights on the inner bottom of the vessel, evenly about the centre of the area available to the crew, according to the maximum number of person to carry (P) as given in Table A.5. This area shall have a minimum headroom clearance of 0,6 m above the swamped waterline. Alternatively, provided they are not immersed above the knee, people may be used instead of test weights, provided that they have a total dry mass of not less than the required mass of test weights if d is taken as 1,1.

Table A.5: Mass of load test weights

Property	Range of Service III*	Range of Service IV-V*
Dry mass more than	d(60 + 15P)	d(50 + 10PL)
Note: *- Mass in kilograms - * refer to Rules for Small Vessel up to 24 m (Pt.3, Vol.VII)*		

4.3.2 Swamp the vessel by applying a downwards force at a position on the gunwale at approximately mid-L_H until the deepest point of the gunwale or coaming is 0,2 m below the water surface. Hold the vessel in this position until the water level has equalized, or for 5 min, whichever is less, and then release the vessel.

Note:

It is often helpful to partially fill the vessel with water before swamping in this manner.

4.3.3 Vessels required to satisfy the level flotation standard shall, after a further 5 min have elapsed, float approximately level with more than two-thirds of the length of the top of the gunwale or coamings (including those across bow or stern) above water.

C. Calculation Method for Basic Flotation Requirement

1. General

1.1 The calculation method for complying with the basic flotation requirement is set out in 2., by showing that when a flooded or inverted vessel is totally immersed, the buoyancy available from the hull structure, fittings, and flotation elements exceeds that required to support the mass of the vessel prepared in accordance with B.2 and loaded in accordance with B.4.3 by a defined margin.

2. Method

Calculate the volume of the various elements of the vessel by direct calculation and/or from a knowledge of the mass and density of the different materials, using the expression:

$$V = m/\rho$$

Where:

V = the volume of an element, in m^3
m = the mass of that element, in kg;
ρ = the density of that element, in kg/m^3.

Calculate the total buoyant volume of the vessel, V_B, by adding together the volumes of :

— the hull structure (see Table A.6),

— the gross volume of fixed tanks for fuel, water, or other stored fluids, and of batteries, and

— the gross volume of air tanks or containers meeting the requirements of D.

Table A.6: Material densities

Material	Density kg/m^3
Miscellaneous equipment	2000
Food and other stores	2000
Stowed sails and ropes	1200
Window glass	2500
Window plastic	1200
Diesel engines	5000
Petrol engines	4000
Outboard engines	3000
Sail-drive struts	3000
Stern-drive struts	3000
HDPE	972
MDPE	945
LDPE	930

Shows that

$$V_B > \frac{m_{TEST}}{930}$$

Where:

V_B = total buoyant volume of the vessel, in m^3;
m_{TEST} = mass of the vessel prepared and loaded in accordance with B.2 and B.4.3 [kg]

D. Flotation Material and Elements

1. Requirements

1.1 Flotation elements shall comply with the requirements in Table A.7. Other types of flotation elements shall be evaluated following the same principles.

1.2 Those materials or parts of the vessel which are not primarily intended to provide flotation but which nevertheless contribute to the flotation characteristics shall not be subject to the requirements in this Annex.

Table A.7: Requirements for flotation elements

Property	Air tank	Air container	Inflated bag and rib collar	Low density material
Airtightness	RT	RT	R	-
Mechanical robustness or protection	R	R	R	R
Draining facility	R	R	-	-
Resistant to or protected from sunlight	-	R	R	R
Fitted with an inflation point	-	-	R	-
Temperature resistant –40 °C to +60 °C	-	-	-	R
Water absorption max. 8 % by volume	-	-	-	RT
Securely fastened to withstand buoyancy force	-	R	R	R
Encapsulated or resistant to liquids	-	-	R	R
Label: “Do not puncture air tank/container/ bag”	R	R	R	-

Note:

1) Flotation element = element which provides “buoyancy” to the vessel and thus influences the flotation characteristics

2) Air tank = tank made of hull construction material, and integral with hull or deck structure

3) Air container = container made of stiff material, and not integral with the hull or deck structure

4) Inflated bag = bag made of flexible material, not integral with hull or deck, accessible for visual inspection and intended always to be inflated when the vessel is being used

(Bags intended to be inflated automatically when immersed (e.g. at the masthead as a means to prevent inversion) are not regarded as flotation elements))

5) Rib collar = heavy duty tubular collar fitted around the periphery of the vessel and always intended to be inflated whenever the vessel is being used

6) Low density material = material with a specific gravity of less than 1,0 primarily incorporated into the vessel to enhance the buoyancy when swamped

7) R = denotes that this property is required but is not subject to a specific test by the builder.

8) RT = denotes that this property is required, and is required to be tested by the builder.

2. Tests

2.1 The water absorption of low-density material shall not exceed 8 % by volume after being submerged for 8 days according to ISO 2896. Material complying with IMO Resolution MSC.81(70 [3] shall be deemed to satisfy this requirement.

2.2 Where air tanks or air containers are used, they shall be subject to a pressure test, carried out at an initial over-pressure, with a permitted pressure drop within 30 s, as given in Table A.8.

2.3 Vessels intended to be fitted with engines of more than 3 kW and which are fitted with integral air tanks which have laminated, glued, welded or bolted seams in their construction, and which air tanks do not comply with the enhanced pressure test, shall have a number of air chambers opened to atmosphere during testing, according to Table A.3.

2.4 Breather holes in air tanks designed for the relief of air pressure due to variations in ambient temperature may be temporarily sealed during the above test, provided that their position does not alter the effectiveness of the tank during the flotation tests of this Annex.

Table A.8: Test pressures

Condition	Enhanced pressure test	Basic pressure test
Chambers required to be opened during flotation tests	None	As detailed in Table A.3
Initial over-pressure	2,5 kPa (250 mm water)	1,25 kPa (125 mm water)
Maximum pressure drop in 30 s	1,0 kPa (100 mm water)	0,75 kPa (75 mm water)