BIRO KLASIFIKASI INDONESIA

RULES FOR CLASSIFICATION AND CONSTRUCTION OF WING-IN-GROUND CRAFT (WIG CRAFT)

EDITION 2006

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Alterations to the preceding Edition are marked by beams at the text margin.

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Section 1

General

A. Documents to be submitted

1. Documents to be submitted for approval relating to an individual section are listed in each Section of these Rules as required. A complete list is attached as Annex A (Documents to be submitted).

2. A time schedule for the submittance of the documents is to be agreed upon between the company and BKI.

B. General Requirements

1. The right of interpretation of their technical Rules rests with BKI alone.

2. The application of the provisions of these Rules is subject to the following general requirements that:

.1 the Rules will be applied in their entirety;

.2 the management of the company operating the craft exercises strict control over its operation and maintenance by a quality-management system in accordance with the International Safety Management (ISM) Code adopted by the International Maritime Organization by resolution A.741(18), as amended;

.3 the management ensures that only persons qualified to operate the specific type of craft used on the intended route are employed;

.4 the distances covered and the worst intended conditions in which operations are permitted will be restricted by the imposition of operational limits;

.5 the craft will at all times be in reasonable proximity to a place of refuge;

.6 adequate communications facilities, weather forecasts and maintenance facilities are available within the area of operation;

.7 suitable rescue facilities one readily available in the intended area of operation;

.8 fire hazard areas such as machinery spaces are protected with fire-resistant materials and fire-extinguishing systems to ensure, as far as is practicable, containment and rapid extinguishing of fire;

.9 efficient facilities are provided for the rapid and safe evacuation of all persons into survival craft;

.10 all passengers and crew are provided with seats and safety belts; safety belts are fastened in all modes of operation;

.11 no enclosed sleeping berths for passengers or crew are provided.

3. Compliance with other Rules

For any items not expressly stipulated or modified for classification purposes by these Rules, the requirements of the Rules for High Speed Craft are to apply wherever relevant.

C. Safety Assessment

Safety Assessment provides a method to systematically evaluate systems with respect to the risk posed to the safety and integrity of the craft. A Safety Assessment study covering all safety relevant systems installed onboard a craft is a prerequisite for the assignment of Class. Procedures for the Safety Assessment process are described in Section 11.

D. Application, Equivalence, Classification

1. The Rules apply to Category A passenger WIG craft of Type A and cargo WIG craft of Type A which are engaged in national and international voyages. Exemptions from some of the requirements of the Rules may be granted when particular circumstances (e.g. restricted services, non-commercial use, very small craft) warrant this.

2. The Rules shall be applied as a complete set of comprehensive requirements. The Rules do not cover requirements for flight stability in the wing in ground-effect mode of operation. This issue has to be demonstrated by the owner/operator to the satisfaction of the Administration.

3. Craft deviating from the Rules in their types, systems, sub-systems or in some of their parts may be classified, provided that their level of safety and integrity are found to be equivalent to BKI's requirements for the respective Character of Class or Class Notation.

4. In addition to the Class Notations as per the Rules for Classification and Survey, Volume I, the following Class Notations may be assigned to a WIG craft:

WIG-A for Category A passenger WIG craft

WIG-CARGO for cargo WIG craft

Cargo WIG craft and Category A passenger craft are defined in E.10 and E.11 respectively.

A Class Notation for maximum permitted operating conditions expressed in terms of a significant wave height H_{S0} [m] for safe take-off and landing and a significant wave height H_{S1} [m] for safe wing in ground-effect flight and for safe emergency landing is added to the notations WIG-A and WIG-CARGO as follows:

WH H_{S0}/H_{S1}

Example: WH 0.5/2.0

E. Definitions

1. For the purpose of these Rules the terms used therein have the meanings defined in the following paragraphs. Definitions are listed in alphabetical order. Additional definitions are given in the general parts of the various Sections.

2. Administration

Administration means the Government of the State whose flag the craft is entitled to fly.

3. All up weight

All up weight means the sum of: basic weight, variable load, and disposable load. It corresponds to the "maximum take-off weight".

4. Auxiliary machinery spaces

Auxiliary machinery spaces are spaces containing:

– internal combustion engines of power output up to and including 110 kW driving generators, sprinkler, drencher or fire pumps, bilge pumps, etc.,

– oil filling stations,

– switchboards of aggregate capacity exceeding 800 kW,

– similar spaces and trunks to such spaces.

5. Base port

Base port means a specific port identified in the route operational manual and provided with:

.1 appropriate facilities providing continuous radio communications with the craft at all times while in ports and at sea;

.2 means for obtaining a reliable weather forecast for the area of operation and its due transmission to all craft in operation. The weather forecast shall cover the duration of the intended voyage plus a time margin for possible rescue operations;

.3 for a category A craft, access to facilities provided with appropriate rescue and survival equipment; and

.4 access to craft maintenance services with appropriate equipment.

6. Basic equipment

Basic equipment means the equipment which is common to all roles for which the operator intends to use the craft. In includes non-consumable fluids other than unusable fuel.

7. Basic weight

Basic weight means the weight of the craft together with its Basic Equipment, including a declared quantity of oil and unusable fuel.

8. Bottom

Bottom means the part of the hull between the keel and the chines

9. Cargo spaces

Cargo spaces mean all spaces other than special category spaces used for cargo and trunks to such spaces.

10. Cargo WIG craft

Cargo WIG craft means any WIG craft other than passenger WIG craft:

.1 with an all up weight of 30 t or less, and

.2 capable of maintaining the main functions and safety systems of unaffected spaces, after damage in any one compartment on board.

11. Category a passenger WIG craft

Category A passenger WIG craft means any passenger WIG craft:

.1 operating on a route where it has been demonstrated to the satisfaction of the flag and port States that there is a high probability that in the event of an evacuation at any point of the route, all passengers and crew can be rescued safely by external rescue services within the least of:

- the time to prevent persons in survival craft from exposure causing hypothermia in the worst intended conditions,
- the time appropriate with respect to environmental conditions and geographical features of the route, or
- 4 hours;

.2 which has access to weather reports and can reach a place of refuge in good time, if weather conditions deteriorate and are forecasted to exceed the worst intended conditions; and

.3 carrying not more than 50 passengers.

12. Chine

Chine means the knuckle at the intersection between the bottom and the sidewall of a craft. For hulls that do not have a clearly identified chine, the chine is the hull point at which the tangent to the hull is inclined 50 ° to the horizontal.

13. Complete stop

Complete stop means the end speed after a stopping manoeuvre such as safety landing or emergency landing and means a speed between 0 and 2 knots.

14. Control stations

Control stations mean those spaces in which the craft's radio or navigating equipment or the emergency source of power and emergency switchboard are located, or where the fire recording or fire control equipment is centralized, or where other functions essential to the safe operation of the craft such as propulsion control, public address, stabilization systems, etc., are located.

15. Convention

Convention means the International Convention for the Safety of Life at Sea, 1974, as amended.

16. Critical design conditions

Critical design conditions means the limiting specified conditions, chosen for design purposes, which the craft shall keep in displacement mode. Such conditions shall be more severe than the "worst intended conditions" by a suitable margin to provide for adequate safety in the survival condition.

17. Cross-deck

Cross-deck means the structure connecting the two hulls of a twin-hull craft.

18. Cruise speed

Cruise speed means the normal operating speed at a reduced level of propulsion power in ground-effect mode.

19. Dark period

Dark period means the time interval between sunset and sunrise.

20. Deadrise angle

Deadrise angle means the athwartship rise of bottom shell plating from keel to the chine. For hulls that do not have a clearly identified deadrise angle, the deadrise angle (α) is the angle between the horizontal and a straight line joining the keel and the chine. For catamarans with non-symmetrical hulls (where inner and outer deadrise angles are different), α is the lesser angle.

21. Disposable load

Disposable load means the weight of all persons and items of load, including fuel and other consumable fluids, carried in the craft other than the basic equipment and variable load.

22. Emergency landing

Emergency landing means a landing procedure whereby the craft decelerates at zero thrust from cruise speed in ground-effect mode to a complete stop in displacement mode.

The procedure may be combined with specific measures aimed at reducing the distance traveled in air and water.

23. Fail-safe structure

Fail-safe structure means one in which, following failure of a part of the structure, there is sufficient strength in the remainder of the structure to permit continued operation of the craft for a limited period.

24. Flexural flap

Flexural flap means a non-controlled elastic flap at the trailing edge of the wings which give way, if a nominal load is exceeded.

25. Front

Front means the forward structure of the hull between both sides and between top and chine.

26. Ground-effect

Ground-effect means a natural phenomenon experienced by an airfoil near the ground (or water surface) where a cushion of air is generated dynamically on the underside of the wing, resulting in an increased lift in combination with a reduced drag. The vertical extent of the ground-effect may be related to the wing area and chord length by (see Fig. 1.1):

h_R = approx. 0,1 c

where

h_R = reference height of tip or endplate of wing above ground; and

c = mean chord length of wing.

The mean chord length is calculated by

c = A_w/B

where

A_w = wing area and other areas contributing to the lift and

B = total wing span.

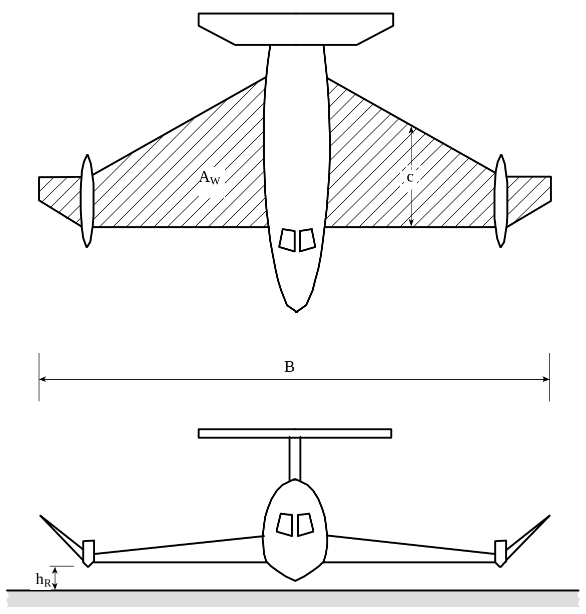

Fig. 1.1

27. Hull

Hull means the outer boundary of the enclosed spaces of the craft, except for the wings and winglets.

28. Hydrofoil

Hydrofoil means a rigid profile generating a hydrodynamic lift force.

29. International Maritime Organization (IMO)

International Maritime Organization (IMO) means the United Nations' specialized agency responsible for improving maritime safety and preventing pollution from ships.

30. LCG

LCG means the longitudinal center of gravity.

31. Lightweight

Lightweight means the displacement of the craft excluding the weight of cargo, fuel, lubricating oil, ballast water, fresh water, and feedwater tanks, consumable stores, passengers and crew and their effects.

32. LSA Code

LSA Code means the International Life-Saving Appliance Code as defined in regulation 3.10 of Chapter III of the International Convention for the Safety of Life at Sea (SOLAS).

33. Machinery spaces

Machinery spaces mean spaces containing internal combustion engines with aggregate total power output of more than 110 kW, generators, fuel units, propulsion machinery, major electrical machinery and similar spaces and trunks to such spaces.

34. Maximum take-off weight

Maximum take-off weight means the maximum permissible total weight of the craft for safe operation in the worst intended conditions, including lightweight, fuel and payload. Payload comprises either cargo or passengers or both.

35. Moulded base line

Moulded base line means the line parallel to the summer load waterline, crossing the upper side of keel plate or the top of sponson at the middle of length L (z = 0).

36. Operating compartment

Operating compartment means the enclosed area from which the navigation and control of the craft is exercised.

37. Operational modes

For a WIG, the following operational modes are to be distinguished:

.1 "Displacement mode" means the regime, whether at rest or in motion, where the weight of the craft is fully or predominantly supported by hydrostatic forces.

.2 "Transitional mode" means the transient mode from the displacement mode to the skimming mode and vice versa.

.3 "Skimming mode" means the mode of steady state operation where the weight of the craft is supported mainly by hydrodynamic forces.

.4 "Take off/Landing mode" means the transient mode from the skimming to the ground-effect mode and vice versa.

.5 "Ground-effect mode" means the steady state operation mode of the WIG craft within the vertical extent of the ground-effect clear from the surface underneath.

38. Passenger

Passenger means every person other than:

.1 the master and members of the crew or other persons employed or engaged in any capacity on board a craft on the business of that craft; and

.2 a child under one year of age.

39. Passenger craft

Passenger craft means a craft which carries passengers.

40. Place of refuge

Place of refuge means any naturally or artificially sheltered area which may be used as a shelter by a craft under conditions likely to endanger its safety.

41. Primary structure

Primary structures mean those portions of the structure, the failure of any part of which would seriously endanger the craft.

42. Public spaces

Public spaces mean those spaces allocated for the passengers.

43. Repairs

Repairs shall normally be effected in accordance with instructions contained in the Technical Manual. Where a significant repair is not covered by the Technical Manual, a suitable repair scheme shall be prepared by the relevant maintenance organization with the assistance, as necessary, of an Approved Design Organization, and shall be subject to CAA approval as a Craft Modification in accordance with Chapter A4-2.

44. Restricted visibility

Restricted visibility means any condition in which visibility is deteriorated by fog, mist, falling snow, heavy rainstorms, sandstorms or any other similar causes.

45. Rudder

Rudder means a control surface with a hydrodynamic or aerodynamic profile provided for directional control of the craft in water or air.

46. Safe fatigue life

Safe fatigue life means the operational period during which there is estimated to be a very low probability of fatigue failure of the part concerned under the action of the repeated loads of variable magnitude in service.

47. Safety landing

Safety landing means the normal landing procedure whereby the propulsion thrust is reduced or stopped. In sea states other than calm the craft is headed against the waves.

48. Service spaces

Service spaces mean those enclosed spaces used for pantries containing food warming equipment but no cooking facilities with exposed heating surfaces, lockers, store-rooms and enclosed baggage rooms.

49. Side

Side means the part of the hull between the chine and the top, aft of the hull point at which the tangent to the hull is inclined 10° to the longitudinal axis of the craft.

50. Significant wave height

Significant wave height means the average height of the one third highest observed wave heights over a given period (double amplitude).

51. Special category spaces

Special category spaces mean those enclosed spaces intended for the carriage of motor vehicles with fuel in their tanks for their own propulsion, into and from which such vehicles can be driven and to which passengers have access for embarking and disembarking, including spaces intended for the carriage of cargo vehicles.

52. Sponson

Sponson means buoyant hydrodynamic structure with a planning bottom, located at the outer ends of the wings, stabilizing the craft when in displacement mode, transitional mode, skimming mode and during take-off and landing.

53. Strength deck

Strength deck is the uppermost complete deck of the hull. It may be stepped.

54. Superstructure

Superstructure means the structure located on the strength deck.

55. Tail stabilizer

Tail stabilizer means rigid aerodynamic profile consisting of tailfin(s) and tailplane stabilizing the craft around the vertical and transverse axes.

56. Tailfin

Tailfin means rigid vertical aerodynamic profile, part of the tail stabilizer.

57. Tailplane

Tailplane means rigid horizontal aerodynamic profile, part of the tail stabilizer.

58. Technical manual

The technical manual shall consist of:

– craft operating manual;

– route operational manual;

– training manual;

– maintenance manual; and

– servicing schedule.

59. Top

Top means the part of the hull above the sides and aft of the front.

60. Type A WIG craft

Type A WIG craft means a WIG craft that operates only within the ground-effect.

61. Servicing schedule

Servicing schedule means the manual produced as part of the Type certification which defines the frequency of actions considered necessary to maintain the serviceability of a WIG craft, and the life limitations to be observed for any Item.

62. Variable load

Variable load means the weight of the crew, their baggage, removable units and equipment, the carriage of which depends upon the role for which the operator intends to use the craft for the particular flight.

63. Wet-deck

Wet-deck means the down-facing, horizontal or near horizontal surface of the cross-deck.

64. WIG craft

WIG craft means a craft which, in its main operational mode is supported clear above the water or ground by lift forces generated by the ground-effect between that surface and one or more air foils forming part of the structure of the craft, and which is not capable of sustained flight outside of that ground- effect.

65. Wing

Wing means the main rigid aerodynamic lifting surface.

66. Winglets

Winglets means an endplate attached to the outermost end of the wing.

67. Worst intended conditions

Worst intended conditions means the specified environmental conditions within which the intentional operation of the craft is provided for in the certification of the craft. This shall take into account parameters such as the worst conditions of wind force allowable, significant wave height (including unfavourable combinations of length and direction of waves), minimum air temperature, visibility and depth of water for safe operation and such other parameters as the Administration may require in considering the type of craft in the area of operation.

F. Units

Unless otherwise specified, the following units are used in the Rules:

- accelerations, in [g]
- angles, in degrees [dgr]
- areas, in [m^2]
- concentrated loads, in [kN]
- displacements, in [t]
- lengths, spans and spacings, in [m]
- pressures, in [kPa]
- section moduli, in [cm^3]
- speeds, in [m/s]
- stresses, in [MPa]
- thickness of plating, in [mm]

G. Abbreviations and Symbols (see alsoFig.1.2)

A_W = total area of the rigid lifting surfaces

AP = aft perpendicular, which means the perpendicular at the intersection of the waterline at drought T with the after side of sternpost or transom.

B = breadth of the craft

B_i = breadth of sponson (index i means number of sponson)

B_C = greatest moulded breadth between the chines

B_H = breadth of the broadest part of the moulded watertight envelope of the rigid hull, excluding appendages (see Fig. 1.2)

B_W = total wing span

D = all up weight

D_{min} = basic weight

FP = forward perpendicular, which means the perpendicular at the foreside of the stem.

H = moulded depth measured vertically from the top of moulded base line to moulded deck line at strength deck amidships

H_{0A} = moulded depth of the highest part of the WIG (including appendages) measured vertically from the moulded base line

H_{S0} = max. significant wave height for safe take-off and landing

H_{S1} = max. significant wave height for wing in ground-effect flight and emergency landing

H_T = moulded depth measured vertically from the top of the hull to the moulded base line

L = Rules length, $L = L_{WL}$, but not less than 0,97 L_H

L_H = length of the hull

LOA = length overall

L_{WL} = length of waterline, which means the overall length of the watertight envelope of the rigid hull, excluding appendages, at or below the design waterline in the displacement mode with no lift or propulsion machinery active.

T = fully loaded draught with the craft floated at rest in calm water and in off-cushion condition

V_{CR} = cruise speed

V_{max} = maximum speed

V_{per} = permissible speed

V_{TO} = verified (tested) take-off speed in the worst starting conditions as defined in the operating manual (see Section 10, B.2.1.3 and B.2.1.4)

g = acceleration of gravity = 9,81 m/s^2

g_{coll} = collision deceleration in [g]

x = longitudinal distance from FP to load center

x_0 = difference between the longitudinal distances L_H and L, measured from FP (see Fig. 1.2)

x_{CG} = longitudinal distance from FP to the centre of gravity

x_{St} = longitudinal distance from FP to the main step

x_{coll} = assumed longitudinal extent of the damage area under the collision condition, measured from FP

y = transverse distance from the craft's center-line to load center

z = height above base line to load center of plate or strength member

z_C = height above base line to chine at longitudinal position x

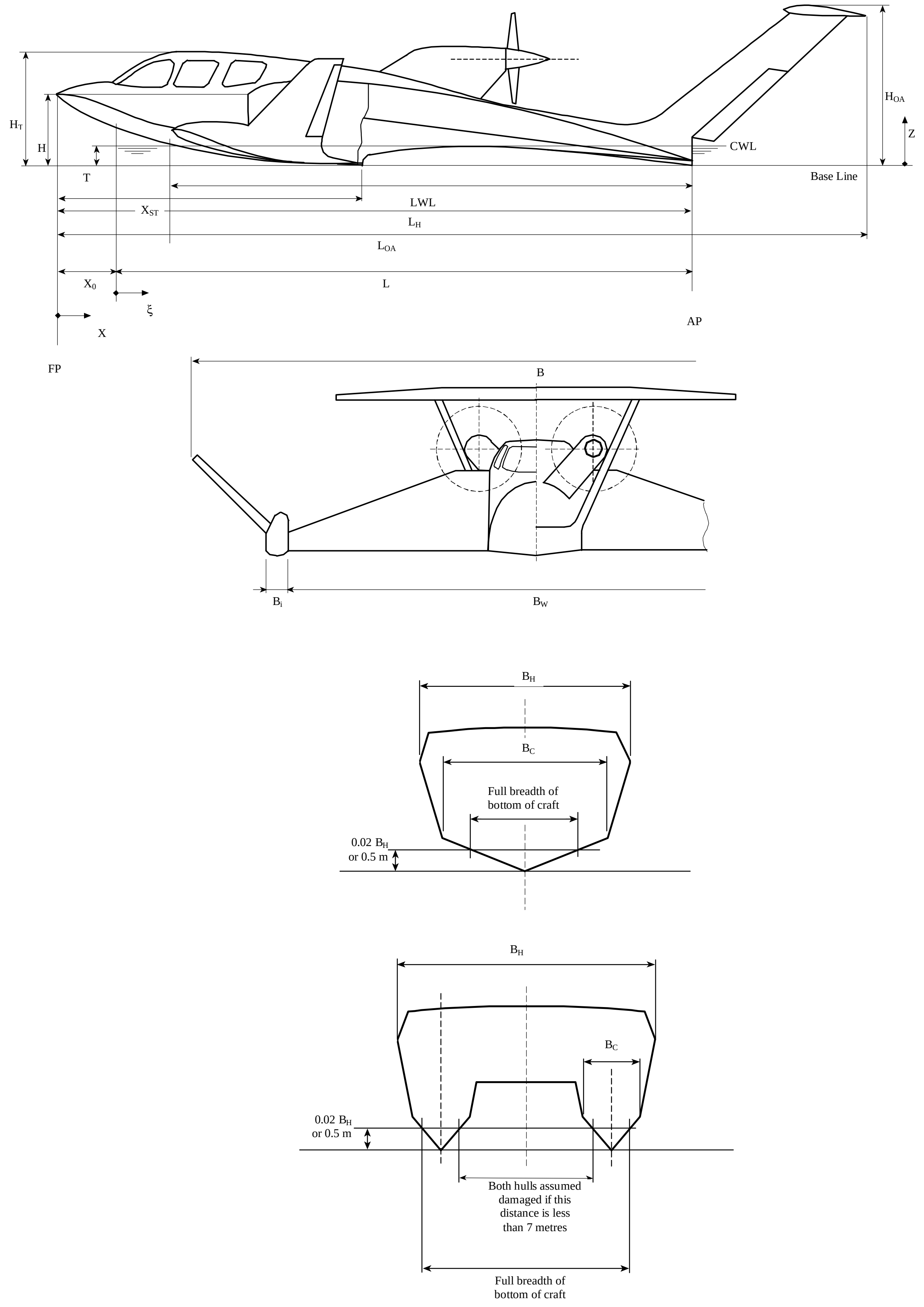
H_T
H
T
X_{ST}
LWL
L_H
L_{OA}
X_0
L
ξ
X
FP
AP
H_{OA}
Z
CWL
Base Line
B
B_i
B_W
B_H
B_C
Full breadth of bottom of craft
0.02 B_H or 0.5 m
B_H
B_C
0.02 B_H or 0.5 m
Both hulls assumed damaged if this distance is less than 7 metres
Full breadth of bottom of craft

Fig. 1.2

Section 2

Buoyancy, Stability and Subdivision

A. Documents to be submitted

The following drawings and documents are to be submitted, at least in triplicate[1] for approval. BKI reserves its right to ask for supplementary copies, if deemed necessary in particular cases.

Further documentation may be required, if deemed necessary by BKI.

- Hull, plotted and numerically;
- Side contour, plotted and numerically;
- Coordinates of non-watertight and non-weathertight openings;
- Hydrostatic tables;
- Cross curve tables;
- Data of boundaries of all sub-compartments and a plan in which these compartments are stated;
- Damage stability investigation, complete input and output data including initial loading conditions;
- Damage control plan;
- Inclining test report;
- Intact stability booklet.

B. General

1. A craft shall be provided with:

- buoyancy and stability characteristics adequate for safety where the craft is operated in the displacement mode, both in the intact condition and the damaged condition;
- stability characteristics adequate for safety when the craft is operated in the transitional, skimming, take off/landing and ground-effect modes; and
- stability characteristics while in the transitional, skimming, take off/landing and ground-effect modes adequate to transfer of the craft in the displacement mode in case of any system fault.

2. Account shall be taken of the effect of icing in the stability calculations as far as it is rational and acceptable for a specific craft.

An example of established practice for ice accretion allowances is given in Annex B for the guidance of the Administration. Depending on the operational conditions, a deicing system may be required by the Administration.

3. Information about WIG craft stability shall contain data connected with providing its stability in all modes as well as the whole restrictions set up for it: range and the navigation seasons, wind force and wave heights, angles of safety putting over the control units and so on.

4. The Administration may introduce additional restrictions for operation in zones of particular wind and wave modes.

These zones of particular wind and wave modes are:

- surf (breakers) wave zones;
- zones of local increase of the wave height and its sternness (bars in the river mouths, the so called waves "crush" and so on);
- zones of local increment of wind speed, direction and gust (in the narrow places, near precipices, rocks, islands, due to formation of whirls behind the coast or floating objects and so on);
- zones of specific wind and waves modes are specified according to data of local hydrometeorological and hydrographical institutions.

5. For the purpose of this and other sections, unless expressly defined otherwise, the following definitions apply:

.1 Down flooding point

Down flooding point means any opening through which flooding of the spaces which comprise the reserve buoyancy could take place while the craft is in the intact or damage condition, and heels to an angle past the angle of equilibrium.

.2 Permeability

Permeability of a space means the percentage of the volume of that space which can be occupied by water.

[1] For Indonesia Flag ship in quadruplicate (one for Indonesian Government)

.3 Skirt

Skirt means a downwards-extending, flexible structure used to contain or divide an air cushion.

.4 Watertight

Watertight in relation to a structure means capable of preventing the passage of water through the structure in any direction under the head of water likely to occur in the intact or damage condition.

.5 Weathertight

Weathertight means that water will not penetrate into the craft in any wind and wave conditions up to those specified as Critical Design Conditions.

6. Conditions of sufficient stability

In the worst load variant in respect of stability the following provisions shall be complied with:

.1 the numerical values of parameters of the static stability curve in the displacement mode in calm water shall not be lower than those in C.2.2;

.2 when in the transitional and take off/landing modes of operation WIG craft shall meet the provisions of C.2.4;

.3 when in the skimming and ground-effect modes of operation, WIG craft shall meet the provisions of C.2.3 and C.2.5;

.4 buoyancy and stability of WIG craft following damage shall meet the provisions of D.1.;

.5 stability of passenger craft shall meet the provisions of F. and of cargo craft the provisions of G. of this Section;

.6 consequences of possible icing on the stability shall be taken into account according to B.2.

C. Intact Stability

1. Intact buoyancy

1.1 All craft shall have a sufficient reserve of buoyancy at the design waterline to meet the intact and damage stability requirements of this Section. The Administration may require a larger reserve of buoyancy to permit the craft to operate in any of its intended modes. This reserve of buoyancy shall be calculated by including only those compartments which are:

.1 watertight;

.2 accepted as having scantlings and arrangements adequate to maintain their watertight integrity; and

.3 situated in locations below a datum, which may be a watertight deck or equivalent structure of a non-watertight deck covered by a weathertight structure as defined in 1.3.1.

1.2 Arrangements shall be provided for checking the watertight integrity of those compartments taken into account in 1.1.

1.3 Where entry of water into structures above the datum as defined in 1.1.3 would significantly influence the stability and buoyancy of the craft, such structures shall be:

.1 of adequate strength to maintain the weathertight integrity and fitted with weathertight closing appliances; or

.2 provided with adequate drainage arrangements; or

.3 an equivalent combination of both measures.

1.4 The means of closing openings in the boundaries of weathertight structures shall be such as to maintain weathertight integrity in all operational conditions.

2. Intact stability

2.1 General

.1 It shall be shown by calculations and/or by trials that in all navigation modes and load cases within proved operation restrictions a craft will go back to the initial position being provoked to rolling, pitching and heave motions or to a heel due to the turning or any their combination.

.2 The roll and pitch stability on the first and/or any other craft of a series shall be qualitatively assessed during operational safety trials as required by Annex D (Definitions, requirements and compliance criteria related to operational and Safety Performance).

The results of such trials may indicate the need to impose operational limitations in all modes.

.3 Where craft are fitted with surface-piercing structures or appendages, precautions shall be taken against dangerous attitudes or inclinations and loss of stability subsequent to a collision with a submerged or floating object in displacement, transitional, take off/landing, skimming and ground-effect modes.

2.2 Intact stability in the displacement mode

.1 WIG craft shall comply with corresponding provisions of Annex C (Residual Stability) for all craft in all permissible loading cases in such degree as it is rational and acceptable.

.2 If characteristics of a craft do not suit to application of 2.2.1 the Administration may allow alternative criteria which are equivalent to those fixed in 2.2.1 which correspond to craft region of operation.

2.3 Intact stability in the skimming mode

In the skimming mode of operation, when turning in calm water, the inner angle of heel shall not exceed 0.5 of the angle of wing (or sponson) entrance into the water. See also C.2.1.

2.4 Intact stability in the transitional and take off/landing modes

In the transitional and the take off/landing modes in the worst permissible conditions and the worst variant of loading (in respect of stability) WIG craft shall stay the minimal time if it will not be demonstrated by full scale tests to the Administration that change of the stability is not risky. Hereby, in the transitional mode the angles of heel shall not exceed the value of 0.8 of the angle corresponding to the entrance of the air wing into the water. In the take-off/landing mode the angle of heel shall not exceed the value of 0.5 of the angle which corresponds to the entrance of the air wing into the water. Stability characteristics in the transitional and take-off/landing modes (including a case of interrupted take-off) shall be verified by full scale tests.

2.5 Intact stability in the ground-effect mode

.1 WIG craft shall possess sufficient inherent static and dynamic stability in the vertical, lateral and longitudinal planes. Compliance with this requirement can be achieved by submitting to the Administration a theoretical analysis of the static and dynamic stability characteristics of the craft operating in the ground-effect mode. The analysis shall be supported by model tests and verified by full scale tests.

For static stability, results of the analysis shall include

- determination of the maximum permissible flight altitude as a function of pitch angle;
- determination of the recommended flight altitude as a function of pitch angle;
- permissible range of the longitudinal centre of gravity as a function of flight altitude.

For dynamic stability, results of the analysis shall include

- range of safe flight altitude as a function of pitch angle.

.2 In the ground-effect mode of operation, when turning in calm water, the inner angle of heel shall not exceed the angle of wing (or sponson) entrance into the water at the design flight altitude.

.3 In the ground-effect mode the stability and controllability at course angles of following wind shall be verified by full scale tests. Under the worst intended conditions and the worst load variant (with regard to stability) at head wind course as well as during turning from the following course to the head wind course, the maximum angle of heel shall not exceed the angle of sponson entrance into the water. The angle of the sponson entrance is determined from the still water surface for the design altitude of flight above waves.

.4 If a WIG craft is specially designed so that when in the ground-effect mode it is supposed to use a contact of the sponson or edge of the wing with the water surface then the safety of such manoeuvre shall be proved and the relevant limitations shall be identified on altitude, speed, depth of sponson submergence, angle of heel, angle of trim, yaw of craft, waves characteristics and so on. Execution of these provisions does not abolish the need to check the satisfaction of provisions which are prescribed in 2.5.1 on execution of a turning manoeuvre without touching the sea surface by the sponson.

.5 See also paragraphs B.1. and C.2.1.3.

2.6 Particular modes and stability verification

.1 Experimental examination of the transverse stability of the full scale craft in calm water is carried out in the following way: by displacement of solid ballast (not less than two heeling moment values); corresponding angles of heel and trim are measured for the displacement, transitional, skimming, take off/landing and ground-effect modes of operation.

.2 Conditions of the experimental examination of the longitudinal stability have to be approved by the Administration in any case.

2.7 Weather criteria

WIG craft operation is restricted by the worst intended conditions (of sea state intensity, of wind force, etc.) which are specified by the design loads and which are to be verified by sea keeping tests conducted during the delivery trials of the first craft of a series.

D. Damage Stability

1. Buoyancy and stability in the displacement mode following damage

1.1 The requirements of this Section apply to all permitted conditions of loading.

1.2 For the purpose of making damage stability calculations, the volume and surface permeabilities shall be in general as shown in Table 2.1:

Table 2.1

Spaces	Permeability
Appropriated to cargo or stores	60
Occupied by accommodation	95
Occupied by machinery	85
Intended for liquids	0 or 95 [1]
Appropriated for cargo vehicles	90
Void spaces	95

[1] whichever results in the more severe requirements

1.3 Notwithstanding 1.2, permeability determined by direct calculation shall be used where a more onerous condition results, and may be used where a less onerous condition results from that provided according to 1.2.

1.4 Administrations may permit the use of low-density foam or other media to provide buoyancy in void spaces, provided that satisfactory evidence is provided that any such proposed medium is the most suitable alternative and is:

– of closed-cell form if foam, or otherwise impervious to water absorption;

– structurally stable under service conditions;

– chemically inert in relation to structural materials with which it is in contact or other substances with which the medium is likely to be in contact and

– properly secured in place and easily removable for inspection of the void spaces.

1.5 Any damage of a lesser extent than that postulated in 1.6 and 1.7, as applicable, which would result in a more severe condition shall also be investigated. The shape of the damage shall be assumed to be a parallelepiped.

1.6 The following side damages shall be assumed anywhere on the periphery of the craft:

– the longitudinal extent of damage shall by $0.1L_H$, or 3 m + $0.03L_H$ or 11 m, whichever is the least;

– the transverse extent of penetration into the craft shall be $0.2B_H$ or $0.05L_H$ or 5 metres, whichever is the least. However, where the craft is fitted with inflated skirts or with non-buoyant side structures, the transverse extent of penetration shall be at least 0.12 of the width of the main buoyancy hull or tank structure; and

– the vertical extent of damage shall be taken for the full depth of the craft.

1.7 Bottom damages shall be assumed anywhere on the bottom of the craft as follows:

– the longitudinal extent of damage shall be 0,1 L_H or 3 m + 0,03 L_H or 11 m, whichever is the least;

– the transverse extent of damage shall be the full breadth of the bottom of the craft or 7 m, whichever is the less, as shown in Fig. 1.2 in Section 1; and

– the vertical extent of penetration into the craft shall be 0,02 B_H or 0,5 m, whichever is the less.

E. Inclining and Stability Information

1. Every craft, on completion of build, shall be inclined and the elements of its stability determined. When an accurate inclining is not practical, the lightship displacement and centre of gravity shall be determined by a lightweight survey and accurate calculation.

2. The master shall be supplied by the owner with reliable information relating to the stability of the craft in accordance with the following provisions of this paragraph. The information relating to stability shall, before issue to the master, be submitted to the Administration for approval, together with a copy there of for their retention, and shall incorporate such additions and amendments as the Administration may in any particular case require.

3. Where any alterations are made to a craft so as materially to affect the stability information supplied to the master, amended stability information shall be provided. If necessary, the craft shall be reinclined.

4. A report of each inclining or lightweight survey carried out in accordance with this chapter and of the calculation therefrom of the lightship condition particulars shall be submitted to the Administration for approval, together with a copy for their retention. The approved report shall be placed on board the craft by the owner in the custody of the master and shall incorporate such additions and amendments as the Administration may in any particular case require. The amended lightship condition particulars so obtained from time to time shall be used by the master in substitution for such previously approved particulars when calculating the craft's stability.

5. Following any inclining or lightweight survey, the master shall be supplied with amended stability information if the Administration so requires. The information so supplied shall be submitted to the Administration for approval, together with a copy thereof for their retention, and shall incorporate such additions and amendments as the Administration may in any particular case require.

6. Stability information demonstrating compliance with the Section shall be furnished in the form of a stability information book which shall be kept on board the craft at all times in the custody of the master. The information shall include particulars appropriate to the craft and shall reflect the craft's loading conditions and mode of operation. Any enclosed superstructures or deckhouses included in the cross curves of stability and the critical downflooding points and angles shall be identified.

7. Every craft shall have scales of draughts marked clearly at the bow and stern. In the case where the draught marks are not located where they are easily readable, or operational constraints for a particular trade make it difficult to read the draught marks, then the craft shall also be fitted with a reliable draught indicating system by which the bow and stern draughts can be determined.

8. The owner or builder, as appropriate, shall ensure that the positions of the draught marks are accurately determined and that the marks are located on the hull in a permanent manner. Accuracy of the draught marks shall be demonstrated to the Administration prior to the inclining experiment.

9. Loading and stability assessment

On completion of loading of the craft and prior to its departure on a voyage, the master shall determine the craft's trim and stability and also ascertain and record that the craft is in compliance with stability criteria of the relevant requirements. The Administration may accept the use of an electronic loading and stability computer or equivalent means for this purpose.

10. Marking and recording of the design

The design waterline shall clearly be marked amidships on the craft's outer sides and shall be recorded in the Wing-in-Ground Craft Safety Certificate. This waterline shall be distinguished by the notation W.

F. Additional Provisions for Passenger Craft

1. General

1.1 Where compliance with this chapter requires consideration of the effects of passenger weight, the following information shall be used:

– The distribution of passengers is 4 persons per square metre.

– Each passenger has a mass of 75 kg.

– Vertical centre of gravity of seated passengers is 0.3 m above seat.

– Vertical centre of gravity of standing passengers is 1.0 m above deck.

– Passengers and luggage shall be considered to be in the space normally at their disposal.

– Passengers shall be distributed on available deck areas towards one side of the craft and in such a way that they produce the most adverse heeling moment.

1.2 The stability of passenger WIG craft shall be verified by the following loading conditions:

– with full number of passengers and cargo and full provisions on board craft ,

– with full number of passengers and cargo and with 10 % of provisions,

– without passengers and cargo and with 10 % of provisions.

Passenger weight and position of their centre of gravity shall be taken in accordance with 1.1.

1.3 The stability of passenger WIG craft in all modes of operation shall be additionally verified in calm water under the load variant with full number of passengers and cargo and with 10 % of provisions but with location of 50 % of the passengers in their seats on one side from the craft centre line. The rest 50 % of the passengers are located in longitudinal passages between the chairs in correspondence with 1.1.

1.4 If in the process of normal operation load variants worse than described in 1.2 and 1.3 are encountered, then these variants shall be verified as well.

1.5 Calculations of form stability levers for WIG craft in the displacement mode shall be carried out with respect of accompanying trim.

2. Intact stability in the displacement mode

.1 WIG craft shall have sufficient stability so that being in calm water its deviation from the horizontal to any direction and in all possible and permitted conditions of cargo placing as well as passenger crowding shall not exceed an angle by which, before entering deck (or the lower surface of the lifting air wing excluding ailerons) into the water there remains 0.1 m or 8 degree whichever is met first.

.2 The angle of the joint action of heeling moments due to passenger crowding according to 1.3 and turning being determined experimentally shall not exceed the angle of entrance of wing into the water.

3. Intact stability in the transitional, skimming and take off/landing modes

The angle of heel due to passenger crowding in calm water in compliance with 1.3 shall not exceed the angle of heel stated in C.2.3 and C.2.4.

4. Intact stability in the ground-effect mode

In the ground-effect mode by the heeling load due to gusting in the worst intended conditions or high-speed turning (whichever is the greater) and which (the load) is directed to the heel side due to passenger crowding in compliance with 1.3 the angle of heel shall not exceed the angle of sponson entrance into the water. Herewith, the summary angle of heel stipulated by passenger crowding and by wind pressure or by passenger crowding and high-speed turning is determined on the basis of calculations, model tests of the designed craft or the craft prototype. The summary angle due to passenger crowding and turning is defined more precisely in the process of the delivery trial tests of the full scale craft.

5. Buoyancy and stability in the displacement mode following damage

5.1 Following any of the postulated damages detailed in D.1.6 and D.1.7, the craft in still water shall have sufficient buoyancy and positive stability to simultaneously ensure that:

.1 after flooding has ceased and a state of equilibrium has been reached, the final waterline be 300 mm below the level of any opening through which further flooding could take place;

.2 the angle of inclination of the craft from the horizontal does not normally exceed 10 ° in any direction. However, where this is clearly impractical, angles of inclination up to 15 ° immediately after damage but reducing to 10 ° within 15 min may be permitted provided that efficient non-slip deck surface and suitable holding points, e.g., holes, bars, etc., are provided;

.3 there is a positive freeboard from the damage waterline to survival craft embarkation positions;

.4 any flooding of passenger compartments or escape routes which might occur will not significantly impede the evacuation of passengers;

.5 essential emergency equipment, emergency radios, power supplies and public address systems needed for organizing the evacuation remain accessible and operational;

.6 the residual stability complies with the appropriate criteria as laid out in Annex C (Residual stability).

5.2 When damage occurs provided that the possibility of safe transition of WIG craft to the skimming or to the ground-effect modes is not excluded and thereby its safety is improved and the independent arrival to the port of refuge is permissible or the approach to a salvage ship is possible, or

Reaching the shore is possible, etc., there shall be recommendations on carrying out such actions.

6. Openings in watertight bulkheads

The openings in watertight bulkheads shall generally be closed by power operated watertight doors. In general such doors shall be of sliding type. Hinged doors may be accepted in case they are not normally submerged in case of damage or when normally closed at sea.

Doors never used at sea need not be power operated. They may be of hinged or sliding type. These doors have to be closed before the voyage commences and are to be kept closed during navigation. They are to be fitted with a device preventing unauthorized opening. The time of closing/opening such doors is to be recorded in the logbook.

The scantling head is the one corresponding to the residual stability lever and in any case is not to be lower than the one of the bulkhead in which it is installed.

7. Inclining and stability information

At periodical intervals not exceeding 2 years, a lightweight survey shall be carried out on all passenger craft to verify any changes in lightweight displacement and longitudinal centre of gravity. The passenger craft shall be reinclined whenever, in comparison with the approved stability information, a deviation from the lightweight displacement exceeding 2% or a deviation of the longitudinal centre of gravity exceeding 1% of L is found or anticipated.

G. Additional Provisions for Cargo Craft

1. Buoyancy and stability in the displacement mode following damage

Following any of the postulated damage detailed in D.1.6 and D.1.7, the craft in still water shall have sufficient buoyancy and positive stability to simultaneously ensure that:

.1 after flooding has ceased and a state of equilibrium has been reached, the final waterline 150 mm below the level of any opening through which further flooding could take place;

.2 the angle of inclination of the craft from horizontal does not normally exceed 15 ° in any direction. However, where this is clearly impractical, angles of inclination up to 20 ° immediately after damage but reducing to 15 ° within 15 min may be permitted provided that efficient non-slip deck surface and suitable holding points, e.g., holes, bars, etc., are provided;

.3 there is a positive freeboard from the damage waterline to survival craft embarkation positions;

.4 essential emergency equipment, emergency radios, power supplies and public address systems needed for organizing the evacuation remain accessible and operational;

.5 the residual stability complies with the appropriate criteria as laid out in Annex C (Residual Stability).

2. Inclining and stability

Where it is satisfied by lightweight survey, weighing or other demonstration that the lightweight of a craft is closely similar to that of another craft of the series to which E.1 has been applied, the Administration may waive the requirement of E.1 for craft to be inclined. In this regard, a craft which lies within the parameters of F.7.1, when compared with a craft of the series which has been inclined, shall be regarded as being closely similar to that craft.

Section 3

Hull Construction

A. Documents to be submitted

The following drawings and documents are to be submitted, in triplicate[1)] for approval. BKI reserves its right to ask for supplementary copies, if deemed necessary in particular cases.

Further documentation may be required, if deemed necessary by BKI.

1. Structures

Table 3.1 lists the structural plans to be submitted.

2. Accommodation and Escape Measures

- Plan showing the arrangement of the passenger compartment containing the indication of seat characteristics, installation, and the characteristic of the safety belts
- Plan showing the means of escape and the means of access to the various craft spaces
- Plan showing the arrangement of means of communication
- Windows, arrangements and details
- Calculation of the collision load and collision length
- Plan showing the arrangement of exits intended to be used in an emergency;
- Evacuation procedure and evacuation time calculation

B. Structures

1. Symbols used, definitions and formulae

A_{AC} means the area of the surface subjected to the air cushion pressure

A_{eff} means the total area of the effective aerodynamic lifting surfaces including (static) air cushions, if provided, but excluding any surface-piercing hydrostatic or hydrodynamic lifting aids as hydrofoils etc.

$$A_{eff} = A_W + A_{AC}\frac{F_{AC}}{2gD}$$

A_i means an area, supported by the respective elements plate, stiffener or girder

A_R means the reference area

A_R = BC^2, but not less than 1.4 $D^{0.667}$

F_{AC} means the air cushion lifting force

$H \geq H_{min}$

for $x = x_R \pm 0.2$ L

$$H_{min} = \frac{L}{12}$$

$H_{S0} \leq H_{S0max}$

H_{S0max} = L / (25 + L / 20))

V_R means the reference (design) take-off speed

$$V_R = 127\left(\frac{D}{A_{eff}}\right)^{0.5} \quad \text{for the prototype craft}$$

V_{Sl} means the vertical speed related to the wave surface

$$V_{SI} = V_V + 4\frac{H_{S0}}{L^{0.5}}$$

V_V means the vertical speed in ground-effect mode

V_V = 0.05 V_R for craft subsequent to the prototype craft

h_s = maximum of:

T (2 – 5 ξ) + H_{Sl}; or

H_{Sl}; or

T (3 ξ – 2) + H_{Sl}

i_x means the radius of gyration in longitudinal direction

i_y means the radius of gyration in transverse direction

$$k_A = 0.455 - 0.35\frac{(r_i^{0.75} - 1.7)}{(r_i^{0.75} + 1.7)}$$

where

r_i = 50 A_i / A_R

k_n depends on frequency f, see Table 3.2

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1) For Indonesia Flag ship in quadruplicate (one for Indonesian Government)

Table 3.1 Documents to be submitted for structural drawing approval/examination

Plan	Containing information	Remarks
General Arrangement	– overview – watertight transverse and long'l bulkheads/compartments – aerodynamic loads and distribution of wing and control surfaces	3 x for information
Midship Section	– moulded dimensions, speeds, limit wave heights, position of centre of gravity and gyration radii – materials and alloys – structural details of hull at main step or x/L = 0.5 and wing spar – typical structural details	3 x for approval/examination
Main Sections	– transverse and longitudinal structure details	3 x for approval/examination
Longitudinal Sections	– position of centre of gravity	3 x for approval/examination
Shell Expansion	– hull, sponson and wing with openings – direction of laminate	3 x for approval/examination
Decks	– openings – static deck loads – structural details with seat rails and lashing points	3 x for approval/examination
Watertight Bulkheads	– openings – position of air vents – structural details	3 x for approval/examination
Machinery Space Structure	– machinery mass and position of centre of gravity – joining details	3 x for approval/examination
Tanks	– position, volumes, liquid densities, setting pressures – structural details with foundations/substructure	3 x for approval/examination
Wing Sections	– openings – structural details	3 x for approval/examination
Control Surfaces	– openings, flaps – structural details	3 x for approval/examination
Equipment	– lateral and profile view of the craft – anchor equipment – calculation	1 x for approval/examination
Windows	– positions, dimensions – strength and specification	3 x for approval/examination
Appendages	– dimensions – loads, load distribution	3 x for approval/examination
Steering Arrangements	– loads – structural details	3 x for approval/examination
Seats	– structural details of crew and passenger seats – dynamic test report – fire test reports	3 x for approval/examination 1 x for type approval 1 x for type approval
Trial and Test Procedure		3 x for approval/examination
Trial Reports		1 x for information
Materials	– specification – arrangement of laminate	1 x for information
Service Area	– sea area, routes	1 x for information
Manuals		1 x for information
Direct Calculation	– any performed direct calculations	1 x for information
Tests and Measurements	– results	1 x for information
Weight Distribution		1 x for information

Table 3.2

f = minimum of (f_P; f_F)	4	8	10	15	20	30	40	1000
k_n	0.33	0.53	0.60	0.71	0.78	0.85	0.88	1.0

Where

$$f_p = 0.5\pi\left(\frac{D_P}{\rho_{Pt}}\right)^{0.5}\left(\frac{a^2+b^2}{a^2b^2}\right)$$

$$f_F = \frac{1}{2\pi}\left(\frac{57.3M_F}{m_F h_F^{\,2}}\right)^{0.5}$$

$$D_P = \frac{Et^3}{12(1-\mu^2)} \quad \text{in [Nm]}$$

ρ_P means the density of plate, in [kg/m³]

h_F means the distance between torsional axis and load centre, in [m]

m_F means the mass of flexible flap, in [kg]

M_F means the torsional moment of the flexible flap causing a rotation of 1,0° with a distributed load assumed to act in the load centre, in [Nm]

$$k_{sl} = 0.5 + 2.5\frac{x}{L_H}$$

for $0 \le x \le 5x_o$

$= 1.0$

for $5x_o < x \le x_R$

$$= 1.0 - 0.5\frac{x - x_R}{L_H - x_R}$$

but not less than 0.5

for $x > x_R$ (Fig.3.1)

$k_W = 1.0$

for $0 \le \xi \le 0.2$

$= 2.2 - 6\xi$

for $0.2 < \xi \le 0.3$

$= 0.4$

for $0.3 \le \xi \le 0.8$

$= 0.5\xi$

for $0.8 < \xi$ (Fig.3.2)

$k_x = 0.6 - 0.28x$ for $0 \le x \le x_R$

$= 32$ for $x > x_R$ (Fig.3.3)

$$k_y = \frac{1}{(1 + r_y^{\,2})^{0.667}}$$

$$k_z = 1 - 0.85\frac{z - z_c}{H_{S0}}$$

but not less than 0.1

$$k_\alpha = \frac{70 - \alpha_i}{70 - \alpha_R}$$

where $10° \le \alpha_i$; $\alpha_R \le 30°$

α_i means the deadrise angle in YZ - plane between horizontal and straight line joining the edges of the respective area

α_R means the deadrise angle in YZ - Plane between horizontal and straight line joining keel and chine measured at x_R

γ_i means the angel in the XZ-plane between the horizontal plane and a straight line through the loadpoint joining the edges of the respective area

$k_\beta = k_{j=0} = 1$

for $x \le x_{St}$ or if no steps exists

$$k_\beta = k_{j-i}(1 - \sin\beta_i)\left(1 - 5\frac{h_j}{b_j}\frac{x_{j+1} - x}{x_{j+1} - x_j}\right)$$

but not less than 0.5

for $x_j < x \le x_{j+1}$:

where

$$\sin\beta \le 0.25\frac{h_j}{b_j} \le 0.1 \quad \text{(Fig.3.4)}$$

βj means the keel angle in XZ-Plane between horizontal and straight line joining the steps j and j + 1 of the hull

bj means the breadth of step at step number j

hj means the height of step at step number j

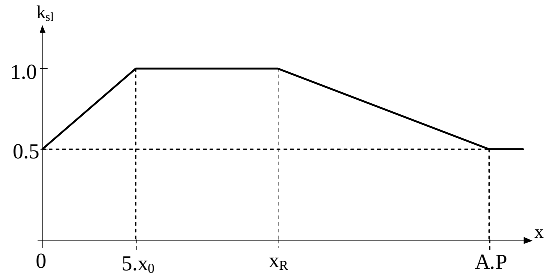

Fig. 3.1

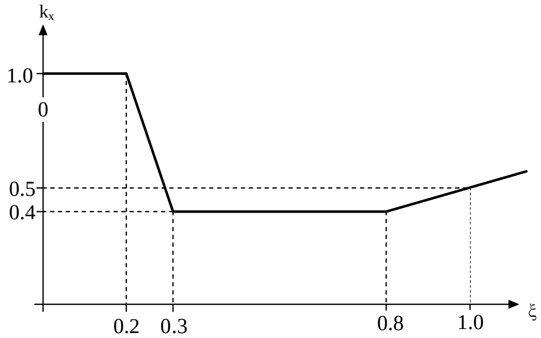

Fig. 3.2

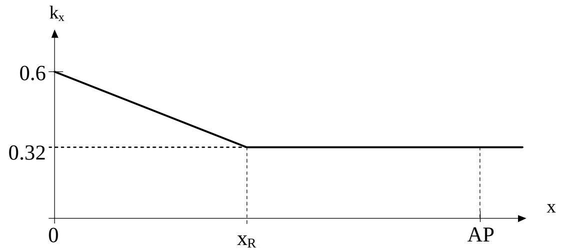

Fig. 3.3

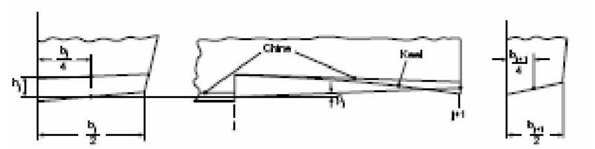

Fig. 3.4

r_y = $\frac{y - 0.5B_H}{i_y}$, but not negative

x_R means the reference (longitudinal) distance from FP to main step or LCG, if no step exists

ξ means the non-dimensional x-coordinate (see Fig. 1.2 in Section 1)

$$\xi = \frac{(x - x_0)}{L}$$

2. Materials

2.1 General requirements

.1 Materials to be used in hull and equipment construction, in delivery condition, are to comply with these requirements or with specific requirements applicable to individual cases; they are to be tested in compliance with the applicable provisions. Quality and testing requirements for materials covered here are outlined in relevant BKI Rules.

.2 These requirements presume that welding and other cold or hot manufacturing processes are carried out in compliance with current sound working practice and relevant BKI provisions. The latter, in particular, may include requirements concerning welding operations and techniques and other manufacturing processes (e.g., specific preheating before welding and/or welding or other cold or hot manufacturing processes followed by an appropriate heat treatment).

.3 Welding process shall be approved for the specified type of material for which the are intended and with limits and conditions as stated in the applicable BKI requirements.

2.2 Steel

The value of the material factor K to be introduced into formulae to check structures given in this Section and in the various Appendices is a function of the minimum upper yield stress R_{eH} value specified for the steel to be used.

K_{Steel} = maximum of

$$\frac{235}{R_{eH}} \text{ or } \frac{295}{R_{eH} + 60}$$

Unless otherwise specified, the Young's modulus for steel is equal to 206 GPa and the Poisson's ratio equal to 0.3.

E_{Steel} = 206 GP

μ_{Steel} = 0.30

2.3 Austenitic steels

Where austenitic steels are applied having a ratio $R_{p0,2} / R_m \leq 0.5$ the 1 % proof stress $R_{p1.0}$ may be used for scantling purposes of the 0.2 % proof stress $R_{p0.2}$ after special approval.

2.4 Aluminium:

The value of the material factor K_{Alu} to be introduced into formulae for checking scantlings of structural members is determined by the following equation:

$$K_{Alu} = \frac{215}{R_{p0.2}} \text{, but not less than } \frac{310}{R_m}$$

$R_{p0.2}$ means the minimum guaranteed yield stress of the parent material in delivery or welded condition, respectively.

R_m means the minimum tensile strength.

Unless otherwise specified, the Young's modulus for aluminium alloys is equal to 70000 N/mm² and the Poisson's ratio equal to 0.33.

E_{Alu} = 70 GPa

μ_{Alu} = 0.33

2.5 FRP

(see Section 12)

2.6 Permissible stresses

(see Table 3.3)

Table 3.3

	local	Global and local	special	aerodynamic loads
σ_{perm}	150/K	175/K	180/K	are to comply with JAR
τ_{perm}	100/K	110/K	115/K	
σ_{vM}	180/K	195/K	200/K	

3. Load factors

n_a aerodynamic load factor in compliance with V-n-Diagram, JAR 25, ($n_a \geq 2.5$)

n_h hydrodynamic load factor

$$n_h = V_R \frac{V_{sl}}{D^{0.333}} \frac{(70 - \alpha_R)}{600}$$

n_x load factor for distributed masses and deck loads

n_x = max (n_a ; 1 + k_x n_h)

n_m load factor for concentrated masses, see Table 3.4

Table 3.4

direction	$\mathbf{n_m}$
ahead	6.0
astern	1.0
transverse	2.7
vertical up	2.0
vertical down	max. of (4.0; n_x)

Required dynamic tests are to be carried out with g_{coll} (see C.3.3)

4. Aerodynamic loads

are to comply with JAR

5. Water loads and pressures

5.1 Load points

Pressure on panels and strength members may be considered uniform and equal to the pressure at the following load points:

Plates

– geometrical centre of the panel, for impact pressure

– geometrical centre of the panel, for horizontal stiffening system

– half of the stiffener spacing above the lower support of panel, for vertical stiffening system

– lower edge of plate when the thickness changes within the vertical stiffened plate field

Stiffeners and Girders

– centre of the area supported by the respective strength member

Where the pressure diagram shows cusps or discontinuities along the span of a strength member, a uniform value is to be taken on the basis of a weighted mean value of pressure calculated along the length.

5.2 Overall loads

The longitudinal, transverse bending moments and shear forces are to considered for hogging and sagging conditions in start, landing and skimming mode.

5.3 Bottom of hull or sponson

The impact pressure considered as acting on the bottom of hull or sponson is not less than:

p_{sl} = $100\ n_h\ D / A_R\ k_{sl}\ k_A\ k_y\ k_\alpha\ k_\beta$

The sea pressure is not less than:

$p_{s,min}$ = $10\ (H_{S1} + T)$

5.4 Lower wing surface or wet-deck

The impact pressure considered as acting on the lower wing surface or wet deck is not less than:

p_{sl} = $n_h\ V_R\ V_W\ k_W\ k_A\ k_y\ k_z\ k_n$

for $z \le 2\ z_C + H_{S0}/0.85$

where

VW = $V_{Sl} + V_R\ (\tan \gamma_i - 0.05)$

but not less than V_{Sl}

The minimum values of pressures to be considered are:

$p_{s,\ min}$ = 5.0 kPa for maximum of $(T;\ z_C) \le z < h_s$

$p_{s,\ min}$ = 2.5 kPa for $h_s \le z \le 2\ H_{S1}$

$p_{s,\ min}$ = 1.0 kPa for $z > 2\ H_{S1}$

$p_{s,\ min}$ = 1.0 kPa for flexural flaps

If slamming is considered to occur on wing or wet deck, the impact pressure on the internal sides (of hull or sponson) is obtained by interpolation between the impact pressures considered as acting on bottom and the slamming at wing or wet deck.

5.5 Front of hull

The pressure considered as acting on the front wall of hull is not less than:

$$P_f = \left(1 + \frac{x_R - x}{L}\right)(8 + 0.7L)\left(1 - \frac{z - T}{2H_{Sl}}\right)\cos\delta$$

δ means the angle in XZ-Plane between vertical and the aft inclined front wall (0° ≤ δ ≤ 40°)

p_f shall not be less than:

$p_{f,\ min}$ = 4 + 0.1 L

5.6 Side and top of hull or sponson and upper surface of wing

The sea pressure is not less than:

p_s = $10\ (h_s - z)$

The minimum values of pressures to be considered are

– for the side:

$p_{s,\ min}$ = 2.5 kPa
for maximum of $(T;\ z_C) \le z \le 2\ H_{S1}$

$p_{s,\ min}$ = 1.0 kPa
for $z > 2\ H_{S1}$

If slamming is considered to occur on wing or wet deck, the impact pressure on the internal sides (of hull or sponson) is obtained by interpolation between the impact pressures considered as acting on bottom and the slamming at wing or wet deck.

– for the top and upper surface of wing:

$p_{s,min}$ = 2.5 kPa

– for the top and upper surface of wing, if not accessible to the passengers:

$P_{s,min}$ = 0.7 kPa

For $z \ge 2\ H_{Sl}$

Such areas are to be clearly indicated.

6. Enclosed decks

The pressure considered as acting on decks is given by the formula:

Where decks are intended to carry masses of significant magnitude, the concentrated loads transmitted to structures are given by the corresponding static loads multiplied by n_x.

The following evenly distributed loads are to be considered

– for passenger and crew deck:

p_d = 1.5 kPa

– for luggage compartment and not accessible, clearly indicated areas:

p_d = 1.5 kP

– for cargo compartment:

p_d = maximum of (p_c; 3.0 kPa),

where

p_c means the uniform pressure due to deck cargo load to be defined by the designer.

6.1 Watertight bulkhead

The pressure considered as acting on watertight sub-division bulkheads is to be taken not less than:

$p_{bhd} = 10\,(z_{bhd} - z)$,

where

$z_{bhd} = z_{wd} + H_{S1}/2$ or the height of bulkhead top

z_{wd} means the maximum height of damage waterline

6.2 Tank

The pressure considered as acting on tank structures is to be taken not less than the greater of:

$p_{t1} = 9.81\, z_t\, \rho\, n_x + 100\, p_v$

$p_{t2} = 9.81\,(z_t + h_{to,min} - z)$
(static design pressure),

where

$h_{to,min}$ = maximum of (h_{to}; $0.25 + V_t$)

V_t means the volume of the tank in m^3

h_{to} means the distance from tank top to overflow

z_t means the height of tank top above base line

p_v means the setting pressure, in bar, of pressure relief valve, when fitted

C. Accommodation and Escape Measures

1. General

1.1 Passenger compartments, public spaces and operating compartment shall be designed and arranged so as to protect passengers and crew from un-favourable environmental conditions and to minimize the risk of injury to occupants during normal and emergency conditions.

1.2 Spaces accessible to passengers shall not contain controls, electrical equipment, high-temperature parts and pipelines, rotating assemblies or other items, from which injury to passengers could result, unless such items are adequately shielded, isolated, or otherwise protected.

1.3 Passenger compartments shall not contain operating controls unless the operating controls are so protected and located that their operation by a crew member shall not be impeded by passengers during normal and emergency conditions.

1.4 Windows shall be of adequate strength and suitable for the worst intended conditions specified in the Permit to Operate and be made of material which will not break into dangerous fragments if fractured.

1.5 The public spaces and the equipment therein shall be designed so that each person making proper use of these facilities will not suffer injury during craft's normal start and landing, emergency landing, stop and manoeuvring in normal cruise and in failure or mal-operation conditions. Compliance shall be shown as described in Annex D (Definitions, requirements and compliance criteria related to operational and safety performance).

2. Public address and information system

2.1 A general emergency alarm system shall be provided. The alarm shall be audible throughout all the accommodation and normal crew working spaces, and the sound pressure level shall be at least 10 dB (A) above ambient noise levels under way in normal cruise operation. The alarm shall continue to function after it has been triggered until it is normally turned off or is temporarily interrupted by a message on the public address system.

2.2 There shall be a public address system covering all areas where passengers and crew have access, escape routes, and places of embarkation into survival craft. The system shall be such that flooding or fire in any compartment does not render other parts of the system inoperable. The public address system and its performance standards shall be approved by the Administration having regard to the "Recommendations on performance standards for public address systems on passenger ships, including cabling (MSC/Circ.808)" and the "Code on Alarms and Indicators, 1995 (resolution A.830(18))" adopted by the International Maritime Organization.

2.3 All passenger craft shall be equipped with illuminated or luminous notices or video information system(s) visible to all sitting passengers, in order to notify them of safety measures.

2.4 The master shall, by means of 2.2, be able to request passengers "please be seated" in all modes of operation.

2.5 Emergency instructions including a general diagram of the craft showing the location of all exits, routes of evacuation, emergency equipment, life-saving equipment and illustration of lifejacket donning shall be available to each passenger and placed near each passenger's seat.

3. Design acceleration levels

3.1 For passenger craft, superimposed vertical accelerations above 1.0 g at longitudinal centre of gravity shall be avoided unless special precautions are taken with respect to passenger safety.

3.2 WIG craft are not designed for a collision when in the ground-effect mode. The possibility for a collision at cruise speed shall be excluded by means of timely manoeuvring in the horizontal plane or landing, as well as by application of special systems for early detection of obstacles. Passenger craft shall be designed for the collision load in skimming mode with respect to the safety in, and escape from, the public spaces and escape routes, including spaces in way of life-saving appliances and emergency source of power.

3.3 The collision load g_{coll} is to be taken as:

– ahead 9.0 g

– astern 1.5 g

– laterally 4.0 g

– vertically up 3.0 g

– vertically down 6.0 g

3.4 Limiting sea states for operation of the craft shall be given in normal operation condition and in the worst intended conditions in all modes.

4. Accommodation design

4.1 Emergency exits and emergency hatches shall not be located within a distance of:

$$X_{coll} = \frac{V_R{}^2}{225}$$

of the extreme forward end of the top of the effective hull girder of the craft.

4.2 Public spaces of WIG craft for 12 or more passengers shall not be located within x_{coll}. It is recommended that the operating compartment is not located within x_{coll}.

4.3 The accommodation shall be designed according to the Guidelines given in Table 3.5 and to performance requirements given in Annex E (Criteria for testing and evaluation of revenue and crew seats), or by other methods which have been proven to give equal protective qualities.

Table 3.5 Overview general design guidelines

Design level: g_{coll} up to 9 g
– Seat with lap belts
– High seatback with protective deformation and padding
– Forward or backward seating direction
– No sofas allowed as seat
– Tables with protective features allowed. Dynamic testing
– Padding of projecting objects
– Baggage placed with protection forward
– Large masses, restrainment and positioning

Other arrangements may be accepted if an equivalent level of safety is achieved.

4.4 Equipment and baggage in public spaces and in the operating compartment shall be positioned and secured so that they remain in the stowed position when exposed to the collision design acceleration according to 3.2.

4.5 Mountings of large masses such as main engines, auxiliary engines, transmissions and electrical equipment shall be proved by calculations to withstand the collision design acceleration according to 3.2 without fracturing.

4.6 Seats, life-saving appliances and items of substantial mass and their supporting structure shall not deform or dislodge under any loads up to those specified in 3.2 in any manner that would impede subsequent rapid evacuation of passengers.

4.7 There shall be adequate handholds on both sides of any passage to enable passengers to steady themselves while proceeding to the exit(s) during evacuation.

5. Seating construction

5.1 A seat shall be provided for each passenger and crew member for which the craft is certified to carry. Such seats shall be arranged in enclosed spaces.

5.2 Seats fitted in addition to those required under 5.1 and which are not permitted to be used in hazardous navigational situations or potentially dangerous weather or sea conditions need not comply with the provisions of 5.3 to 5.6 or 6. Such seats shall be secured according to 4.6 and clearly identified as not being able to be used in hazardous situations.

5.3 The installation of seats shall be such as to allow adequate access to any part of the accommodation space. In particular, they shall not obstruct access to, or use of, any essential emergency equipment or means of escape.

5.4 Seats and their attachments, and the structure in the proximity of the seats, shall be of a form and design, and so arranged, such as to minimize the possibility of injury and to avoid trapping of the passengers after the assumed damage in the collision design condition according to 3.2. Dangerous projections and hard edges shall be eliminated or padded.

5.5 Seats for passengers and crew, seat belts, seat arrangement and adjacent parts such as tables shall be designed for the actual design acceleration which is taken as the greater of: collision acceleration as it is indicated in 3.2 and acceleration in all operating modes with respect to the respective direction taking into account peculiarities of WIG craft.

5.6 All seats, their supports and their deck attachments shall have good energy-absorbing characteristics and shall meet the requirements of Annex E (Criteria for testing and evaluation of revenue and crew seats).

6. Safety belts

6.1 One-hand-release safety belts shall be provided for each passenger and crew seat, to obtain the protective performance measures described in Annex E (Criteria for testing and evaluation of revenue and crew seats).

7. Exits and means of escape

7.1 In order to ensure immediate assistance from the crew in an emergency situation, the operating compartment shall be located with due regard to easy, safe and quick access to the public spaces from inside the craft.

7.2 The design of the craft shall be such that all occupants may safely evacuate the craft into survival craft under all emergency conditions, by day or by night. The positions of all exits which may be used in an emergency, and of all life-saving appliances, the practicability of the evacuation procedure, and the evacuation time to evacuate all passengers and crew shall be demonstrated.

7.3 Public spaces, evacuation routes, exits, life-jacket stowage, survival craft stowage, and the embarkation stations shall be clearly and permanently marked and illuminated as required in Section 6.

7.4 Each enclosed public space and similar permanently enclosed space allocated to passengers or crew shall be provided with at least two exits arranged in the opposite ends of the space. Exits shall be safely accessible and shall provide a route to a normal point of boarding or disembarking from the craft.

7.5 Exit doors shall be capable of being readily operated from inside and outside the craft in daylight and in darkness. The means of operation shall be obvious, rapid and of adequate strength.

7.6 The closing, latching and locking arrangements for exits shall be such that it is readily apparent to the appropriate crew member when the doors are closed and in a safe operational condition, either in direct view or by an indicator. The design of external doors shall be such as to eliminate the possibility of jamming by ice or debris.

7.7 The craft shall have a sufficient number of exits which are suitable to facilitate the quick and unimpeded escape of persons wearing approved life-jackets in emergency conditions, such as collision damage or fire.

7.8 Sufficient space for a crew member shall be provided adjacent to exits for assisting the rapid evacuation of passengers.

7.9 All exits, together with their means of opening, shall be adequately marked for the guidance of passengers. Adequate marking shall also be provided for the guidance of rescue personnel outside the craft.

7.10 Footholds, ladders, etc., provided to give access from the inside to exits shall be of rigid construction and permanently fixed in position. Permanent handholds shall be provided whenever necessary to assist persons using exits, and shall be suitable for conditions when the craft has developed any possible angles of list or trim.

7.11 At least two unobstructed evacuation paths shall be available for the use of each person. Evacuation paths shall be disposed such that adequate evacuation facilities will be available in the event of any likely damage or emergency conditions, and evacuation paths shall have adequate lighting supplied from the main and emergency sources of power.

7.12 The dimensions of passages, doorways and stairways which form part of evacuation paths shall be such as to allow easy movement of persons when wearing lifejackets. There shall be no protrusions in evacuation paths which could cause injury, ensnare clothing, damage lifejackets or restrict evacuation of disabled persons.

7.13 Adequate notices shall be provided to direct passengers to exits.

7.14 Provision shall be made on board for embarkation stations to be properly equipped for evacuation of passengers into life-saving appliances. Such provision shall include handholds, anti-skid treatment of the embarkation deck, and adequate space which is clear of cleats, bollards and similar fittings.

Note:

The following paragraphs of the Guidelines on evacuation are not applicable for the purpose of classification. The evacuation procedure falls under the responsibility of the Administration and is based on international safety requirements. Presently, no such international requirements exist for WIG craft. The IMO Sub-Committee on Design and Equipment, however, has established a Correspondence Group dealing with Guidelines for the Safety of WIG craft. The following text reflects the current state as per 31.01.2001 of deliberations in the Correspondence Group related to Category A passenger WIG craft of type A and cargo WIG craft of type A, and is here reproduced for information only. It may serve as a basis for discussions with the Administration. The current status can be provided by BKI.

8. Evacuation time

8.1 *"Evacuation time" is the experimental time in the course of which untrained people in number being equal to number of seats and the crew have demonstrated to escape craft and embark on the rescue means after an alarm resulting in the announcement "Abandon ship!" by the master.*

8.2 *An evacuation procedure, including a critical path analysis, shall be developed for the information of the Administration in connection with the approval of fire insulation plans and for assisting the owners and builders in planning the evacuation demonstration required in 8.3. The evacuation procedures shall include:*

- *the emergency announcement made by the master;*
- *contact with base port;*
- *the donning of lifejackets;*
- *manning of survival craft and emergency stations;*
- *the shutting down of machinery and oil fuel supply lines;*
- *the order to evacuate;*
- *the deployment of survival craft and marine escape systems and rescue boats;*
- *the bowsing in of survival craft;*
- *the supervision of passengers;*
- *the orderly evacuation of passengers under supervision;*
- *crew checking that all passengers have left the craft;*
- *the evacuation of crew;*
- *releasing the survival craft from the craft; and*
- *the marshalling of survival craft by the rescue boat, where provided.*

8.3 *Achievement of the experimental evacuation time (as ascertained in accordance with 8.1) shall be verified by a practical demonstration conducted under controlled conditions in the presence of the Administration, and shall be fully documented and verified for passenger craft by the Administration.*

8.4 *Evacuation demonstrations shall be carried out with due concern for the problems of mass movement or panic acceleration likely to arise in an emergency situation when rapid evacuation is necessary. The evacuation demonstrations shall be dry shod with the survival craft initially in their stowed positions and be conducted as follows:*

- *The evacuation time on a category A craft shall be the time elapsed from the moment the first abandon craft announcement is given, with any passengers distributed in a normal voyage configuration, until the last person has embarked in a survival craft, and shall include the time for passengers and crew to don lifejackets.*
- *The evacuation time shall include the time necessary to launch, inflate and secure the survival craft alongside ready for embarkation.*

8.5 *The evacuation time shall be verified by an evacuation demonstration (half trial) which shall be performed using the survival craft and exits on one side, for which the critical path analysis indicates the greatest evacuation time, with the passengers and crew allocated to them.*

8.6 *On craft where a half trial is impracticable, the Administration may consider a partial evacuation trial using a route which the critical path analysis shows to be the most critical.*

8.7 *The demonstration shall be carried out in controlled conditions in the following manner in compliance with the evacuation plan.*

- *The demonstration shall commence with the craft afloat in harbour, in reasonably calm conditions, with all machinery and equipment operating in the normal seagoing condition.*

– *All exits and doors inside the craft shall be in the same position as they are under normal seagoing condition.*

– *Safety belts shall be fastened.*

– *The evacuation routes for all passengers and crew shall be such that no person need enter the water during the evacuation.*

8.8 *For passenger craft, a representative composition of persons with normal health, height and weight shall be used in the demonstration, and shall consist of different sexes and ages so far as it is practicable and reasonable.*

8.9 *The persons, other than the crew selected for the demonstration, shall not have been specially drilled for such a demonstration.*

8.10 *An emergency evacuation demonstration shall be carried out for all new designs of WIG craft and for other craft where evacuation arrangements differ substantially from those previously tested.*

8.11 *The specific evacuation procedure followed during the craft's initial demonstration on which certification is based shall be included in the craft operating manual together with the other evacuation procedures contained in 8.2. During the demonstration, video recordings shall be made, both inside and outside the craft, which shall form an integral part of the training manual required by Section 10, B.2.3.*

9. Baggage and cargo compartments

9.1 Provision shall be made to prevent shifting of baggage and cargo compartment contents, having due regard to occupied compartments and accelerations likely to arise. If safeguarding by positioning is not practicable, adequate means of restraint for baggage and cargo shall be provided. Shelves and over-head shelves for storage of carry-on baggage in passenger compartment(s) shall be provided with adequate means to prevent the luggage from falling out in any conditions that may occur.

9.2 Controls, electric equipment, high-temperature parts, pipelines or other items, the damage or failure of which could affect the safe operation of the craft or which may require access by crew members during a voyage, shall not be located in baggage, store and cargo compartments unless such items are easily accessible and adequately protected so that they cannot be damaged or, where applicable, operated inadvertently by loading, by unloading or by movement of the contents of the compartment.

9.3 Loading limits, if necessary, shall be durably marked in those compartments.

9.4 Having regard to the purpose of the craft, the closures of the exterior openings of the luggage and cargo compartments as well as special-category spaces shall be appropriately weathertight.

10. Noise levels

10.1 The noise level in passenger compartments shall be kept as low as possible to enable the public address system to be heard, and shall not in general exceed 75 dB(A).

10.2 The maximum noise level in the operating compartment shall not in general exceed 65 dB(A) to facilitate communication within the compartment and external radio communications.

Section 4

Directional Control, Height Control and Stabilization System

A. Documents to be submitted

The following drawings and documents are to be submitted in triplicate[1)] for approval. They shall contain all data necessary for verifying scantlings and power calculations and shall include material specifications. BKI reserves the right to ask for supplementary copies if deemed necessary in particular cases.

– Assembly and general drawings of all directional and height control surfaces in connection with their control systems.

– Diagram and description of the control systems architecture.

– Detail drawings of all load-transmitting components.

– Diagrams of hydraulic and electric equipment, if applicable;

– Hardware and Software fault tolerance architectures, if applicable.

– Plan showing the design of pressure vessels.

– Plan for verification and validation in accordance with IEC 1508, if applicable.

B. Directional and Height Control Systems

1. General

1.1 Craft shall be provided with means for directional and height controls of adequate strength and suitable design to enable the craft's heading, height above water and direction of travel to be effectively controlled to the maximum extent possible in the prevailing conditions and craft speed without undue physical effort at all speeds and in all conditions for which the craft is to be certified. The performance shall be verified in accordance with Annex D (Definitions, requirements and compliance criteria related to operational and safety performance).

1.2 Directional and height control may be achieved by means of control surfaces in air or water. A control surface also may be a steerable propeller or jet. If necessary the control angles of surfaces must be limited depending on the speed of the craft. Any other arrangement will be given special consideration.

1.3 For the purpose of this Section, a directional and height control system includes any steering device or devices, any mechanical linkages and all power or manual devices, controls and actuating systems.

1.4 Control surfaces are to be mounted on substantial seatings in order to transmit the force sufficiently to the hull structure

1.5 Important load-transmitting components and components subjected to internal pressure are to be made of steel or other approved ductile material.

2. Mechanical cable systems

2.1 For mechanical cables no cable shall be smaller than 3.2 mm in diameter. Each cable system must be designed so that there will be no hazardous change in cable tension through the range of travel under operating conditions and temperature variations.

2.2 Each kind and size of pulley must correspond to the cable with which it is used. Pulleys and sprockets must have closely fitted guards to prevent the cables and chains from being displaced or fouled. Each pulley must lie in the plane passing through the cable so that the cable does not rub against the pulley flange.

2.3 Fairleads must be installed so that they do not cause change in cable direction of more than three degrees.

2.4 Clevis pins subject to load or motion and retained only by cotter pins may not be used in the control system.

2.5 Turnbuckles must be attached to parts having angular motion in a manner that will positively prevent binding throughout the range of travel.

2.6 Each mechanical cable, cable fitting, turnbuckle, splice, and pulley must be approved.

2.7 Control system joints (in push-pull systems) that are subject to angular motion, except those in ball and roller bearing systems, must have a special factor of safety of not less than 3.33 with respect to the ultimate bearing strength of the softest material

[1)] For Indonesia Flag ship in quadruplicate (one for Indonesian Government)

used as a bearing. This factor may be reduced to 2,0 for joints in cable control systems. For ball or roller bearings, the approved ratings may not be exceeded.

2.8 There must be provisions for visual inspection of fairleads, pulleys, terminals, and turnbuckles.

3. Electronic systems

Electronic controlled systems must be constructed with "fault tolerance". The "fault tolerance" must provide protection against design faults, such as those in software, as well as against hardware faults. The control system has to be designed in such a way that faults do not result in system failure within the required reliability of the system.

4. Hydraulic systems

4.1 The pipes of hydraulic systems are to be made of seamless or longitudinally welded steel tubes. At the discretion of the Society, copper may be used.

4.2 Approved high-pressure hose assemblies may be used for short pipe connections.

4.3 Hydraulic power supply and piping for directional and height control is not to be used for other purposes. At the discretion of the Society, exemptions may be permitted for water jets and similar units.

4.4 In the event of loss of hydraulic fluid, the second control system is to remain fully serviceable.

4.5 Tanks forming part of a hydraulic control system are to be fitted with fluid level indicators.

4.6 A low-level alarm is to be provided at the craft's operating position.

4.7 Filters for cleaning the fluid are to be located in the piping system.

5. Testing of materials

The materials of important load-transmitting components, including pressurized pipes and casings, are to be tested in the presence of the Surveyor in accordance with Rules for Materials, Volume V.

6. Additional requirements

6.1 A design incorporating a power drive or an actuation system employing powered components for normal directional or height control shall provide a secondary, independent means of actuating the device.

6.2 The actuation system is to be operated by power in any case where the maximum effective torque to be applied to the directional or height control device exceeds 25 kNm.

6.3 The means of actuating the height control device and the secondary means of actuating the directional control device may be manually driven when BKI is satisfied that this is adequate, bearing in mind the craft's size and design and any limitations of speed or other parameters that may be necessary.

6.4 The secondary means of actuating the directional or height control device is to be power-operated if the effective torque to be applied by the secondary means exceeds 40 kNm.

6.5 The directional and height control systems shall be constructed so that a single failure in one drive or system, as appropriate, will not render any other one inoperable or unable to bring the craft to a safe situation. BKI may allow a short period of time to permit the connection of a secondary control device when the design of the craft is such that such delay will not hazard the craft.

6.6 If necessary to bring the craft to a safe condition, power drives for directional and height control devices shall become operative automatically, and respond correctly, within 1s of power or other failure.

6.7 Directional and height control devices involving variable geometry of the craft shall, so far as is practicable, be so constructed that any failure of the drive linkage or actuating system will not significantly hazard the craft.

6.8 Control surfaces are to be provided with suitable mechanical stopping arrangements at the maximum design control surface angle.

6.9 Power-operated directional and height control systems are to be provided with power cut-off arrangements which stop the control surface before the mechanical stoppers are reached. These arrangements are to be synchronized with the control surface itself and not with the control system.

7. Demonstrations

7.1 The limits of safe use of any of the control system devices shall be based on demonstrations and verification process in accordance with Annex D (Definitions, requirements and compliance criteria related to operational and safety performance).

7.2 Any limitation on the operation of the craft as may be necessary to ensure that the redundancy or safeguards in the systems provide equivalent safety shall be included in the craft operating manual.

7.3 Each hydraulic or electric power unit is to be subjected to a type test in the manufacturer's workshop according to a program accepted by BKI. During the test, no overheating, excessive vibration or other irregularities are to occur. After the test the power unit is to be dismantled and inspected.

7.4 Pressure vessels including cylinders and pipes are to be subjected to a pressure test. The test pressure is to be 1.5 times the maximum working pressure. Tightness tests are to be conducted on components for which this is appropriate.

8. Control position

8.1 All directional and height control systems shall be operated from the craft's operating station.

8.2 Adequate indications shall be provided at the operating station to provide the person controlling the craft with verification of the correct response of the directional and height control surfaces to this demand, and also to indicate any abnormal responses or malfunction. The indications of control surfaces response or surface angle indicator shall be independent of the systems for control. The logic of such feedback and indications shall be consistent with the other alarms and indications so that in an emergency operators are unlikely to be confused.

8.3 Controls are to be so designed that the control surfaces cannot move unintentionally.

C. Stabilization Systems

Stabilization system is a system intended to stabilize the main parameters of the craft's attitude: heel, trim, course and height and control the craft's motions: roll, pitch, yaw and heave. These Rules apply only to WIGs which possess sufficient inherent static and dynamic stability, to be demonstrated in all modes of operation by full scale tests to the Administration in accordance with the requirements of Section 2, C.2.2 to 2.6. This term excludes the need for any stabilization system. This term also excludes devices not associated with the safe operation of the craft, e.g. motion reduction or ride control systems.

Section 5

Fire Safety

A. Documents to be submitted

Depending on the design of the craft the following drawings and documents are to be submitted as applicable, at least in triplicate[1)] for approval. BKI reserves its right to ask for supplementary copies, if deemed necessary in particular cases.

– Documents showing the measures of structural fire protection (fire-resisting subdivision, use of materials etc.)

– Plan showing the arrangement of the means of escape

– Schematic plan concerning the natural and mechanical ventilation, with indication of location of dampers and identification numbers of the fans serving each craft section.

– Plan showing automatic fire detection systems including fire alarm systems.

– Plan relating to the fixed water fire-extinguishing system (pumps, piping, etc.).

– Plan relating to the arrangement of fixed foam, gas, water mist or other approved fire-extinguishing systems.

– Plan relating to the arrangement of fixed pressure water-spraying system for special category spaces.

– Constructional plans relevant to pressure vessels or bottles serving fixed fire extinguishing systems.

– Plans of pumping and drainage means for the water delivered by fixed fire-extinguishing systems.

– Fire control plan.

Further documentation may be required, if deemed necessary by BKI.

B. General Provisions

1. The following basic principles underlie the provisions in this Section and are embodied therein as appropriate, having regard to the potential fire hazard involved:

.1 maintenance of the main functions and safety systems of the craft, including propulsion and control, fire-detection, alarms and extinguishing capability of unaffected spaces, after fire in any one compartment on board;

.2 subdivision of the craft by fire-resisting boundaries;

.3 restricted use of combustible materials and materials generating smoke and toxic gases in a fire;

.4 detection, containment and extinction of any fire in the space of origin;

.5 protection of means of escape and access for fire-fighting;

.6 immediate availability of fire-extinguishing appliances; and

.7 maintenance of structural integrity during fire extinguishing and evacuation time.

2. The provisions of this Section are based on the following conditions:

.1 Where a fire is detected, the crew immediately puts into action the fire-fighting procedures and informs the base port of the accident.

.2 For all types of fuel the provisions of Section 7, C.1 and C.2 are to be complied with. The use of fuel with a flashpoint below 43 °C is not recommended. However, fuel with a lower flashpoint may be used subject to compliance with the provisions specified in E.2.7.

.3 The use of fuel with a flashpoint lower than 35 °C may be accepted for small craft up to 12 passengers, provided that special safety measures specified in Section 7, C.7.4 are considered.

.4 Enclosed spaces having reduced lighting such as cinemas, discothèques, and similar spaces are not permitted.

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1) For Indonesia Flag ship in quadruplicate (one for Indonesian Government)

.5 Passenger access to special category spaces is prohibited during the voyage.

.6 Smoking on board is prohibited.

.7 Dangerous goods are not carried, except in limited quantities in accordance with Section 18 of the "General Introductions to the International Maritime Dangerous Goods (IMDG) Code".

C. Definitions

1. Fire Test Procedures Code

Fire Test Procedures Code (FTP Code) means the "International Code for Application of Fire Test Procedures", as adopted by the Maritime Safety Committee of the International Maritime Organization by resolution MSC.61(67), as may be amended.

2. Fire-resisting divisions

Fire-resisting divisions are those divisions formed by bulkheads and decks which comply with the following:

.1 They shall be constructed of non-combustible or fire-restricting materials which by insulation or inherent fire-resisting properties satisfy the requirements of .2 to .6.

.2 They shall be suitably stiffened.

.3 They shall be so constructed as to be capable of preventing the passage of smoke and flame up to the end of the appropriate fire protection time.

.4 Where required, they shall maintain load carrying capabilities up to the end of the appropriate fire protection time.

.5 They shall have thermal properties such that the average temperature on the unexposed side will not rise more than 140 °C above the original temperature, nor will the temperature at any one point, including any joint, rise more than 180 °C above the original temperature during the appropriate fire protection time.

.6 A test for a prototype bulkhead and deck in accordance with the FTP Code shall be required to ensure that it meets the above requirements.

3. Fire-restricting materials

Fire-restricting materials are those materials which have properties complying with the FTP Code.

4. Non-combustible material

Non-combustible material is a material which neither burns nor gives off flammable vapours in sufficient quantity for self-ignition when heated to approximately 750 °C, this being determined in accordance with the FTP Code.

5. A standard fire test

A standard fire test is one in which specimens of the relevant bulkheads, decks or other constructions are exposed in a test furnace by a specified test method in accordance with the FTP Code

6. Steel or other equivalent material

Where the words "steel or other equivalent material" occur, "equivalent material" means any non-combustible material which, by itself or due to insulation provided, has structural and integrity properties equivalent to steel at the end of the applicable exposure to the standard fire test (e.g. aluminium alloy with appropriate insulation).

7. "Low flame-spread"

Low flame-spread means that the surface thus described will adequately restrict the spread of flame, this being determined in accordance with the FTP Code.

8. Smoke-tight or capable of preventing the passage of smoke

Smoke-tight or capable of preventing the passage of smoke means that a division made of non-combustible or fire-restricting materials is capable of preventing the passage of smoke.

D. Structural Fire Protection

1. The hull, superstructure, structural bulkheads, decks, deck-houses and pillars shall be constructed of approved non-combustible materials having adequate structural properties. The use of other fire-restricting materials may be permitted provided the requirements of this chapter are complied with and the materials are in compliance with the FTP Code.

2. Fire hazard areas shall be enveloped in fire-resisting divisions. The following spaces shall be regarded as fire hazard areas:

– machinery spaces
– special category spaces
– auxiliary machinery spaces
– service spaces
– spaces other than control stations that are adjacent to control stations

3. Fire-resisting divisions shall be constructed to resist exposure to the standard fire test for a period which is the greatest of 30 min. or thrice repeated demonstration time necessary for embarkation on the rescue means, plus 7 min. for detection and extinction of fire and plus the time required for landing the craft to the water and stand still.

4. If the structures specified in 3. are made of aluminium alloy, their insulation shall be such that the temperature of the core does not rise more than 200 °C above the ambient temperature for a period of 30 minutes.

5. If the structures specified in 3. are made of combustible material, their insulation shall be such that their temperatures will not rise to a level where deterioration of the construction will occur during the exposure to the standard fire test in accordance with the FTP Code to such an extent that the load-carrying capability in a period of 30 minutes will be impaired.

6. The construction of all doors, and door frames in fire-resisting divisions, with the means of securing them when closed, shall provide resistance to fire as well as to the passage of smoke and flame equivalent to that of the bulkheads in which they are situated. Also, where a fire-resisting division is penetrated by pipes, ducts, electrical cables etc., arrangements shall be made to ensure that the fire-resisting integrity of the division is not impaired and necessary testing shall be carried out in accordance with the FTP Code.

7. Main load-carrying structures within fire hazard areas shall be arranged to distribute load such that there will be no collapse of the construction of the hull and superstructure when it is exposed to fire for the structural fire protection time. The load-carrying structure shall also comply with the requirements of 4. and 5.

8. Control stations for ventilators, for fuel shut down system, remote control of fire-extinction systems as well as indication panels of fire detection shall be located in the craft operating compartment.

9. All separating divisions, ceilings or linings if not a fire resisting division, shall be of non-combustible or fire restricting materials. Draught stops shall be of non-combustible or fire-restricting material.

10. Where insulation is installed in areas in which it could come into contact with any flammable fluids or their vapours, its surface shall be impermeable to such flammable fluids of vapours. Visual inspection of these surfaces shall be possible.

11. Furniture and furnishings in public spaces shall comply with the following standards:

.1 all case furniture is constructed entirely of approved non-combustible or fire-restricting materials, except that a combustible veneer with a calorific value not exceeding 45 MJ/m^2 may be used on the exposed surface of such articles;

.2 all other furniture, such as chairs, sofas and tables, is constructed with frames of non-combustible materials;

.3 all draperies, curtains and other suspended textile materials have qualities of resistance to the propagation of flame, this being determined in accordance with the FTP Code.

.4 all upholstered furniture has qualities of resistance to the ignition and propagation of flame this being determined in accordance with the FTP Code.

.5 all deck finish materials comply with the FTP Code.

12. The following surfaces shall, as a minimum standard, be constructed of materials having low flame-spread characteristics:

.1 exposed surfaces in corridors and stairway enclosures, and of bulkheads, wall and ceiling linings in all public spaces, service spaces, control stations and internal assembly and evacuation stations.

.2 surfaces in concealed or inaccessible spaces in corridors and stairway enclosures, public spaces, service spaces, control stations and internal assembly and evacuation stations.

13. Any thermal and acoustic insulation shall be of non-combustible or of fire-restricting material. Vapour barriers and adhesives used in conjunction with insulation, as well as insulation of pipe fittings for cold service systems need not be non-combustible or fire-restricting, but they shall be kept to the minimum quantity practicable and their exposed surfaces shall have low flame spread characteristics.

14. Exposed surfaces in corridors and stairway enclosures, and of bulkheads (including windows), wall and ceiling linings, in all public spaces, service spaces, control spaces and internal assembly and evacuation stations shall be constructed of materials which, when exposed to fire, are not capable of producing excessive quantities of smoke or toxic products, this being determined in accordance with the FTP Code.

15. The exhaust gas pipes shall be arranged so that the risk of fire is kept to a minimum. To this effect, the exhaust system shall be insulated and all compartments and structures which are contiguous with the exhaust system, or those which may be affected by increased temperatures caused by waste gases in normal operation or in an emergency, shall be constructed of non-combustible material or be shielded and insulated with non-combustible material to protect from high temperatures.

16. The design and arrangement of the exhaust manifolds or pipes shall be such as to ensure the safe discharge of exhaust gases.

17. Internal stairways shall be fully enclosed with smoke-tight or fire-resisting divisions in accordance with the provision of this Section. A stairway connecting only two decks needs only be enclosed at one deck by means of divisions and self-closing doors.

18. In public spaces, service spaces, control stations, corridors and stairways, air spaces enclosed behind ceilings, paneling or linings shall be suitably divided by close-fitting draught stops not more than 14 m apart. On craft provided with only a single public space, draught stops need not be provided in such public space.

19. Openings in fire-resisting divisions

19.1 Except for the hatches between cargo, special-category, store, and baggage spaces and between such spaces and the weather decks, all openings shall be provided with permanently attached means of closing which shall be at least as effective for resisting fires as the divisions in which they are fitted.

19.2 It shall be possible for each door to be opened and closed from each side of the bulkhead by one person only.

19.3 Fire doors bounding fire hazard areas and stairway enclosures other than those which are normally locked shall satisfy the following requirements:

.1 The doors shall be self-closing.

.2 Doors required to be self-closing shall not be fitted with hold-back hooks. However, hold-back arrangements fitted with remote release devices of the fail-safe type may be utilized.

19.4 The requirements for integrity of fire-resisting divisions of the outer boundaries facing open spaces of a craft shall not apply to glass partitions, windows and side scuttles. Similarly, the requirements for integrity of fire-resisting divisions facing open spaces shall not apply to exterior doors in superstructures and deck-houses.

E. Provisions to Systems and Equipment

1. Ventilation

1.1 The main inlets and outlets of all ventilation systems shall be capable of being closed from outside the spaces being ventilated. In addition, such openings to fire hazard areas shall be capable of being closed from the operating compartment.

1.2 All ventilation fans shall be capable of being stopped from outside the spaces which they serve, and from outside the spaces in which they are installed. Ventilation fans serving the fire hazard areas shall be capable of being operated from the operating compartment. The means provided for stopping the power ventilation to the machinery space shall be separated from the means provided for stopping ventilation of other spaces.

1.3 Fire hazard areas and spaces serving as assembly stations shall have independent ventilation systems and ventilation ducts. Ventilation ducts for fire hazard areas shall not pass through other spaces, unless they are contained within a trunk or in an extended machinery space or casing protected in accordance with Section 5, D.3. Ventilation ducts of other spaces shall not pass through fire hazard areas. Ventilation outlets from fire hazard areas shall not terminate within a distance of 1 m from any control station, evacuation station or external escape route.

1.4 Where a ventilation duct passes through a fire-resisting or smoke-tight division, a fail-safe automatic closing fire damper shall be fitted adjacent to the division. The duct between the division and the damper shall be of steel or other equivalent material and insulated to the same standard as required for the fire-resisting division. The fire-damper may be omitted where ducts pass through spaces surrounded by fire-resisting divisions without serving those spaces providing that the duct has the same structural fire protection time as the division it penetrates. Where a ventilation duct passes through a smoke-tight division, a smoke damper shall be fitted at the penetration unless the duct which passes through the space does not serve that space.

1.5 Where ventilation systems penetrate decks, the arrangements shall be such that the effectiveness of the deck in resisting fire is not thereby impaired and precautions shall be taken to reduce the likelihood of smoke and hot gases passing from one between deck space to another through the system.

1.6 All dampers fitted on fire-resisting or smoke-tight divisions shall also be capable of being manually closed from each side of the division in which they are fitted, except for those dampers fitted on ducts serving spaces not normally manned such as stores and toilets that may be manually operated only from outside the served spaces. All dampers shall also be capable of being remotely closed from the operating compartment.

1.7 Ducts shall be made of non-combustible or fire-resistant material. Short ducts, however, may be of combustible materials subject to the following conditions:

.1 their cross-section does not exceed 0.02 m^2;

.2 their length does not exceed 2 m;

.3 they may only be used at the terminal end of the ventilation system;

.4 they shall not be situated less than 600 mm from an opening in a fire-resisting or fire-restricting division; and

.5 their surfaces have low flame spread characteristics.

1.8 Additional provisions for special category spaces

1.8.1 There shall be provided an effective power ventilation system for special-category spaces sufficient to give at least 10 air changes per hour while navigating and 20 air changes per hour at the quayside during vehicle loading and unloading operations. The system for such spaces shall be entirely separated from other ventilation systems and shall be operating at all times when vehicles are in such spaces. Ventilation ducts serving special-category spaces capable of being effectively sealed shall be separated for each such space. The system shall be capable of being controlled from a position outside such spaces.

1.8.2 The ventilation shall be such as to prevent air stratification and the formation of air pockets.

1.8.3 Means shall be provided to indicate in the operating compartment any loss or reduction of the required ventilating capacity.

1.8.4 Ventilation ducts, including dampers, shall be made of steel or other equivalent material.

2. Fuel and other flammable fluid tanks and systems

2.1 The following provisions refer to fuel. They refer to other flammable fluids only, if they constitute a significant hazard potential. Further requirements see Section 7, C.1. and C.2.

2.2 Tanks containing fuel and other flammable fluids shall be separated from passenger, crew, and baggage compartments by vapour-proof enclosures or cofferdams which are suitably ventilated and drained.

2.3 Fuel tanks shall not be located in or contiguous to fire hazard areas. However, flammable fluids of a flashpoint not less than 60 °C may be located within such areas provided the tanks are made of steel or other equivalent material.

2.4 Every fuel pipe which, if damaged, would allow oil to escape from a storage, settling or daily service tank shall be fitted with a cock or valve directly on the tank capable of being closed from a position outside the space concerned in the event of a fire occurring in the space in which such tanks are situated.

2.5 Pipes, valves and couplings conveying flammable fluids shall be of steel or such alternative material satisfactory in accordance with the "Guidelines for the Application of Plastic Pipes on Ships", adopted by the Organization by resolution A.753(18), in respect of strength and fire integrity having regard to the service pressure and the spaces in which they are installed. Wherever practicable, the use of flexible pipes shall be avoided.

2.6 Pipes, valves and couplings conveying flammable fluids shall be arranged as far from hot surfaces or air intakes of engine installations, electrical appliances and other potential sources of ignition as is practicable and be located or shielded so that the likelihood of fluid leakage coming into contact with such sources of ignition is kept to a minimum.

2.7 In every craft in which fuel with a flashpoint below 43 °C is used, the arrangements for the storage, distribution and utilization of the fuel shall be such that, having regard to the hazard of fire and explosion which the use of such fuel may entail, the safety of the craft and of persons on board is preserved. The arrangements shall comply, in addition to the requirements of 2.1 to 2.5, with the following provisions:

.1 any part of the fuel system shall be located outside the hull or in such a way that fuel vapour cannot accumulate in enclosed spaces.

.2 arrangements shall be made to prevent over-pressure in any fuel tank or in any part of the fuel system, including the filling pipes. Any relief valves and air or overflow pipes shall discharge to a position which is safe;

.3 earthed electrical distribution systems shall not be used, with the exception of earthed intrinsically safe circuits;

.4 suitable certified safe type electrical equipment in accordance with the recommendations published by the International Electrotechnical Commission and, in particular, "Publication 92 – Electrical Installations in Ships" shall be used in all spaces where fuel leakage could occur, including the ventilation system. Only electrical equipment and fittings essential for operational purposes shall be fitted in such spaces;

.5 a fixed vapour-detection system shall be installed in each space through which fuel lines pass, with alarms provided in the operating compartment.

.6 any fuel gauge installation shall be of intrinsic safe type.

.7 during bunkering operations, no passenger shall be on board the craft or in the vicinity of the bunkering station, and adequate "No Smoking" and "No Naked Lights" signs shall be posted. Vessel-to-shore fuel connections shall be of closed type and suitably earthed during bunkering operations;

.8 the provision of fire detection and extinguishing systems in spaces where non-integral fuel tanks are located shall be in accordance with paragraphs F. and G.; and

.9 refueling of the craft shall be done at the approved refueling facilities, detailed in the route operational manual, at which the following fire appliances are provided:

- a suitable foam applicator system consisting of monitors and foam-making branch pipes capable of delivering foam solution at a rate of not less than 500 l/min for not less than 10 min;
- dry powder extinguishers of total capacity not less than 50 kg; and
- carbon dioxide extinguishers of total capacity not less than 16 kg.

2.8 Fuel with a flashpoint below 35 °C shall not be used unless the provisions of Section 5, B.2.3 are complied with.

3. Hydraulic system

3.1 The used hydraulic liquid shall be non-combustible.

F. Fire Detection Systems

1. Fire hazard areas and other enclosed spaces in the accommodation not regularly occupied, such as toilets, shall be provided with an approved automatic smoke-detection system to indicate in the operating compartment the location of outbreak of a fire in all normal operating conditions of the installations. Where a smoke detection system is impracticable due to adverse environmental conditions, an approved automatic fire detection system of an other type shall be fitted. Main propulsion machinery room(s) shall in addition have detectors sensing other than smoke.

2. Requirements

The fixed fire-detection and fire alarm systems shall comply with the following requirements.

2.1 General requirements

.1 Any required fixed fire-detection and fire alarm system shall be capable of immediate operation at all times.

.2 Power supplies and electric circuits necessary for the operation of the system shall be monitored for loss of power or fault conditions as appropriate. Occurrence of a fault condition shall initiate a visual and audible fault signal at the control panel which shall be distinct from a fire signal.

.3 There shall be not less than two sources of power supply for the electrical equipment used in the operation of the fixed fire-detection and fire alarm system, one of which shall be an emergency source. The supply shall be provided by separate feeders reserved solely for that purpose. Such feeders shall run to an automatic change-over switch situated in or adjacent to the control panel for the fire-detection system.

.4 Detectors shall be grouped into sections. The activation of any detector shall initiate a visual and audible fire signal at the control panel and indicating units. If the signals have not received attention within two minutes an audible alarm shall be automatically sounded through-out the service spaces, control stations and machinery spaces. This alarm sounder system need not be an integral part of the detection system.

.5 The control panel shall be located in the operating compartment.

.6 Indicating units shall, as a minimum, denote the section in which a detector has operated. At least one unit shall be so located that it is easily accessible to responsible members of the crew at all times, when at sea or in port, except when the craft is out of service.

.7 Clear information shall be displayed on or adjacent to each indicating unit about the spaces covered and the location of the sections.

.8 In passenger craft, if there is no fire-detection system capable of remotely and individually identifying each detector, a section of detectors shall not serve spaces on both sides of the craft nor on more than one deck. In passenger craft fitted with individually identifiable fire detectors, a section may serve spaces on both sides of the craft and on several decks.

.9 A section of fire detectors which covers a control station or a service space, shall not include a machinery space.

.10 Fire detectors shall be operated by heat, smoke or other products of combustion, flame, or any combination of these factors. Detectors operated by other factors indicative of incipient fires may be considered provided that they are no less sensitive than such detectors. Flame detectors shall only be used in addition to other detectors.

.11 Suitable instructions and component spares for testing and maintenance shall be provided.

.12 The function of the detection system shall be periodically tested by means of equipment producing hot air at the appropriate temperature, or smoke or aerosol particles having the appropriate range of density or particle size, or other phenomena associated with incipient fires to which the detector is designed to respond. All detectors shall be of a type such that they can be tested for correct operation and restored to normal surveillance without the renewal of any component.

.13 The fire-detection system shall not be used for any other purpose.

.14 Fire-detection systems with a zone address identification capability shall not be so arranged that:

- a loop cannot be damaged at more than one point by a fire;
- means are provided to ensure that any fault (e.g. power break; short circuit; earth) occurring in the loop shall not render the whole loop ineffective;
- all arrangements are made to enable the initial configuration of the system to be restored in the event of failure (electrical, electronic, informatic); and
- the first initiated fire alarm shall not prevent any other detector to initiate further fire alarms.

2.2 Installation requirements

.1 At least one fire detector shall be installed in each space required acc. to F.1. Consideration shall be given to the installation of special purpose smoke detectors within ventilation ducting.

.2 Detectors shall be located for optimum performance. Positions near beams and ventilation ducts or other positions where patterns of air flow could adversely affect performance and positions where impact or physical damage is likely shall be avoided. In general, detectors which are located on the overhead shall be a minimum distance of 0.5 m away from bulkheads.

.3 The maximum spacing of detectors shall be in accordance with the Table 5.1 below:

Table 5.1

Type of detector	Maximum distance apart between centres	Maximum distance away from bulkheads
Heat	9 m	4,5 m
Smoke	11 m	5,5 m

.4 Electrical wiring which forms parts of the system shall be so arranged as to avoid machinery spaces and other enclosed fire hazard areas except, where it is necessary, to provide for fire detection or fire alarm in such spaces or to connect to the appropriate power supply.

2.3 Design requirements

.1 The system and equipment shall be suitably designed to withstand supply voltage variation and transients, ambient temperature changes, vibration, humidity, shock, impact and corrosion to be expected for the particular craft.

.2 Smoke detectors required by paragraph 2.2.2 shall be certified to operate before the smoke density exceeds 12.5 % obscuration per metre, but not until the smoke density exceeds 2 % obscuration per metre.

.3 Heat detectors shall be certified to operate before the temperature exceeds 78 °C but not until the temperature exceeds 54 °C, when the temperature is raised to those limits at a rate less than 1 °C per minute. At higher rates of temperature rise, the heat detector shall operate within temperature limits having regard to the avoidance of detector insensitivity or over-sensitivity.

.4 The permissible temperature of operation of heat detectors may be increased to 30 °C above the maximum deck head temperature in drying rooms and similar spaces of a normal high ambient temperature.

.5 Flame detectors corresponding to 2.1.10 shall have a sensitivity sufficient to determine flame against an illuminated space background and a false signal identification system.

3. A fixed fire-detection and fire alarm system for machinery spaces shall comply with the following requirements:

.1 The fire-detection system shall be so designed and the detectors so positioned as to detect rapidly the onset of fire in any part of those spaces and under any normal conditions of operation of the machinery and variations of ventilation as required by the possible range of ambient temperatures. Except in spaces of restricted height and where their use is specially appropriate, detection systems using only thermal detector shall not permitted.

The detection system shall initiate audible and visual alarms distinct in both respects from the alarms of any other system not indicating fire to ensure that the alarms are heard and ob- served in the operating compartment.

.2 After installation, the system shall be tested under varying conditions of engine operation and ventilation.

G. Fire-extinguishing Systems and Equipment

1. General provisions

1.1 All craft shall be provided with a fixed water fire-extinguishing system acc. to 2. and a minimum number of portable fire extinguishers acc. to 3.

Very small craft of up to 12 passengers need not comply with the provisions acc. to 2.

1.2 In addition, fire hazard areas as mentioned below shall be protected by an approved fixed fire extinguishing system operable from the operating compartment, which is adequate for the fire hazard that may exist. The system shall be capable of local manual control and remote control from the operating compartment. The fire hazard areas to which this provision applies are:

– Machinery spaces

– special category spaces

1.3 Any fire-extinguishing system and equipment shall meet the provisions of 2. to 5., as applicable. Depending on size, craft characteristics and operational area, alternative arrangements may be accepted.

1.4 When alternative provisions to the fire-extinguishing systems and equipment are proposed, such as water spraying systems, foam systems or water mist systems, they shall be designed in accordance with applicable international regulations.

2. Fixed water fire-extinguishing system

Fire pump(s), and appropriate associated equipment shall be fitted as follows:

.1 At least one independently driven fire pump shall be provided. The capacity of the fire pump, acting through a fire main and hoses, shall be sufficient to project at least one jet of water to each part of the craft. This shall be based on a length of throw of 12 m from a nozzle of 12 mm diameter. The minimum pump capacity shall be 10 m³/h.

.2 The fire main shall be so arranged that a water jet can at all times be projected to each part of the craft through a single length of hose not exceeding 20 m. At least two fire hydrants shall be provided.

.3 Each fire hose shall be of non-perishable material. Fire hoses, together with any necessary fittings and tools, shall be kept ready for use in conspicuous positions near the hydrants. All fire hoses in interior locations shall be connected to the hydrants at all times. One fire hose shall be provided for each hydrant as required by .2.

.4 Each fire hose shall be provided with a nozzle of an approved dual purpose type (i.e. spray/jet type) incorporating a shutoff.

3. Portable fire-extinguishers

The operating compartment, public spaces and service spaces shall be provided with portable fire extinguishers of at least 5 kg dry powder or 9 ltr foam as follows:

– operating compartment:

  1 fire extinguisher,

– public spaces:

  1 fire extinguisher for each 25 passengers; and

– service spaces:

  1 fire extinguisher.

In addition, one extinguisher of at least 5 kg dry powder or 9 ltr foam shall be positioned outside the machinery space entrance.

4. Gas fire-extinguishing systems

In all craft where gas is used as the extinguishing medium, the quantity of gas shall be sufficient to provide two independent discharges. The second discharge into the space shall only be activated (released) manually from a position outside the space being protected. Where the space has a second fixed means of extinguishing installed, then the second discharge shall not be required.

4.1 General provisions

The fixed gas fire-extinguishing systems shall comply with the following requirements:

.1 The use of a fire-extinguishing medium which, either by itself or under expected conditions of use will adversely affect the earth's ozone layer and/or gives off toxic gases in such quantities as to endanger persons shall not be permitted.

.2 The necessary pipes for conveying fire-extinguishing medium into protected spaces shall be provided with control valves so marked as to indicate clearly the spaces to which the pipes are led. Non-return valves shall be installed in discharge lines between cylinders and manifolds. Suitable provision shall be made to prevent inadvertent admission of the medium to any space.

.3 The piping for the distribution of fire-extinguishing medium shall be arranged and discharge nozzles so positioned that a uniform distribution of medium is obtained.

.4 Means shall be provided to close all openings which may admit air to, or allow gas to escape from, a protected space.

.5 Where the volume of free air contained in air receivers in any space is such that, if released in such space in the event of fire, such release of air within that space would seriously affect the efficiency of the fixed fire-extinguishing system, an additional quantity of fire-extinguishing medium, shall be provided.

.6 Means shall be provided for automatically giving audible warning of the release of fire-extinguishing medium into any space in which personnel normally work or to which they have access. The alarm shall operate for a suitable period before the medium is released.

.7 The means of control of any fixed gas fire-extinguishing system shall be readily accessible and simple to operate and shall be grouped together in as few locations as possible at positions not likely to be cut off by a fire in a protected space. At each location there shall be clear instructions relating to the operation of the system, having regard to the safety of personnel.

.8 Automatic release of fire-extinguishing medium shall not be permitted.

.9 Where the quantity of extinguishing medium is required to protect more than one space, the quantity of medium available need not be more than the largest quantity required for any one space so protected.

.10 Pressure containers required for the storage of fire-extinguishing medium shall be located outside protected spaces in accordance with .13.

.11 Means shall be provided for the crew to safely check the quantity of medium in the containers.

.12 Containers for the storage of fire-extinguishing medium and associated pressure components shall be designed to pressure codes of practice having regard to their locations and maximum ambient temperatures expected in service.

.13 When the fire-extinguishing medium is stored outside a protected space, it shall be stored in a room which shall be situated in a safe and readily accessible position and shall be effectively ventilated. Any entrance to such a storage room shall preferably be from the open deck and in any case shall be independent of the protected space. Access doors shall open outwards, and bulkheads and decks including doors and other means of closing any opening therein, which form the boundaries between such rooms and adjoining enclosed spaces, shall be gas tight. Such storage rooms shall be treated as control stations.

.14 Spare parts for the system shall be stored on board or at a base port.

4.2 Carbon dioxide systems

In addition to 4.1, the following shall be met for CO_2 systems:

.1 For machinery spaces, the quantity of carbon dioxide carried shall be sufficient to give a minimum volume of free gas equal to the larger of the following volumes, either:

– 40 % of the gross volume of the largest machinery space so protected, the volume to exclude that part of the casing above the level at which the horizontal area of the casing is 40 % or less of the horizontal area of the space concerned taken midway between the tank top and the lowest part of the casing; or

– 35 % of the gross volume of the largest machinery space protected, including the casing.

– the above percentages may be reduced to 35 % and 30 % respectively for cargo craft.

.2 For the purpose of this paragraph the volume of free carbon dioxide shall be calculated at 0.56 m^3/kg.

.3 For machinery spaces, the fixed piping system shall be such that 85 % of the gas can be discharged into the space within 2 min.

– Two separate controls shall be provided for releasing carbon dioxide into a protected space and to ensure the activation of the alarm. One control shall be used to discharge the gas from its storage containers. A second control shall be used for opening the valve of the piping which conveys the gas into the protected spaces.

– The two controls shall be located inside a release box clearly identified for the particular space. If the box containing the controls is to be locked, a key to the box shall be in a break-glass type enclosure conspicuously located adjacent to the box.

5. Fixed pressure water-spraying system

Each special category space shall be fitted with an approved fixed pressure water-spraying system for manual operation in accordance with the "Recommendation on Fixed Fire-Extinguishing Systems for Special-Category Spaces", adopted by the International Maritime Organization by resolution A.123(V) which shall protect all parts of any deck and vehicle platform in such space, provided that the Administration may permit the use of any other fixed fire- extinguishing system that has been shown by full- scale test in conditions simulating a flowing petrol fire in a special category space to be not less effective in controlling fires likely to occur in such a space.

6. Suitable arrangements shall be made for the drainage of water discharged by any water fire-extinguishing system.

H. Additional Provisions for Special Category Spaces

1. Indicators shall be provided in the operating compartment which shall indicate when any door leading to or from the special category space is closed.

2. Fire-extinguishing equipment

2.1 There shall be provided in each special category space:

.1 at least three water fog applicators;

.2 one portable foam applicator unit consisting of an air foam nozzle of an inductor type capable of being connected to the fire main by a fire hose, together with a portable tank containing 20 *l* of foam-making liquid and one spare tank. The nozzle shall be capable of producing effective foam suitable for extinguishing an oil fire of at least 1.5 m^3/min. At least two portable foam applicator units shall be available in the craft for use in such space; and

.3 portable fire extinguishers of 12 kg dry powder or equivalent shall be located so that no point in the space is more than approximately 15 m walking distance from an extinguisher, provided that at least one portable extinguisher is located at each access to such space.

3. Precautions against ignition of flammable vapours

3.1 On any deck or platform, if fitted, on which vehicles are carried and on which explosive vapours might be expected to accumulate, except platforms with openings of sufficient size permitting penetration of petrol gases downwards, equipment which may constitute a source of ignition of flammable vapours and, in particular, electrical equipment and wiring, shall be installed at least 450 mm above the deck or platform. Electrical equipment installed at more than 450 mm above the deck or platform shall be of a type so enclosed and protected as to prevent the escape of sparks. However, if the installation of electrical equipment and wiring at less than 450 mm above the deck or platform is necessary for the safe operation of the craft, such electrical equipment and wiring may be installed provided that it is of a type approved for use in an explosive air/fuel mixture.

3.2 Electrical equipment and wiring, if installed in an exhaust ventilation duct, shall be of a type approved for use in explosive air/fuel mixtures of petrol and air and the outlet from any exhaust duct shall be sited in a safe position, having regard to other possible sources of ignition.

Note:

The following two paragraphs are not applicable for the purpose of classification. The certification of fire control plans falls under the responsibility of the Administration and is based on international safety requirements. Presently, no such international requirements exist for WIG craft. The IMO Sub-Committee on Design and Equipment, however, has established a Correspondence Group dealing with Guidelines for the Safety of WIG craft. The following text reflects the current state as per 31.01.2001 of deliberations in the Correspondence Group related to Category A passenger WIG craft of type A and cargo WIG craft of type A, and is here reproduced for in- formation only. It may serve as a basis for discussions with the Administration. The current status can be provided by BKI.

I. Fire Control Plans

1. *There shall be permanently exhibited, for the guidance of the master and officers of the craft, fire control plans showing clearly for each deck the following positions: the control stations, the sections of the craft which are enclosed by fire-resisting divisions together with particulars of the fire alarms, fire detection systems, fixed fire extinguishing systems and portable fire-extinguishing equipment, the means of access to the various compartments and decks in the craft, the ventilating systems (including particulars of the master fan controls, the positions of dampers and identification numbers of the ventilating fans serving each section of the craft), the location of the international shore connection, if fitted, and the position of all means of control referred to in* E.1.2, E.2.4 *and* F.1. *The text of such plans shall be in the official language of the flag state and in accordance with "Graphical Symbols for Fire Control Plans", adopted by the International Maritime Organization by resolution A.654(16). However, if the language is neither English nor French, a translation into one of those languages shall be included..*

2. *A duplicate set of fire control plans or a booklet containing such plans shall be permanently stored in a prominently marked weathertight enclosure outside the deckhouse for the assistance of shore-side fire-extinguishing personnel.*

J. Additional Provisions for Passenger Craft

1. Arrangement

Control stations, stowage positions of life-saving appliances, escape routes and places of embarkation into survival craft shall not, as far as practicable, be located adjacent to any fire hazard area.

K. Additional Provisions for Cargo Craft

1. Life-saving appliances stowage positions, escape routes and places of embarkation into survival craft shall be located in or adjacent to the passenger compartment.

2. Cargo spaces

2.1 Cargo spaces, except open deck areas or refrigerated holds, shall be provided with an approved automatic smoke-detection system complying with F.2. to indicate in the operating compartment the location of outbreak of a fire in all normal operating conditions of the installations and shall be protected by an approved fixed fire-extinguishing system complying with G.4. operable from the operating compartment or gas storage room.

2.2 Where a CO_2 system for cargo spaces is used, the quantity of carbon dioxide available shall, unless otherwise provided, be sufficient to give a minimum volume of free gas equal to 30 % of the gross volume of the largest cargo space so protected in the craft.

Section 6

Life-Saving Appliances and Arrangements

Note:

This Section of the Rules is not applicable for the purpose of classification. The certification of life-saving appliances and arrangements falls under the responsibility of the Administration and is based on international safety requirements. Presently, no such international requirements exist for WIG craft. The IMO Sub-Committee on Design and Equipment, however, has established a Correspondence Group dealing with Guidelines for the Safety of WIG craft. The following text reflects the current state as per 31.01.2001 of deliberations in the Correspondence Group related to Category A passenger WIG craft of type A and cargo WIG craft of type A, and is here reproduced for information only. It may serve as a basis for discussions with the Administration. The current status can be provided by BKI.

A. General and Definitions

1. *Life-saving appliances and arrangements shall enable abandonment of the craft in accordance with the requirements of* Section 3, C.7 *(Exits and means of escape) and* Section 3, C.8 *(Evacuation time).*

2. *Except where otherwise provided in these Guidelines, the life-saving appliances and arrangements required by this Section shall meet the detailed specifications set out in "Chapter III of the International Convention for the Safety of Life at Sea (SOLAS)", the "International Life-Saving Appliance Code" as defined in Chapter III of SOLAS and be approved by the Administration.*

3. *Before giving approval to life-saving appliances and arrangements, the Administration shall ensure that such life-saving appliances and arrangements:*

.1 *are tested to confirm that they comply with the requirements of this Section, in accordance with the "Revised Recommendation on Testing of Life-Saving Appliances", adopted by the International Maritime Organization by resolution MSC 81(70); or*

.2 *have successfully undergone, to the satisfaction of the Administration, tests which are substantially equivalent to those specified in those recommendations.*

4. *Before giving approval to novel life-saving appliances or arrangements, the Administration shall ensure that such appliances or arrangements:*

.1 *provide safety standards at least equivalent to the requirements of this Section and have been evaluated and tested in accordance with the "Code of Practice for the Evaluation, Testing and Acceptance of Prototype Novel Life-Saving Appliances and Arrangements" (LSA Code), adopted by the International Maritime Organization by resolution A.520(13); or*

.2 *have successfully undergone, to the satisfaction of the Administration, evaluation and tests which are substantially equivalent to those recommendations.*

5. *Before accepting life-saving appliances and arrangements that have not been previously approved by the Administration, the Administration shall be satisfied that life-saving appliances and arrangements comply with the requirements of this Section.*

6. *Except where otherwise provided in these Guidelines, life-saving appliances required by this Section for which detailed specifications are not included in the LSA Code shall be to the satisfaction of the Administration.*

7. *The Administration shall require life-saving appliances to be subjected to such production tests as are necessary to ensure that the life-saving appliances are manufactured to the same standard as the approved prototype.*

8. *Procedures adopted by the Administration for approval shall also include the conditions whereby approval would continue or would be with-drawn.*

9. *The Administration shall determine the period of acceptability of life-saving appliances which are subject to deterioration with age. Such life-saving appliances shall be marked with a means for* *determining their age or the date by which they shall be replaced.*

10. *For the purposes of this Section, unless expressly provided otherwise:*

.1 *"Embarkation ladder" is the ladder provided at survival craft embarkation stations to permit safe access to survival craft after launching.*

.2 *"Embarkation station" is the place from which a survival craft is boarded. An embarkation station may also serve as an assembly station, provided there is sufficient room, and the muster station activities can safely take place there.*

.3 *"Float-free launching" is that method of launching a survival craft whereby the craft is automatically released from a sinking craft and is ready for use.*

.4 *"Immersion suit" is a protective suit which reduces the body heat-loss of a person wearing it in cold water.*

.5 *"Inflatable appliance" is an appliance which depends upon non-rigid, gas-filled chambers for buoyancy and which is normally kept uninflated until ready for use.*

.6 *"Launching appliance or arrangement" is a means of transferring a survival craft or rescue boat from its stowed position safely to the water.*

.7 *"Marine evacuation system (MES)" is an appliance designed to rapidly transfer a large number of persons from an embarkation station by means of a passage to a floating plat form for subsequent embarkation into associated survival craft or directly into associated survival craft.*

.8 *"Novel life-saving appliance or arrangement" is a life-saving appliance or arrangement which embodies new features not fully covered by the provisions of this Section but which provides an equal or higher standard of safety.*

.9 *"Rescue boat" is a boat designed to assist and rescue persons in distress and to marshal survival craft.*

.10 *"Retrieval" is the safe recovery of survivors.*

.11 *"Retro-reflective material" is a material which reflects in the opposite direction a beam of light directed on it.*

.12 *"Survival craft" is a craft capable of sustaining the lives of persons in distress from the time of abandoning the craft.*

.13 *"Thermal protective aid" is a bag or suit of waterproof material with low thermal conductance.*

B. Communications

1. *Craft shall be provided with the following radio life-saving appliances:*

.1 *at least three two-way VHF radiotelephone apparatus shall be provided on every passenger WIG craft and on every cargo WIG craft. Such apparatus shall conform to performance standards not inferior to the "Recommendation on Performance Standards for Survival Craft Portable Two-Way VHF Radiotelephone Apparatus", adopted by the International Maritime Organization by resolution A.809(19);*

.2 *at least one radar transponder shall be carried on each side of every passenger WIG craft and of every cargo WIG craft. Such radar transponders shall conform to performance standards not inferior to the "Recommendation on Performance Standards for Survival Craft Radar Transponders for Use in Search and Rescue Operations", adopted by the International Maritime Organization by resolution A.802(19). The radar transponders shall be stowed in such locations that they can be rapidly placed in any one of the liferafts. Alternatively, one radar transponder shall be stowed in each survival craft.*

2. *Craft shall be provided with the following on-board communications and alarm systems:*

.1 *an emergency means comprising either fixed or portable equipment or both for two-way communications between emergency control stations, assembly and embarkation stations and strategic positions on board; and*

.2 *a general emergency alarm system complying with the requirements of paragraph 7.2.1 of the LSA Code to be used for summoning passengers and crew to muster stations and to initiate the actions included in the muster list.*

The system shall be supplemented by either a public address system complying with paragraph 7.2.2 of the LSA Code or other suitable means of communication. The systems shall be operable from the operating compartment.

3. Signalling equipment

.1 *All craft shall be provided with a portable daylight signalling lamp which is available for use in the operating compartment at all times and which is not dependent on the craft's main source of electrical power.*

.2 *Craft shall be provided with not less than 12 rocket parachute flares, complying with the requirements of paragraph 3.1 of the LSA Code, stowed in or near the operating compartment.*

C. Personal Life-Saving Appliances

1. *At least one lifebuoy shall be provided adjacent to each normal exit from the craft, subject to a minimum of two being installed.*

2. *Lifebuoys fitted adjacent to each normal exit from the craft shall be fitted with buoyant lines of at least 30 m in length.*

3. *A lifejacket complying with the requirements of paragraph 2.2.1 or 2.2.2 of the LSA Code of the Convention shall be provided for every person on board the craft and, in addition:*

.1 *a number of lifejackets suitable for children equal to at least 10 % of the number of passengers on board shall be provided or such greater number as may be required to provide a lifejacket for each child;*

.2 *every passenger craft shall carry lifejackets for not less than 5 % of the total number of persons on board. These lifejackets shall be stowed in conspicuous places on deck or at assembly stations;*

.3 *all lifejackets shall be fitted with a light, which complies with the requirements of paragraph 2.2.3 of the LSA Code of the Convention.*

4. *Lifejackets shall be so placed as to be readily accessible and their positions shall be clearly indicated.*

5. *An immersion suit, of an appropriate size, complying with the requirements of regulation III/33 of the Convention shall be provided for every person assigned to crew the rescue boat.*

6. *An immersion suit or anti-exposure suit shall be provided for each member of the crew assigned, in the muster list, to duties in an MES party for embarking passengers into survival craft. These immersion suits or anti-exposure suits need not be required if the craft is constantly engaged on voyages in warm climates where, in the opinion of the Administration, such suits are unnecessary.*

D. Muster List, Emergency Instructions and Manuals

1. *Clear instructions to be followed in the event of an emergency shall be provided for each person on board.*

2. *Muster lists complying with the requirements of regulation III/37 of the Convention shall be exhibited in conspicuous places throughout the craft including the control compartment, engine-room and crew accommodation spaces.*

3. *Illustrations and instructions in appropriate languages shall be posted in public spaces and be conspicuously displayed at muster stations, at other passenger spaces and near each seat to inform passengers of:*

.1 *their assembly station;*

.2 *the essential actions they must take in an emergency;*

.3 *the method of donning lifejackets.*

4. *Every passenger craft shall have passenger assembly stations:*

.1 *in the vicinity of, and which provide ready access for all the passengers to, the embarkation stations unless in the same location; and*

.2 *which have ample room for the marshalling and instruction of passengers.*

5. *A training manual complying with the requirements of* Section 10, B.2.3 *(Training Manual) shall be carried on board.*

E. Operating Instructions

1. *Poster or signs shall be provided on or in the vicinity of survival craft and their launching controls and shall:*

.1 *illustrate the purpose of controls and the procedures for operating the appliance and give relevant instructions and warnings:*

.2 *be easily seen under emergency lighting conditions;*

.3 *use symbols in accordance with "Symbols related to Life-Saving Appliances and Arrangements", adopted by the Organization by resolution A.760(18), as amended by resolution MSC 82(70)*

F. Survival Craft Stowage

1. *Survival craft shall be securely stowed as close as possible to the passenger accommodation and embarkation stations. The stowage shall be such that each survival craft can be safely launched in a simple manner and remain secured to the craft during and subsequent to the launching procedure. The length of the securing lines and the arrangements of the bowsing lines shall be such as to maintain the survival craft suitably positioned for embarkation. The Administrations may permit the use of adjustable securing and/or bowsing lines at exits where more than one survival craft is used. The securing arrangements for all securing and bowsing lines shall be of sufficient strength to hold the survival craft in position during the evacuation process.*

2. *Survival craft shall be so stowed as to permit release from their securing arrangements at or near to their stowage position on the craft and from a position at or near to the operating compartment.*

3. *So far as is practicable, survival craft shall be distributed in such a manner that there is an equal capacity on both sides of the craft.*

4. *The launching procedure for inflatable liferafts shall, where practicable, initiate inflation. Where it is not practicable to provide automatic inflation of liferafts (for example, when the liferafts are associated with an MES), the arrangement shall be such that the craft can be evacuated within the time specified in* Section 3, C.7 *(Exits and means of escape)*

5. *Survival craft shall be capable of being launched and then boarded from the designated embarkation stations in all operational conditions of the displacement mode and also in all conditions of flooding after receiving damage to the extent pre- scribed in* Section 2, D.1.6 *and* D.1.7.

6. *Survival craft launching stations shall be in such positions as to ensure safe launching having particular regard to clearance from the propeller or other propulsion facilities.*

7. *During preparation and launching, the survival craft and the area of water into which it is to be launched shall be adequately illuminated by the lighting supplied from the main and emergency sources of electrical power required by* Section 8, B.2 *(Main source of electrical power) and by* Section 8, B.3 *(Emergency source of electrical power).*

8. *Means shall be available to prevent any discharge of water on to survival craft when launched.*

9. *Each survival craft shall be stowed:*

.1 *so that neither the survival craft nor its stowage arrangements will interfere with the operation of any other survival craft or rescue boat at any other launching station;*

.2 *in a state of continuous readiness;*

.3 *fully equipped; and*

.4 *as far as practicable, in a secure and sheltered position and protected from damage by fire and explosion.*

10. *Every liferaft shall be stowed with its painter permanently attached to the craft and with a float free arrangement complying with the requirements of paragraph 4.1.6 of the LSA Code so that, as far as practicable, the liferaft floats free and, if inflatable, inflates automatically should the WIG craft sink.*

11. *Rescue boats shall be stowed:*

.1 *in a state of continuous readiness for launching in not more than 5 min;*

.2 *in a position suitable for launching and recovery; and*

.3 *so that neither the rescue boat nor its stowage arrangements will interfere with the operation of survival craft at any other launching station.*

12. Rescue boats and survival craft shall be secured and fastened to the deck so that they at least withstand the loads likely to arise due to a defined horizontal collision load for the actual craft and the vertical design load at the stowage position.

G. Survival Craft and Rescue Boat Embarkation and Recovery Arrangements

1. Embarkation stations shall be readily accessible from accommodation and work areas.

2. Evacuation routes, exits and embarkation points shall comply with the requirements of Section 3, C.7 *(Exits and means of escape).*

3. Alleyways, stairways and exits giving access to the muster and embarkation stations shall be adequately illuminated by lighting supplied from the main and emergency source of electrical power required by Section 8, A. *(Electrical Installations).*

4. MES or equivalent means of evacuation shall be provided in order to avoid persons entering the water to board survival craft. Such MES or equivalent means of evacuation shall be so designed as to enable persons to board survival craft in all operational conditions of the displacement mode and also in all conditions of flooding after receiving damage to the extent prescribed in Section 2, D.1.6 *and* 1.7 *(Buoyancy, Stability and Subdivision).*

5. Subject to survival craft and rescue boat embarkation arrangements being effective within the environmental conditions in which the craft is permitted to operate and in all undamaged and pre- scribed damage conditions of trim and heel, where the freeboard between the intended embarkation position and the waterline is not more than 1.5 m, the Administration may accept a system where persons board liferafts directly.

6. Rescue boat embarkation arrangements shall be such that the rescue boat can be boarded and launched directly from the stowed position and recovered rapidly when loaded with its full complement of persons and equipment.

7. A safety knife shall be provided at each MES embarkation station.

H. Line-throwing Appliance

A line-throwing appliance complying with the requirements of paragraph 7.1 of the LSA Code shall be provided.

I. Operational Readiness, Maintenance and Inspections

1. Operational readiness

Before the craft leaves port and at all times during the voyage, all life-saving appliances shall be in working order and ready for immediate use.

2. Maintenance

.1 Instructions for on-board maintenance of life-saving appliances complying with the requirements of regulation 36 of the International Convention for the Safety of Life at Sea (SOLAS) shall be provided and maintenance shall be carried out accordingly.

.2 The Administration may accept, in lieu of the instructions required by .1, a shipboard planned maintenance programme which includes the requirements of regulation III/36 of the SOLAS Convention.

3. Weekly inspection

The following tests and inspections shall be carried out weekly:

.1 all survival craft, rescue boats and launching appliances shall be visually inspected to ensure that they are ready for use;

.2 all engines in rescue boats shall be run ahead and astern for a total period of not less than3 min provided the ambient temperature is above the minimum temperature required for starting the engine;

.3 the general emergency alarm system shall be tested.

4. Monthly inspections

Inspection of the life-saving appliances, including survival craft equipment shall be carried out monthly using the checklist required by regulation III/36.1 of the SOLAS Convention to ensure that they are complete and in good order. A report of the inspection shall be entered in the log-book.

5. Servicing of inflatable liferafts, inflatable lifejackets and inflated rescue boats

Every inflatable liferaft and inflatable lifejacket and MES shall be serviced:

- *at intervals not exceeding 12 months, provided where in any case this is impracticable, the Administration may extend this period by one month;*
- *at an approved servicing station which is competent to service them, maintains proper servicing facilities and uses only properly trained personnel in accordance with the "Recommendation on Conditions for the Approval of Servicing Stations for Inflatable Liferafts", adopted by the Organization by resolution A.761(18).*

6. *All repairs and maintenance of inflated rescue boats shall be carried out in accordance with the manufacturer's instructions. Emergency repairs may be carried out on board the craft; however, permanent repairs shall be effected at an approved servicing station.*

7. Periodic servicing of hydrostatic release units

Hydrostatic release units shall be serviced:

- *at intervals not exceeding 12 months, provided where in any case this is impracticable, the Administration may extend this period by one month;*
- *at a servicing station which is competent to service them, maintains proper servicing facilities and uses only properly trained personnel.*

J. Survival Craft and Rescue Boats

1. *All craft shall carry:*

1.1 *survival craft with sufficient capacity as will accommodate not less than 100 % of the total number of persons the craft is certified to carry, subject to a minimum of two such survival craft being carried;*

1.2 *in addition, survival craft with sufficient aggregate capacity to accommodate not less than 10 % of the total number of persons the craft is certified to carry;*

1.3 *in the event of any one survival craft being lost or rendered unserviceable, sufficient survival craft to accommodate the total number of persons the craft is certified to carry;*

1.4 *at least one rescue boat for retrieving persons from the water.*

1.5 *WIG craft of less than 30 m in length may be exempted from carrying a rescue boat, provided the craft meets all of the following requirements:*

1.5.1 *the craft is arranged to allow a helpless person to be recovered from the water;*

1.5.2 *recovery of the helpless person can be observed from the navigating bridge; and*

1.5.3 *the craft is sufficiently manoeuvrable to close and recover persons in the worst intended conditions.*

1.6 *notwithstanding the provisions of .4 and .5 above, craft shall carry sufficient rescue boats to ensure that, in providing for abandonment by the total number of persons the craft is certified to carry:*

1.6.1 *not more than nine of the liferafts provided in accordance with 1.1 are marshalled by each rescue boat; or*

1.6.2 *if the Administration is satisfied that the rescue boats are capable of towing a pair of such liferafts simultaneously, not more than 12 of the liferafts provided in accordance with 1.1 are marshalled by each rescue boat; and*

1.6.3 *the craft can be evacuated within the time specified in* Section 3, C.8.1 *(Evacuation time).*

2. *Where the Administration considers it appropriate, in view of the sheltered nature of the voyages and the suitable climatic conditions of the in- tended area of operations, the Administration may permit the use of open reversible inflatable liferafts complying with* Annex F *on category A passenger WIG craft as an alternative to liferafts complying with paragraph 4.2 or 4.3 of the LSA Code.*

Section 7

Propulsion and Auxiliary Machinery; Remote Control, Alarm and Safety Systems

A. Documents to be submitted

The following drawings and documents are to be submitted, at least in triplicate[1)] for approval. BKI reserves the right to ask for supplementary copies, if deemed necessary in particular cases.

Further documentation may be required, if deemed necessary by BKI.

1. Propulsion machinery systems

– Plans showing the general arrangement of the machinery installation together with all drawings of parts and installations subject to testing, to the extent specified in the relevant sections of Rules of Machinery Installations, Volume III are to be submitted, before the start of manufacture.

– Plans and drawings showing the design and arrangement of transmission components such as shaftings, couplings, clutches and gears in propulsion, manoeuvring and lifting devices.

– Plans showing the design and arrangement of propulsion devices.

– The drawings must contain all the data necessary for approval. Where necessary, strength calculations according to recognised calculation procedures and descriptions of the plant are to be submitted.

– Maintenance and inspection charts showing intervals and specifying tasks to be carried out.

– Once the documents submitted have been approved by BKI they are binding. Subsequent modifications require BKI's approval before being put into effect.

2. Auxiliary machinery systems

– Machinery arrangement plan showing the layout of machinery components such as engines, fans, heat exchangers, generators, switchboards, pumps, excluding pipes, valves and accessories.

– Maintenance and inspection charts showing intervals and specifying tasks to be carried out.

Drawings of:

– Tank arrangement for fuel and other flammable fluids

– Fuel systems (bunkering, transfer and service)

– Lubricating oil systems, including storage and distribution

– Hydraulic Systems

– Cooling water systems (seawater and fresh water)

– Starting arrangement for propulsion engines

– Exhaust gas systems

– Bilge pumping and drainage systems

– Air, overflow and sounding pipes

– Ballast systems

– Sanitary systems

– Fittings on side and bottom

– Arrangement of remote controlled valves

– Ventilation Systems for machinery spaces and other technical spaces

The drawings or accompanying lists are to include the following particulars:

– Outside diameters and wall thickness of pipes

– Materials for pipes, valves and fittings

– Type and capacity of pumps

– Type of pipe connection, flexible hose assemblies and expansion elements

– Maximum working pressures

– Temperature ranges

– Equipment list

3. Remote control, alarm and safety systems

– Layout diagrams showing the location of individual components, input and output devices, control cabinets and interconnection lines between the components

– Wiring and piping diagrams including details of their material and connecting units

[1)] For Indonesia Flag ship in quadruplicate (one for Indonesian Government)

– Plans and specifications showing the working principles of the system with comprehensive description

– List of instruments stating name of manufacturers, types, working ranges, set points and application with regard to their environmental conditions

– Plans of control and monitoring panels with details on their instrumentation and control devices

– List of operating values of machinery and limits for alarm and safety action threshold

– Diagrams of electric and non-electric power supply

– System analysis of programmable electronic systems including hardware configuration algorithms

– Plan for verification and validation in accordance with IEC 1508, if applicable

B. Machinery Systems

1. General

1.1 The machinery, associated piping systems and fittings relating to main machinery and auxiliary power units shall be of a design and construction adequate for the service for which they are intended. They shall be so installed and protected as to reduce any danger to persons on board to a minimum, due regard being paid to moving parts, hot surfaces and other hazards. The design shall pay regard to the materials used in the construction, the purpose for which the equipment is intended, the working conditions to which it will be subject and the environmental conditions on board.

1.2 All surfaces with temperatures exceeding 220 °C where impingement of flammable liquids may occur as a result of a system failure shall be insulated. The insulation shall be impervious to flammable liquids and vapours.

1.3 Means shall be provided to ensure that the machinery can be brought into operation from the dead craft condition without external aid.

1.4 All parts of machinery, hydraulic, pneumatic and other systems and their associated fittings which are under internal pressure shall be subjected to appropriate tests including a pressure test before being put into service for the first time.

1.5 Provision shall be made to facilitate cleaning, inspection and maintenance of main propulsion and auxiliary machinery.

1.6 The reliability of machinery installed in the craft shall be adequate for its intended purpose.

1.7 BKI may accept machinery, which does not show detailed compliance with the Rules, if it has been used satisfactorily in a similar application, provided that:

– the design, construction, testing, installation and prescribed maintenance are adequate for its use in a marine environment; and

– an equivalent level of safety will be achieved and can be demonstrated.

1.8 Information such as is necessary to ensure that machinery can be installed correctly regarding such factors as operating conditions and limitations shall be made available by the manufacturers.

1.9 Main propulsion machinery and all auxiliary machinery essential to the propulsion and the safety of the craft shall, as fitted in the craft, be designed to operate in all modes of operation when the craft is upright and when inclined at any angle of list up to and including 15° either way under static conditions and 30° under dynamic conditions (rolling) either way and simultaneously inclined by dynamically (pitching) 20° by bow or stern. BKI may permit deviation from these angles, taking into consideration the type, size and service conditions of the craft.

1.10 In addition, machinery as stated in 1.9 shall be capable of continuous operation under the vertical aerodynamic accelerations according to the v-n diagram required in Section 3, B.4.

1.11 All pressure vessels and associated piping systems should be of a design and construction adequate for the purpose intended and should be so in- stalled and protected as to minimize danger to persons on board. In particular, attention should be paid to the materials used in the construction and the working pressures and temperatures at which the item will operate and then need to provide an adequate margin of safety over the stresses normally produced in service. Every pressure vessel and associated piping systems should be fitted with adequate means to prevent over-pressures in service and be subject to a hydraulic test before being put into service, and where appropriate at subsequent specified intervals, to a pressure suitably in excess of the working pressure.

1.12 Arrangements shall be provided to ensure that, in the event of failure in any liquid cooling system, such failure is rapidly detected and alarmed and means instituted to minimize the effects of such failures on machinery supplied by the system.

2. Engine (general)

2.1 All engines to be fitted into WIG craft are subject to drawing approval and type approval test by BKI Head Office.

2.2 WIG craft shall be fitted with gas turbines or diesel engines as power sources. Other means of power generation need to be agreed in advance by BKI on a case by case basis. The requirements for these sources will be stipulated depending on the particular application.

2.3 The engines and their essential auxiliaries shall be fitted with adequate safety monitoring and control devices in respect of speed, temperature, pressure and other operational functions. Control of the machinery shall be from the operating compartment. The machinery installation shall be suitable for operation as in an unmanned machinery space, in accordance with Part E of chapter II-1 of the IMO International Convention for the Safety of Life at Sea (SOLAS), as amended, including automatic fire detection system, remote machinery instrumentation and alarm system.

2.4 The engines shall be protected against over-speed, loss of lubricating oil pressure, loss of cooling medium, high temperature, malfunction of moving parts and overload. Safety devices shall not cause complete engine shutdown without prior warning, except in cases where there is a risk of complete breakdown or explosion. Such safety devices shall be capable of being tested.

2.5 At least two independent means of stopping the engines quickly from the operating compartment under any operating conditions shall be available. Duplication of the actuator fitted to the engine shall not be required.

2.6 The major components of the engine shall have adequate strength to withstand the thermal and dynamic conditions of normal operation. The engine shall not be damaged by a limited operation at a speed or at temperatures exceeding the normal values but within the range of the protective devices.

2.7 The design of the engine shall be such as to minimise the risk of fire or explosion and to enable compliance with the fire precaution requirements of Section 5 (Fire safety).

2.8 Provision shall be made to drain all excess fuel and oil to a safe position so as to avoid a fire hazard.

2.9 Provision shall be made to ensure that, whenever practical, the failure of systems driven by the engine shall not unduly affect the integrity of the major components.

2.10 The ventilation arrangements in the machinery spaces shall be adequate under all envisaged operating conditions. Where appropriate, arrangements shall ensure that enclosed engine compartments are forcibly ventilated to the atmosphere before the engine can be started.

2.11 Any engines shall be so installed as to avoid excessive vibration within the craft.

3. Gas turbines

3.1 Gas turbines shall be designed to operate in the marine environment and shall be free from surge or dangerous instability throughout its operating range up to the maximum steady speed approved for use. The turbine installation shall be arranged to ensure that the turbine cannot be continuously operated within any speed range where excessive vibration, stalling, or surging may be encountered.

3.2 The gas turbines shall be designed and installed such that any reasonably probable shedding of compressor or turbine blades will not endanger the craft, other machinery, occupants of the craft or any other persons.

3.3 Requirements of 2.6 shall apply to gas turbines in respect of fuel which might reach the interior of the jet pipe or exhaust system after a false start or after stopping.

3.4 Turbines shall be safeguarded as far as practicable against the possibility of damage by ingestion of contaminants from the operating environment. Information regarding the recommended maximum concentration of contamination shall be made available. Provision shall be made for preventing the accumulation of salt deposits on the compressors and turbines and, if necessary, for preventing the air intake from icing.

3.5 In the event of a failure of a shaft or weak link, the broken end shall not hazard the occupants of the craft, either directly or by damaging the craft or its systems. Where necessary, guards may be fitted to achieve compliance with these requirements.

3.6 Each engine shall be provided with an emergency over speed shutdown device connected, where possible, directly to each rotor shaft.

3.7 Where an acoustic enclosure is fitted which completely surrounds the gas generator and the high pressure pipes containing flammable liquids, a fire detection and extinguishing system shall be provided.

3.8 Details of the manufacturers' proposed automatic safety devices to guard against hazardous conditions arising in the event of malfunction in the turbine installation shall be provided.

3.9 The manufacturers shall demonstrate the soundness of the casings. Intercoolers and heat exchangers shall be hydraulically tested on each side separately.

4. Diesel engines for main propulsion and essential auxiliaries

4.1 Any main diesel propulsion system shall have satisfactory torsional vibration and other vibrational characteristics verified by individual and combined torsional and other vibration analyses for the system and its components from power unit through to propulsor.

4.2 All external high-pressure fuel delivery lines between the high-pressure fuel pumps and fuel nozzles shall be protected with a jacketed tubing system capable of containing fuel from a high-pressure line failure. The jacketed tubing system shall include a means for collection of leakages and arrangements shall be provided for an alarm to be given of a fuel line failure.

4.3 The lubrication system and arrangements shall be efficient at all running speeds, due consideration being given to the need to maintain suction and avoid the spillage of oil in all conditions of list and trim and degree of motion of the craft.

4.4 Arrangements shall be provided to ensure that visual and audible alarms are activated in the event of either lubricating oil pressure or lubricating oil level falling below a safe level, considering the rate of circulation of oil in the engine. Such events shall also cause automatic reduction of engine speed to a safe level, but automatic shutdown shall only be activated by conditions leading to a complete breakdown, fire or explosion.

5. Transmissions

5.1 The transmission shall be of adequate strength and stiffness to enable it to withstand the most adverse combination of the loads expected in service, such as normal operation loads, vibration loads, inertia and gyroscopic loads, without exceeding acceptable stress levels for the materials concerned. The mountings of transmission components shall not break loose under the loads arising from the collision accelerations of Section 3, C.3. (Design acceleration levels) and C.4.5 (Accommodation design).

5.2 The design of shafting, bearings and mounts shall be such that hazardous whirling and excessive vibration cannot occur at any speed up to 105 % of the shaft speed attained at the designed overspeed trip setting of the prime mover.

5.3 Lateral vibrations

Resilient Mountings are to be designed such that no significant resonances can occur within the operational speed range.

5.4 The strength and fabrication of the transmission shall be such that the probability of hazardous fatigue failure under the action of the repeated loads of variable magnitude expected in service is extremely remote throughout its operational life. Compliance shall be demonstrated by suitably conducted tests, and by designing for sufficiently low stress levels, combined with the use of fatigue resistant materials and suitable detail design.

5.5 Where a clutch is fitted in the transmission, normal engagement of the clutch shall not cause excessive stresses in the transmission or driven items. Inadvertent operation of any clutch shall not produce dangerously high stresses in the transmission or driven item.

5.6 Provision shall be made such that a failure in any part of the transmission, or of a driven component, will not cause damage, which might hazard the craft or its occupants.

5.7 Where failure of lubricating fluid supply or loss of lubricating fluid pressure could lead to hazardous conditions, provision shall be made to enable such failure to be indicated to the operating crew in adequate time to enable them as far as practicable to take the appropriate action before the hazardous condition arises.

6. Propulsion and lift devices

6.1 Propulsion devices are those which directly provide the propulsive thrust and include machinery items and any associated ducts, vanes, scoops and nozzles, the primary function of which is to contribute to the propulsive thrust.

6.2 The propulsion devices shall be of adequate strength and stiffness. The design data, calculations and trials, where necessary, shall demonstrate the ability of the device to withstand the loads which can arise during the operations for which the craft is to be certified, so that the possibility of catastrophic failure is extremely remote.

6.3 The design of propulsion devices shall pay due regard to the effects of allowable corrosion, electrolytic processes between different metals, erosion or cavitation which may result from operation in environments in which they are subject to spray, salt, sand, etc.

6.4 The design data and testing of propulsion devices shall pay due regard, as appropriate, to any pressure which could be developed as a result of a duct blockage, to steady and cyclic loadings, to loadings due to external forces and to the use of the devices in manoeuvring and reversing and to the axial location of rotating parts.

6.5 Appropriate arrangements shall be made to ensure that:

– ingestion of birds or foreign matter is minimized;

– the possibility of injury to personnel from shafting or rotating parts is minimized.

C. Auxiliary Systems

1. General

1.1 Fluid systems shall be designed and arranged as to assure a safe and adequate flow of fluid at a prescribed flow rate and pressure under all conditions of craft operation. The probability of a failure or a leakage in any one fluid system causing damage to the electrical system, a fire or an explosion hazard shall be extremely remote. Attention shall be directed to the avoidance of flammable liquid impingement on hot surfaces in the event of leakage or fracture of the pipe.

1.2 The maximum allowable working pressure in any part of the fluid system shall not be greater than the design pressure, having regard to the allowable stresses in the materials. Where the maximum allowable working pressure of a system component, such as a valve or a fitting, is less than that computed for the pipe or tubing, the system pressure shall be limited to the lowest of the component maximum allowable working pressures. Every system which may be exposed to the pressures higher than the system's maximum allowable working pressure shall be safeguarded by appropriate relief devices.

1.3 Tanks shall be pressure-tested to a pressure that will assure a safety margin in excess of the working pressure of the item. The test on any storage tank or reservoir shall take into account any possible static head in the overflow condition and the dynamic forces arising from craft motions as defined in Section 3, C.3. Piping systems for compressed air and flammable liquids with a design pressure greater than 0.35 MPa are to be subjected to a hydraulic pressure test of 1.5 times the design pressure prior to installation on board. After assembly on board all piping systems covered by these Rules are to be subjected to a tightness test. The stipulated pressure tests are to be carried out in the presence of a Surveyor.

1.4 Materials used in piping systems shall be compatible with the fluid conveyed and be selected giving due regard to the risk of fire. Non-metallic piping material may be permitted in certain systems provided the integrity of the hull and watertight decks and bulkheads is maintained, in accordance with the International Maritime Organization Resolution A. 753 (18) "Guidelines for the Application of Plastic Pipes on Ships".

1.5 Flexible hose assemblies and expansion bellows used in fuel, lubricating oil, hydraulic oil, bilge, fresh and sea water cooling systems shall be of approved type, in accordance with the "List of Type Tested Products and of Approved Products, Procedures and Manufactures" issued by Biro Klasifikasi Indonesia.

1.6 Pipe connections shall be designed in accordance with Rules for Machinery Installations, volume III.

2. Arrangement of fuel, lubricating oil and other flammable oil

2.1 The provisions of Section 5, B.2.2 are to be applied.

2.2 Pipe connections of fuel, lubricating oil and other flammable oil lines shall be screened or otherwise suitably protected to avoid, as far as practicable, oil spray or oil leakages onto hot surfaces, into machinery air intakes or other sources of ignition. The number of joints in such piping systems shall be kept to a minimum, in accordance with the IMO MSC/Circular 647 "Guidelines to minimize leakages from flammable liquid systems".

2.3 Fuel, lubricating oils and other flammable oils shall not be carried forward of public spaces and crew accommodation.

2.4 Fuel system arrangements

In a craft in which fuel is used, the arrangements for the storage, distribution and utilization of the fuel shall be such as to ensure the safety of the craft and persons on board and shall at least comply with the following provisions:

.1 As far as practicable, all parts of the fuel system containing oil under pressure exceeding 0.18 N/mm² shall not be placed in a concealed position such that defects and leakage cannot readily be observed.

The machinery spaces in way of such parts of the fuel system shall be adequately illuminated.

.2 The ventilation of machinery spaces and spaces housing fuel tanks shall be sufficient under all normal conditions to prevent accumulation of oil vapour.

.3 Location of fuel tanks shall be in accordance with Section 5, E.2.3

.4 No fuel tank shall be situated where spillage or leakage there from can constitute a hazard by falling on heated surfaces. Reference is made to the fire safety requirements in Section 5, E.2.3.

.5 Fuel pipes shall be fitted with cocks or valves in accordance with Section 5, E.2.4.

.6 Every fuel tank shall, where necessary, be provided with a save-all or gutters to catch any fuel which may leak from such tanks.

.7 For ascertaining the amount of fuel contained in any fuel tank type approved level transmitters are to be provided. In passenger craft such means shall not require penetration below the top of the tank. Their failure or overfilling of the tanks shall not permit release of fuel.

Level transmitters arranged within tanks containing fuel with a flash point of 60 °C and below are to be of (electrical) certified safe type. The amount of fuel is to be displayed at the operating compartment.

.8 Provision shall be made to prevent over pressure in any oil tank or in any part of the fuel system, including the filling pipes. Any relief valves and air or overflow pipes shall discharge to a safe position and, for fuel of flash point less than 43 °C shall terminate with flame arresters of approved type.

.9 Fuel pipes and their valves and fittings shall be of steel or of other equivalent material. Hose assemblies and compensators shall only be used where necessary for compensation of relative movement. They shall be as short as possible and are to be visible and accessible at all times.

.10 Non-metallic flexible hose assemblies and compensators are to be of flame resistant type, in accordance with the IMO Resolution A. 753 (18) "Guidelines for the Application of Plastic Pipes on Ships".

2.5 Lubricating oil arrangements

.1 The use of sight-flow glasses in lubricating systems is permitted provided they are shown by test to have a suitable degree of fire resistance;

.2 lubricating oil storage tanks with a capacity of less than 500 *l* may be permitted without remote operated valves as required in 2.4.5.

2.6 Arrangements for other flammable oils

The arrangements for storage, distribution and utilization of other flammable oils employed under pressure in power transmission systems, control and activating systems and heating systems shall be such as to ensure the safety of the craft and persons on board. In locations where sources of ignition are present, such arrangements shall at least comply with the provisions of 2.4.4 and 2.4.7 and with the provisions of 2.4.8 and 2.4.9 in respect of strength and construction.

2.7 Arrangements within machinery spaces

In addition to the requirements of 2.1 to 2.6, fuel and lubricating oil systems arranged within machinery spaces shall comply with the following:

.1 Where fuel tanks are filled automatically or by remote control, means shall be provided to prevent overflow spillages. Other equipment which treats flammable liquids automatically shall have arrangements to prevent overflow spillages.

.2 In cases where fuel with a flash point 60 °C and lower will be used the requirements of Section 4, B.2 and Para. 7.3 in this Section are to be observed.

3. Bilge pumping and drainage systems

3.1 Arrangements shall be made for draining of any watertight compartment other than the compartments intended for permanent storage of liquid. Where, in relation to particular compartments, drainage is considered not necessary, drainage arrangements may be omitted, but it shall be demonstrated that the safety of the craft will not be impaired.

3.2 Spaces situated above the water level in the worst anticipated damage conditions may be drained directly overboard through scuppers fitted with non-return valves.

3.3 Where bilge pumping is necessary for the safety of the craft, compartments are to be emptied by a dedicated system with power bilge pumps of adequate capacity. Where the failure of any single bilge pump reduces the capacity of the system

Inadequately, a back-up system shall be readily available such that propulsion or manoeuvrability of the vessel is not significantly impaired.

3.4 The bilge pumping system shall be capable of operation under all possible values of list and trim after the craft has sustained the postulated damage in Section 2, D.1.6 and 1.7. The bilge pumping system shall be so designed as to prevent water flowing from one compartment to another and from sea into the craft. The necessary valves and pumps for operation of the bilge system arranged for any compartment shall be capable of being operated from the operating compartment. All valves in connection with the bilge pumping arrangements shall be provided for manual operation and shall be in positions which are accessible under ordinary circumstances.

3.5 Any unattended compartment for which bilge pumping arrangements are required shall be provided with a bilge alarm.

3.6 Bilge pumps may be used for other duties such as fire fighting or general service but not for pumping fuel or other flammable liquids.

3.7 Sea inlet valves shall be capable of being closed from the operating compartment.

3.8 All bilge suction piping up to the connection to the pumps shall be independent of other piping.

4. Ballast systems

4.1 Water ballast shall not be carried in tanks intended for fuel. Where this is not practicable oily-water separating equipment shall be fitted. Alternative means such as discharge to shore facilities provided for disposing of the oily-water ballast may be accepted. The provisions of this paragraph are without prejudice to the provisions of the International Convention for the Prevention of Pollution from Ships in force.

4.2 Where a fuel transfer system is used for ballast purposes, the system shall be isolated from any water ballast system and meet the requirements for fuel systems and the International Convention for the Prevention of Pollution from Ships in force.

5. Cooling systems

The cooling arrangements provided shall be adequate to maintain all lubricating and hydraulic fluid temperatures within manufacturers' recommended limits during all operations for which the craft is to be certified.

6. Air intake systems

Arrangements shall provide sufficient air to the power source and must give adequate protection against salt, water, leaking fuel and industrial accumulation such as dust, sand etc. Means are to be provided against damage due to ingress of foreign matter.

7. Ventilation systems

7.1 Machinery spaces shall be adequately ventilated so as to ensure that when machinery therein is operating at full power in the worst intended conditions, an adequate supply of air is maintained to the spaces for the safety and comfort of personnel and the operation of the machinery.

7.2 Auxiliary machinery spaces shall be adequately ventilated appropriate for the purpose of those spaces. The ventilation arrangements shall be adequate to ensure that the safe operation of the craft is not put at risk.

7.3 The ventilation of machinery spaces and spaces housing fuel tanks shall be sufficient for all operating conditions to prevent accumulation of fuel or oil vapour.

7.4 In cases where fuel with a flash point below 35 °C is used the following explosion protection measures are to be provided:

.1 In enclosed or semi-enclosed spaces housing petrol engines or petrol containers, all electrical equipment shall be of a certified safe type (Ignition protected, explosion-group IIA, temperature class T3). This includes electric starters and generators.

.2 If it is not possible to use fully ignition protected appliances, the machinery space is to be pre-ventilated by mechanically driven fans of the extraction type.

.3 Prior to starting of the engine at least a five times air exchange of the machinery space is to be ensured. An interlock between the fan motor and the petrol engine starter shall be provided to ensure that the engine can only be started after pre-ventilation of the machinery space as specified above.

.4 If the ventilation fans described under 7.4.2 are installed in the machinery space, they must be ignition protected. Electric motors for fans not ignition protected shall be fitted outside of the machinery space and outside of the ventilation duct.

8. Exhaust systems

8.1 All exhaust systems shall be adequate to assure correct functioning of the machinery and that operation of the craft is not put at risk. The exhaust system shall be designed and constructed to ensure the safe discharge of exhaust gases without fire hazard. Overheating of adjacent components and penetrated craft structure is to be prevented.

8.2 All parts with surface temperatures above 220 °C are to be effectively insulated with non-combustible materials. The insulation must be such that oil or fuel cannot penetrate into insulation material.

8.3 Exhaust systems shall be so arranged as to minimize the intake of gases into manned spaces, air-conditioning systems, and engine intakes. The view from the control station shall not be impaired by exhaust gases. Exhaust systems shall not discharge into air cushion intakes.

8.4 Pipes through which exhaust gases are discharged through the hull in the vicinity of the water-line shall be fitted with erosion/corrosion resistant shut-off flaps or other devices on the shell or pipe end and acceptable arrangements made to prevent water flooding the space or entering the engine exhaust manifold.

8.5 Gas turbine engine exhausts shall be arranged so that hot exhaust gases are directed away from areas to which personnel have access, either on board the craft or in the vicinity of the craft when berthed.

9. Drinking water and sanitary installations

9.1 A drinking water tank shall be separated from tanks containing liquids other than drinking water, ballast water, distillate or feed water.

9.2 Drinking water pipe lines shall not be connected to pipe lines carrying other media and shall not be laid through tanks which do not contain drinking water.

9.3 When installing sanitary equipment, the official regulations applicable to the area of operation shall be observed.

9.4 A sewage tank shall be fitted with a vent line leading into the open, a flushing connection and a high level alarm.

D. Remote Control, Alarm and Safety Systems

1. Definitions

1.1 "Remote control systems" comprise all equipment necessary to operate units from a control position where the operator cannot directly observe the effect of these actions.

1.2 "Back-up control systems" comprise all equipment necessary to maintain control of essential functions required for the craft's safe operation when the main control systems have failed or malfunctioned.

2. General

2.1 Failure of any remote or automatic control systems shall initiate an audible and visual alarm and shall not prevent normal manual control.

2.2 Manoeuvring and emergency controls shall permit the operating crew to perform the duties for which they are responsible in a correct manner without difficulty, fatigue or excessive concentration.

2.3 The operation of the remote control from the craft's operating station shall be so designed and constructed that under normal conditions it does not require the operator's particular attention of the details of the machinery.

The remote control system design consisting of steel cable links or equivalent, is to be submitted to BKI for special consideration.

If evidence on the required reliability cannot be given by relevant documentation, the equipment has to be subject to an approval according to the Rules of BKI.

2.4 Remote control systems for propulsion machinery and directional and height control shall be equipped with back-up systems controllable from the operating station.

2.5 The machinery including propellers, jets, flaps or other means, which affect the speed and direction of thrust, must be controllable from the craft's operating station in all WIG craft modes of operation.

2.6 In principle, the remote control is to be performed by a single control device for each independent propulsion unit with automatic performance of all associated services including, where necessary, means of preventing overload and prolonged running in critical speed ranges of the propulsion unit.

In cases, where multiple propulsion units are designed to operate simultaneously, the command on their controls shall be designed for the possibility of being connected in one control device, in order to select individual or common control of the units, as necessary for the appropriate mode of operation.

Movement of the control device shall take place in the same direction as the desired motion of the craft.

2.7 Each control position shall be provided with means to indicate, which of them is in control.

2.8 After restoration of normal conditions following an automatic shut-down, the machinery shall not start inadvertently before the control device has been reset to stop. Following an automatic slow-down– if provided – the propulsion of the craft shall not accelerate inadvertently before the control device has been reset to the actual step of speed, to which the power of the propulsion had been decreased. Alternatively other arrangements may be provided for the operator to consciously admit starting or acceleration of propulsion machinery.

Remote starting of a propulsion unit is to be automatically inhibited, if conditions exist which may hazard the machinery, e.g. clutch engaged, shut-down activated, etc.

2.9 The power for the control system has to be supplied from the same source, which supplies the essential services for the propulsion units. The control system of each propulsion unit shall have its individual source of power.

2.10 The closed loop system including governor and plant must be stable under all conditions. This may be checked during sea trials for normal and misfiring conditions, clutch-in procedures, etc.

3. Emergency controls

The craft's operating station shall be provided with controls for use in an emergency to:

.1 activate fixed fire-extinguishing systems;

.2 close ventilation openings and stop ventilating machinery supplying spaces covered by fixed fire-extinguishing systems, if not incorporated in .1;

.3 shut off fuel supplies to machinery in main and auxiliary machinery spaces;

.4 disconnect all electrical power sources from the normal power distribution system (the operating control shall be guarded to reduce the risk of inadvertent or careless operation); and

.5 stop main engine(s) and auxiliary machinery.

Unless it is considered impracticable a single failure of the emergency controls shall not have an inadvertent effect on the system which it serves. In case of such a failure an alarm shall be given in the operating compartment.

The stopping device for main engine(s) shall be independent from the remote control system at the craft's operating station.

4. Alarm system

4.1 Alarm systems shall be provided with means, which announce at the craft's operating compartment, by visual and audible means, malfunction or unsafe conditions. Alarms shall be maintained until they are accepted and the visual indications of individual alarms shall remain until the fault has been corrected, should the alarm automatically reset to the normal operating condition. If an alarm has been accepted and a second fault occurs before the first is rectified, the audible and visual alarms shall operate again. Alarm systems shall incorporate a test facility.

4.2 Alarms giving indication of conditions requiring immediate action shall be distinctive and in full view of crew members in the operating compartment, and shall be provided for the following:

.1 activation of a fire detection system;

.2 total loss of normal electrical supply;

.3 overspeed of main engines;

.4 thermal runaway of any permanently installed nickel-cadmium battery.

4.3 Alarms with a visual display distinct from that of emergency alarms shall indicate conditions requiring action to prevent degradation to an unsafe condition. These shall be provided for at least the following:

.1 exceeding the limiting value of any craft, machinery or system parameter other than engine overspeed;

.2 failure of normal power supply to powered directional or height control devices;

.3 failure of compass system;

.4 low level of a fuel tank contents;

.5 fuel oil tank overflow;

.6 extinction of side or stern navigation lights;

.7 low level of contents of any fluid reservoir the contents of which are essential for normal craft operation;

.8 failure of any connected electrical power source;

.9 failure of any ventilation fan installed for ventilating spaces in which inflammable vapours may accumulate;

.10 engine fuel line failure as required by Section 7, B.4.2.

4.4 With reference to item 4.3.1, in particular the machinery has to be monitored in the scope as listed in Tables 7.1 to 7.5.

4.5 All warnings required by .4.1 and .4..2 shall be provided at all stations at which control functions may be exercised.

4.6 The alarm system shall meet appropriate constructional and operational requirements for required alarms in accordance with the "Code on Alarms and Indicators" adopted by the International Maritime Organization by resolution A.686(17).

4.7 Equipment monitoring the passenger, cargo and machinery spaces for fire and flooding shall, so far as is practicable, form an integrated sub-centre incorporating monitoring and activation controls for all emergency situations. This sub-centre may require feed-back instrumentation to indicate that actions initiated have been fully implemented.

5. Safety system

5.1 Where arrangements are fitted for overriding any automatic shutdown system for the main propulsion machinery in accordance with Section 7, B.2.4, they shall be such as to preclude inadvertent operation. When a shutdown system is activated, an audible and visual alarm shall be given at the operating station. Means shall be provided to override the automatic shutdown except in cases where there is a risk of complete breakdown or explosion.

5.2 In case of need, the master may have a possibility to cancel the safety devices which could have caused the propelling machinery to stop (except for the over speed one). Control of this device is to be such as to preclude inadvertent operation; the indication “safety devices off” shall be clearly visible.

5.3 Safety systems are to be designed as far as practicable to be independent of the alarm and control system and their power supply, such that a failure or malfunction in these systems will not prevent the safety system from operating. Safety systems including their power supply should be separate for each propulsion unit.

5.4 Electrical circuits of safety systems for propulsion machinery and essential systems, which in case of their failure have sudden effect on the availability of the propulsion, directional and height control of the craft shall be such, that a single failure in the system cannot result, as far as practicable, in a loss of propulsion, directional and height control. The electrical circuits of safety systems for other machinery, which have no sudden effect on the availability of the propulsion and steering, may be designed as suitable for their purpose with the most effective protection of the machinery.

5.5 The power for the safety system should be supplied from the main source of electrical power. Provisions shall be made for supplying power uninterrupted to the safety system for at least 15 minutes following a failure of the craft's main source of electrical power. The electric and pneumatic supplies are to be monitored.

6. Stand by systems

6.1 Where stand-by units are required, they should start-up automatically

– on failure of operational units

– to preserve stored energy resources (e.g. compressed air)

– following restoration of the power supply after an interruption to service due to a failure of the craft's main source of electric power

– on operational demand, if auxiliary machinery are operated in staggered service.

6.2 The threshold for activation of the stand-by system should be such, that normal operation is restored before the safety system is activated.

6.3 The changeover to a stand-by unit due to a fault is to be signaled visually and audibly. However, an alarm must not be tripped in the case of machinery installations with auxiliary machines driven mechanically from the propulsion plant where the stand-by machines start up automatically in the lower speed range.

6.4 Sets which have suffered a malfunction and have shut down automatically may only be provided for restart after manual reset independent of the alarm acknowledgement.

Table 7.1 Propulsion engines

Parameter	Alarm level	Remark
Lubricating oil pressure	low	
Lubricating oil temperature inlet	high	
Differential pressure across lubricating oil filter	high	
Pressure or flow of cooling water	low	
Temperature of cooling water outlet	high	
Level in cooling water expansion tank	low	
Deviation of each cylinder from average of exhaust gas temperature, or Exhaust gas temperature of each cylinder	high low + high	if cylinder power above 130 kW
Exhaust gas temperature after turbocharger	high	if cylinders not monitored individually
Pressure of fuel oil to engine	low	if supplied by electrical pumps
Temperature of fuel oil to engine	low + high	if heated
Pressure of control air	low	
Pressure of starting air	low	
Safety system	failure	

Table 7.2 Propulsion gas turbines

Parameter	Alarm level	Remark
Lubricating oil pressure	low	
Lubricating oil temperature	high	
Differential pressure across lubricating oil filter	high	
Bearing temperature	high	
Exhaust gas temperature outlet	high	
Vibrations	high	
Axial displacement	high	
Combustion/ignition	failure	
Hydraulic service oil pressure	low	
Safety system	failure	

Table 7.3 Transmission, shaft gears

Parameter	Alarm level	Remark
Lubricating oil pressure to gears	low	
Lubricating oil temperature of gears with slide bearings	high	
Servo oil pressure of gears and transmissions	low	
Thrust bearing temperature	high	
Stern tube temperature	high	

Table 7.4 Main diesel generator sets

Parameter	Alarm level	Remark
Lubricating oil pressure	low	
Pressure of flow of cooling water	low	
Temperature of cooling water outlet	high	
Starting power capacity	low	
Voltage	low	
Frequency	low	
Over speed	tripped	
Safety system	failure	

Table 7.5 Miscellaneous

Parameter	Alarm level	Remark
Remote control of propulsion	failure	
Safety system of each machinery	tripped	
Override of safety system	activated	
Power of alarm system	failure	
Electrical non-essential consumers	tripped	
Insulation resistance	low	
Emergency controls	failure	
Fire alarm system	failure	
Stand-by function of auxiliaries	start	
Machinery spaces bilge level	high	2 sensores at least for each machinery space
Fuel oil service tank temperature	high	if heated above flash-point
Gas detection system	high (20 % UEG)	if fuel flash-point ≤ 61 °C
Height control system	failure	
Pre-ventilation of machinery room	failure	if fuel flash-point ≤ 61 °C
Directional control system	failure	if non mechanic

Section 8

Electrical Installations, Navigation Equipment and Radiocommunications

A. Documents to be submitted

The following drawings and documents are to be submitted, at least in triplicate[1)] for approval. The Society reserves its right to ask for supplementary copies, if deemed necessary in particular cases.

1. Electrical installations

– Single line general diagram of the electrical power generating and distribution with description of the operation modes (including emergency installation).

– Data sheets of generators

– Data sheets and circuit diagrams of UPS units

– Electrical power balance

– List of circuits including, for each supply and distribution circuit, data concerning the nominal current, the cable type, length and cross section, nominal and setting values of the protective and control devices.

– Diagram of the main cable runs showing cables for duplicated equipment and the location of the main and emergency switchboards.

– Functional circuit diagram of the main switchboard and a list with the main components.

– Functional circuit diagram of the emergency switchboard and a list with the main components.

– Diagram of the most important section boards.

– Diagram of the supply, monitoring and control systems of the steering gear.

– Diagram of the supply, monitoring and control systems of the propulsion plant.

– Diagram of the general alarm system.

– Diagram of the navigation-light switchboard.

– Electrical diagram of the engines fire alarm and fire extinguishing system.

– Electrical diagram of the compartments fire alarm and fire extinguishing system.

– Electrical diagram of the explosion suppression in the tank ventilation.

– Diagram and description of the altitude measuring unit.

– Diagram of the public address system or other inter-communication systems.

– Electrical diagram of the ice and rain protection system.

– Description of the lightning protection in case of plastic steering rudders and flaps.

– Diagram of EMC measurements for essential electronic installations.

– Diagrams of switchboards for control, indication and alarm of watertight doors.

– Diagram of the emergency lighting system

2. Navigation equipment

– Visibility from the control station in the operating compartment.

– Arrangement of navigation equipment in the operating compartment.

– Configuration of consoles, including equipment.

– List of equipment, including type, manufacturer and type approval authority.

– Block diagrams showing the functionally connected appliances, as well as their power supply.

3. Radiocommunication

– Antenna drawings (location of antennas and EPIRB).

– Radio equipment arrangement drawings (layout on control station).

– Cable diagrams (antenna connections, power connection, interface connection).

– List of radio equipment (product description, type, manufacturer, approval no., approval authority).

– Battery capacity calculation for the reserve source of energy (with list of connected consumers and their load).

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1) For Indonesia Flag ship in quadruplicate (one for Indonesian Government)

B. Electrical Installations

1. General

1.1 Electrical installations shall be such that:

.1 all electrical auxiliary services necessary for maintaining the craft in normal operation and habitable conditions will be ensured without recourse to the emergency source of electrical power;

.2 electrical services essential for safety will be ensured under various emergency conditions; and

.3 the safety of passengers, crew and craft from electrical hazards will be ensured.

1.2 The electrical system shall be designed and installed so that the probability of the craft being at risk of failure of a service is extremely remote.

1.3 Where loss of particular essential service would cause serious risk to the craft, the service shall be fed by at least two independent circuits fed in such a way that no single failure in the electrical supply or distribution systems would affect both supplies.

1.4 The securing arrangements for heavy items, i.e. accumulator batteries, shall prevent excessive movement during the accelerations according to Section 3, C.3. (Design acceleration levels).

1.5 Precautions shall be taken to minimize risk of supplies to essential and emergency services being interrupted by the inadvertent or accidental opening of switches or circuit-breakers.

1.6 Electronic equipment essential for propulsion, directional and height control purposes shall be approved and installed according to a recognised EMC Standard.

2. Main source of electrical power

2.1 A main source of electrical power of sufficient capacity to supply all those services mentioned in 1.1 shall be provided. The main source of electrical power shall consist of at least two generators sup- plying two main circuits.

2.2 The capacity of these generators shall be such, that in the event of any one generator being stopped or failing in the ground-effect mode, it will still be possible to supply those services necessary to provide the normal operational conditions of propulsion, directional and height control in ground-effect and safety. Minimum comfortable conditions of habitability shall also be ensured which include at least adequate services for heating, domestic refrigeration, mechanical ventilation, and sanitary and fresh water.

2.3 The arrangements of the craft's main source of electrical power shall be such that the services referred to in 1.1.1 can be maintained regardless of the speed of the propulsion machinery.

2.4 One source of power independent from the main propulsion plant shall be capable of providing the electrical services necessary to start the main propulsion plant from dead craft condition.

2.5 Where charging units or converters constitute an essential part of the electrical supply system required by this Section, the system shall be so arranged as to ensure the same continuity of supply as is stated in 2.2.

2.6 A main electric lighting system, which shall provide illumination throughout those parts of the craft normally accessible to and used by passengers and crew shall be supplied from the main source of electrical power.

2.7 The main switchboard shall be located in a dry space with a minimum risk of fire.

2.8 The connection of generators and any other duplicated equipment shall be equally divided between the two main circuits. The generators shall operate in single operation. Equivalent arrangements may be permitted to the satisfaction of BKI.

2.9 Separation and duplication of electrical supply shall be provided for duplicated consumers of essential services. During normal operation the systems may be connected to the same power-bus, but facilities for easy separation shall be provided. Each system shall be able to supply all equipment necessary to maintain the control of propulsion, steering, stabilization, navigation, lighting and ventilation, and allow starting of the largest essential electric motor at any load. Automatic load-dependent disconnection of non-essential consumers may be allowed.

2.10 Main generators installed outside of the hull shall be equipped with a suitable protective device, which in the event of a short circuit inside the generator or in the cable between generator and circuit breaker opens the breaker and de-energizes the generator.

3. Emergency source of electrical power

3.1 An emergency and a transitional source of electrical power shall be provided that meets the requirements detailed in 3.12.

3.2 The emergency source of electrical power, transitional source of electrical power, emergency switchboard and emergency lighting switchboard shall be located above the waterline in the final condition of damage as referred to in Section 2, D.1.6 and D.1.7 (Buoyancy, Stability and Subdivision), operable in that condition and readily accessible.

3.3 The location of the emergency source of electrical power and the transitional source of emergency power, the emergency switchboard and the emergency electrical lighting switchboards in relation to the main source of electrical power and the main switchboard shall be such as to ensure that a fire or other casualty in spaces containing the main source of electrical power, will not interfere with the supply, control, and distribution of emergency electrical power. As far as practicable, the space containing the emergency source of electrical power, the transitional source of emergency electrical power and the emergency switchboard shall not be contiguous to the boundaries of main machinery spaces or those spaces containing the main source of electrical power or the main switchboard.

3.4 Distribution systems shall be so arranged that the feeders from the main and emergency sources are separated both vertically and horizontally as widely as practicable.

3.5 The emergency source of electrical power may be an accumulator battery which shall be capable of:

.1 carrying the emergency electrical load without recharging while maintaining the voltage of the battery throughout the discharge period within 12 % above or below its nominal voltage;

.2 automatically connecting to the emergency switchboard in the event of failure of the main source of electrical power; and

3.6 An indicator shall be mounted in a suitable space at the craft's operating compartment to indicate when the batteries constituting either the emergency source of electrical power or the transitional source of emergency electrical power referred to in 4. are being discharged.

3.7 The emergency switchboard shall be supplied during normal operation from one main circuit by an interconnection feeder which shall be adequately protected at the main switchboard against overload and short circuit and which shall be disconnected automatically at the emergency switchboard upon failure of the main source of electrical power. If one of the main circuits fulfils the requirements for the emergency switchboard (except when item 5. applies), no additional emergency switchboard will be required.

3.8 In order to ensure ready availability of the emergency source of electrical power, arrangements shall be made where necessary to disconnect automatically non-emergency circuits from the emergency switchboard to ensure that power shall be available to the emergency circuits.

3.9 The emergency accumulator battery shall be so designed and arranged as to ensure that it will function at full rated power when the craft is upright and when the craft has a list or trim in accordance with Section 7, B.1.9 (Machinery, General) including any damage cases considered in Section 2, D.1.6. and 1.7 (Damage stability), or is in any combination of angles within those limits.

3.10 Where accumulator batteries are installed to supply emergency, back up or engine start-up services, provisions shall be made to charge them in situ from a reliable on-board supply. Charging facilities shall be designed to permit the supply of services, regardless of whether battery is on charge or not. Means shall be provided, by which the batteries on board can be checked before each journey (e.g. minimum allowable voltage at a laid down load). The risk of overcharging or overheating the batteries shall be minimized. Means for efficient air ventilation shall be provided. A total number of two battery systems and two chargers for all battery services except for radio installations shall be sufficient.

3.11 The electrical power available shall be sufficient to supply all those services that are essential for safety in an emergency, due regard being paid to such services as may have to be operated simultaneously. The emergency source of electrical power shall be capable, having regard to starting currents and the transitory nature of certain loads, of supplying simultaneously at least the following services for the periods specified hereinafter, if they depend upon an electrical source for their operation:

3.12 The emergency source of power shall be capable of supplying simultaneously the following services:

.1 for a period of 12 h, the "not under command" lights; and

.2 for a period of 5 h emergency lighting:

- at the stowage positions of life-saving appliances;
- at all escape routes, such as alleyways, stairways, embarkation points, etc;
- in the public spaces;
- in the machinery spaces and main emergency generating spaces, including their control positions;
- in control stations;

- at the stowage positions for firemen's outfits; and
- at the steering gear;

.3 for a period of 5 h;

- main navigation lights, except for "not under command" lights;
- electrical internal communication equipment for announcements for passengers and crew required during evacuation;
- fire-detection and general alarm system and manual fire alarms,
- remote control devices of fire-extinguishing systems, if electrical; and
- craft navigational and radio facilities as set out in C.2.2 (Navigational equipment) and D.3 (Radio installations).
- essential electrically powered instruments and controls for propulsion machinery, if alternate sources of power are not available for such devices;

.4 for a period of 4 h of intermittent operation:

- the daylight signalling lamps, if they have no independent supply from their own accumulator battery; and
- the craft's whistle, if electrically driven;

.5 for a period of 30 min or 60 min, in accordance with the structural fire protection times (A 30 or A 60) of the separating bulkhead(s) between passenger space(s) and engine room: the fire-extinguisher systems required by Section 4.

.6 for a period of 30 min: any watertight doors, required by Section 2, F.6. to be power operated, together with their indicators and warning signals

.7 for a period of 10 min: power drives for directional and height control devices, including those required to direct thrust forward and astern, unless there is a manual alternative acceptable to BKI as complying with Section 4, B. (Directional and height control systems).

3.13 Provisions shall be made for the periodic testing of the complete emergency system, including the emergency consumers required by 3.12 and shall include the testing of automatic starting arrangements.

3.14 Distribution systems shall be so arranged that fire in any main vertical zone will not interfere with services essential for safety in any other such zone. This requirement will be met if main and emergency feeders passing through any such zone are separated both vertically and horizontally as widely as is practicable.

4. Starting arrangements for generator driving engines

4.1 The generator driving engines shall be capable of being readily started in their cold condition at a temperature of 0 °C. If this is impracticable, or if lower temperatures are likely to be encountered, provisions shall be made for heating arrangements to ensure ready starting of the engines.

4.2 The main generator driving engines shall be equipped with starting devices with a stored energy capability of at least six consecutive starts. The source of stored energy shall be protected to preclude critical depletion by the automatic starting system. A second source of energy shall all be provided for an additional six starts.

5. Directional and height control

5.1 Where directional and height control of a craft is essentially dependent on the continuous availability of electric power, it shall be served by at least three independent circuits, two of which shall be fed from the main circuit and one from the emergency source of electric power including the transitional source, both located in such a position as to be unaffected by fire or flooding affecting the main source of power. Failure of either supply shall not cause any risk to the craft or passengers during switching to the alternative supply. These circuits shall be provided with short circuit protection and an overload alarm.

5.2 Protection against excess current may be provided, in which case it shall be for not less than twice the full load current of the motor or circuit so protected, and shall be arranged to accept the appropriate starting current with a reasonable margin. Where three-phase supply is used, an alarm shall be provided in a readily observed position in the craft's operating compartment that will indicate failure of any one of the phases.

5.3 Where such systems are not essentially dependent on the continuous availability of electric power but at least one alternative system, not dependent on the electric supply, is installed, then the electrically powered or controlled system may be fed by a single circuit protected in accordance with 5.2.

5.4 The provisions of Section 4, B. (Directional and height control systems) for power supply of the directional control systems and stabilization systems of the craft shall be met.

6. Precautions against shock, fire and other hazards of electrical origin

6.1 Exposed metal parts of electrical machines or equipment which are not intended to be live but which are liable under fault conditions to become live shall be earthed unless the machines or equipment are:

.1 supplied at a voltage not exceeding 55 V direct current or 55 V, root-mean-square between conductors; auto-transformers shall not be used for the purpose of achieving this voltage; or

.2 supplied at a voltage not exceeding 250 V by safety isolating transformers supplying only one consuming device; or

.3 constructed in accordance with the principle of double insulation.

6.2 All electrical apparatus shall be so constructed and so installed as not to cause injury when handled or touched in the normal manner.

6.3 Main and emergency switchboards shall be so arranged as to give easy access, as may be needed, to apparatus and equipment, without danger to personnel. The sides and the rear and, where necessary, the front of switchboards shall be suitably guarded. Exposed live parts having voltages to earth exceeding a voltage to be specified by BKI shall not be installed on the front of such switchboards. Where necessary, non-conducting mats or gratings shall be provided at the front and rear of the switchboard.

6.4 When a distribution system, whether primary or secondary, for power, heating or lighting, with no connection to earth is used, a device capable of continuously monitoring the insulation level to earth and of giving an audible and visual indication of abnormally low insulation values shall be provided. For limited secondary distribution systems BKI may accept a device for manual checking of the insulation level.

6.5 Cables and wiring

6.5.1 Power cables and control or communication cables as well as cables of each main supply and emergency supply shall be installed on separated cable runs. Power and control cables for emergency consumers shall be fire-resistant when they pass through fire risk areas. Where, for safety reasons, a system has duplicated supply- and/or control cables, the cable routes shall be placed as far apart as possible. All metal sheaths and armour of cables shall be electrically continuous and shall be earthed.

6.5.2 All electric cables and wiring external to equipment shall be at least of a halogen-free flame-retardant type and shall be so installed as not to impair their original flame-retarding properties. Where necessary for particular applications, BKI may permit the use of special types of cables such as radio frequency cables, which do not comply with the fore- going. Cables, cores and wires are normally to be approved by BKI, on the basis of IEC 92-standards or LN, MIL-W. Use of other cables is subject to special considerations by BKI, and to appropriate and satisfactory testing.

Where cables are bunched, provisions are to be made to limit fire propagation. This may comprise by either of the following methods:

– use of cables successfully tested according to IEC Report 332.3, or to an equivalent testing procedure,

– fitting of suitable fire stop screens,

– use of an appropriate protective coating.

6.5.3 Cables and wiring serving essential or emergency power, lighting, internal communications or signals shall, so far as practicable, be routed clear of machinery spaces and their casing and other high fire risk areas. Where practicable, all such cables shall be run in such a manner as to preclude their being rendered unserviceable by heating of the bulkheads that may be caused by a fire in an adjacent space.

6.5.4 Where cables which are installed in hazardous areas introduce the risk of fire or explosion in the event of an electrical fault in such areas, special precautions against such risks shall be taken to the satisfaction of BKI.

6.5.5 Cables and wiring shall be installed and supported in such manner as to avoid chafing or other damage.

6.5.6 Terminations and joints in all conductors shall be so made as to retain the original electrical, mechanical, flame-retarding and, where necessary, fire-resisting properties of the cable.

6.6 Circuits

6.6.1 Each separate circuit shall be protected against short circuit and against overload, except as permitted in 5. or where BKI may exceptionally otherwise permit. For supplies with 400 cycles the impedance of the circuits shall be observed.

6.6.2 The rating or appropriate setting of the overload protective device for each circuit shall be permanently indicated at the location of the protective device.

6.6.3 When the protective device is a fuse it shall be placed on the load side of the disconnect switch serving the protected circuit.

6.6.4 Lighting fittings shall be so arranged as to prevent temperature rises which could damage the cables and wiring, and to prevent surrounding material from becoming excessively hot.

6.6.5 All lighting and power circuits terminating in a bunker or cargo space shall be provided with a multiple-pole switch outside the space for disconnecting such circuits.

6.7 Accumulator compartments

6.7.1 Accumulator batteries shall be suitably housed, and compartments used primarily for their accommodation shall be properly constructed and efficiently ventilated.

6.7.2 Electrical or other equipment, which may constitute a source of ignition of flammable vapours, shall not be permitted in these compartments.

6.7.3 The following additional provisions from .1 to .7 shall be met, and provisions from .8 to .13 shall be met also for non-metallic craft:

.1 The electrical distribution voltages throughout the craft may be either direct current or alternating current and shall not exceed:

- 500 V for power, cooking, heating, and other permanently connected equipment; and
- 250 V for lighting, internal communications and receptacle outlets.

.2 For electrical power distribution earthed systems with non hull-return are acceptable. Where applicable, the provisions of Section 5, 2.7.3 and 2.7.4 (Fire Safety, Fluid and other flammable fluid tanks and systems) shall also be met.

.3 Effective means shall be provided so that voltage may be cut off from each and every circuit and sub-circuit and from all apparatus as may be necessary to prevent danger.

.4 Electrical equipment shall be so designed that the possibility of accidentally touching live parts, rotating or moving parts as well as heated surfaces which might cause burns or initiate fire is minimized.

.5 Electrical equipment shall be adequately secured. The probability of fire or dangerous consequences arising from damage to electrical equipment shall be reduced to an acceptable minimum.

.6 The rating or appropriate setting of the over-load protective device for each circuit shall be permanently indicated at the location of the protection device.

.7 Where it is impracticable to provide electrical protective devices for certain cables supplied from batteries, e.g. within battery compartments and in engine starting circuits, unprotected cable runs shall be kept as short as possible and special precautions shall be taken to minimise risk of faults, e.g. use of single core cables with additional sleeve over the insulation of each core, with shrouded terminals.

.8 In order to minimise the risk of fire, structural damage, electrical shock and radio interference due to lightning strike or electrostatic discharge, all metal parts of the craft shall be bonded together, in so far as possible in consideration of galvanic corrosion between dissimilar metals, to form a continuous electrical system, suitable for the earth return of electrical equipment and to connect the craft to the water when water-borne. The bonding of isolated components inside the structure is not generally necessary, except in fuel tanks.

.9 Each pressure refueling point shall be provided with a means of bonding the fuelling equipment to the craft.

.10 Metallic pipes capable of generating electrostatic discharges, due to the flow of liquids and gases, shall be bonded so as to be electrically continuous throughout their length and shall be adequately earthed.

.11 Primary conductors provided for lightning discharge currents shall have a minimum cross section of 50 mm^2 in copper or equivalent surge carrying capacity in aluminium.

.12 Secondary conductors provided for the equalisation of static discharges, bonding or equipment, etc., but not for carrying lightning discharges shall have a minimum cross-section of 5 mm^2 copper or equivalent surge current carrying capacity in aluminium.

.13 The electrical resistance between bonded objects and the basic structure shall not exceed 0.05 Ohms except where it can be demonstrated that a higher resistance will not cause a hazard. The bonding path shall have sufficient cross-sectional area to carry the maximum current likely to be imposed on it without excessive voltage drop.

Note:

The following parts C, D and E of this Section of the Rules is not applicable for the purpose of classification. The certification of navigational equipment, radiocommunication and operating compartment layout falls under the responsibility of the Administration and is based on international safety requirements. Presently, no such international requirements exist for WIG craft. The IMO Sub-Committee on Design and Equipment, however, has established a Correspondence Group dealing with Guidelines for the Safety of WIG craft. The following text reflects the current state as per 31.01.2001 of deliberations in the Correspondence Group related to Category A passenger WIG craft of type A and cargo WIG craft of type A, and is here reproduced for information only. It may serve as a basis for discussions with the Administration. The current status can be provided by BKI.

C. Navigational Equipment

1. General

1.1 *The information derived from the navigational equipment to be displayed as required by 2.1 shall be installed so that the indicators are visible from each operating station.*

1.2 *The navigational equipment and its installation shall be to the satisfaction of the Administration.*

2. Navigational Equipment

2.1 *Every WIG Craft shall be provided with:*

.1 *means to determine the craft's heading;*

.2 *means suitable for use at all times during the intended voyage to establish and update the craft's position by automatic means;*

.3 *means to measure and display the available depth of water in displacement mode. This requirement can be omitted, if the design of the craft shows an extreme shallow draught;*

.4 *WIG craft intended for operation in conditions with restricted visibility as defined in COLREG or during dark periods should be provided with means to determine and display the range and bearing of radar transponders operating in the X-band and of other surface craft, obstructions, buoys, shorelines and navigational marks to assist in navigation and in collision avoidance;*

.5 *WIG craft intended for operation in conditions with restricted visibility as defined in COLREG or during dark periods should be provided with an obstacle detection and avoidance system which is capable of:*

- *processing data of the craft's position, heading and speed;*
- *locating all floating and semi-submerged obstacles relative to the craft position and the predicted course;*
- *calculating a collision avoiding trajectory, including crash stop;*
- *giving alarm to the operating compartment crew, if a collision-avoiding manoeuvre is necessary;*
- *displaying the obstacle by the night vision equipment;*
- *displaying the collision-avoiding trajectory in the operating compartment;*
- *allowing the master to confirm or override the proposed trajectory;*
- *transferring the trajectory data to the automatic heading/track control systems; and*
- *starting the collision avoiding manoeuvre.*

.6 *A craft not equipped with radar installation and encountering conditions of restricted visibility en route shall revert to the skimming or displacement mode and proceed with safe speed.*

.7 *means to measure and indicate speed and distance over ground;*

.8 *means to enhance the night vision, when operational conditions justify the provision of such equipment;*

.9 *means to automatically control and keep to a heading and/or straight track;*

.10 *means to determine and display pitch, roll and actual altitude above sea level;*

.11 *means to determine and display the rate of turn;*

.12 *a searchlight, which is controllable from the operating station; and*

.13 *a signalling lamp.*

2.2 *At least the navigational equipment required by 2.1, item 1., 2., 10. and 11., shall be supplied by a source of energy independent of the craft's electrical system.*

D. Radiocommunication

1. General

1.1 *Every WIG craft, while at sea, shall be provided with appropriate facilities for continuous radio-communications capable of complying the functional requirements, prescribed in 2., to participate in the GMDSS and complying with the requirements of 3.*

1.2 *The radiocommunication equipment and its installation shall be to the satisfaction of the Administration.*

2. Functional requirements

2.1 *Every WIG craft shall be provided with a radio installation capable of, unless exempted, complying with the following functional requirements throughout its intended voyage:*

.1 *transmitting ship-to-shore distress alerts by at least two separate and independent means, each using a different radiocommunication service;*

.2 *of receiving shore-to-ship distress alerts;*

.3 *of transmitting and receiving ship-to-ship alerts;*

.4 *of transmitting and receiving search and rescue coordinating communications;*

.5 *of transmitting and receiving on-scene communication;*

.6 *of transmitting and receiving signals for homing;*

.7 *of transmitting and receiving maritime safety information;*

.8 *of transmitting and receiving general radio-communications; and*

.9 *of transmitting and receiving bridge-to-bridge communications.*

3. Radio installations

3.1 *The radio installation, unless exempted, shall:*

.1 *be so located that no harmful interference of mechanical, electrical or other origin affects its proper use, and so as to ensure electromagnetic computability and avoidance of harmful interaction with other equipment and systems;*

.2 *be so located as to ensure the greatest possible degree of safety and operational availability;*

.3 *be protected against harmful effects of water, extremes of temperature and other adverse environmental conditions;*

.4 *be provided with reliable, permanently arranged electrical lighting, independent of the main sources of electrical power, for the adequate illumination of the radio controls for operating the radio installation;*

.5 *be clearly marked with the call sign, the ship station identity and other codes as applicable for the use of the radio installation; and*

.6 *be supplied by a reserve source of energy independent of the craft's electrical system.*

4. Radio equipment

4.1 *Every WIG craft shall be provided with radio equipment suitable for the intended voyages within the sea areas, which are established by the Governments off its coasts (IMO Res. A.801(19) – "Provisions of Radio services for the GMDSS" and COMSAR/Circ.8 – GMDSS master plan).*

4.2 *The radio equipment to be provided shall comply, unless exempted, with the requirements of "Chapter IV of the International Convention for the Safety of Life at Sea (SOLAS)" for the GMDSS sea areas.*

4.3 When operational conditions justify, craft shall be provided with an Automatic Identification System (AIS).

E. Operating Compartment Layout

1. Principles relating to design and arrangement of systems

1.1 *The systems and equipment in the operating compartment shall be designed and arranged for:*

.1 *facilitating the tasks to be performed by the master in making full appraisal of the situation and in navigating the WIG craft safely under all operational conditions;*

.2 *promoting effective and safe compartment resource management;*

.3 *enabling the master to have convenient and continuous access to essential information which is presented in a clear and unambiguous manner, using standardized symbols and coding systems for controls and displays;*

.4 *indicating the operational status of automated functions and integrated components, systems or sub-systems;*

.5 *allowing for expeditious, continuous and effective information processing and decision making by the master;*

.6 *preventing or minimizing excessive or unnecessary work and any conditions or distractions on the bridge which may cause fatigue or interfere with the vigilance of the master; and*

.7 *minimizing the risk of human error, and detecting such error if it occurs, through monitoring and alarm systems, in time for the master to take appropriate action.*

1.2 *Field of vision from and design and arrangement of the operating compartment shall be in line with requirements of the International Convention for the Safety of Life at Sea (SOLAS), 1974, as amended and to the satisfaction of the Administration.*

Section 9

Handling, Controllability and Performance; Anchoring, Towing and Berthing

A. Documents to be submitted

– A detailed drawing, showing all the elements necessary for the evaluation of the equipment number (EN) of the craft, is to be submitted together with the calculations of the EN according to B.5.2.

–. The anchoring equipment to be fitted on each craft is to be specified.

– Windlass, brake and stopper are subject to approval by BKI. The relevant documentation is to be submitted.

– Description of the anchoring procedure and associated equipment.

– Description of the towing procedure and associated equipment.

– Description of the berthing procedure and associated equipment.

B. Handling, Controllability and Performance

1. General

The operational safety of the craft in normal service conditions and in equipment failure situations shall be documented and verified by full-scale tests of the prototype craft. The objective of tests is to determine information to be included in the craft operating manual in relation to:

.1 operating limitations;

.2 procedures for operation of the craft within the limitations;

.3 actions to be taken in the event of prescribed failure; and

.4 limitations to be observed for safe operation subsequent to prescribed failures.

Operational information shall be available on board for guidance, or craft shall have an instrument system for on-line check of operational performance which shall be approved by the Administration taking into account the standards for the processing and presentation of measurements developed by the International Maritime Organization.

As a minimum, the system shall measure accelerations in three axes close to the craft longitudinal centre of gravity.

2. Proof of compliance

2.1 The information on controllability and manoeuverability in the operating manual shall include the characteristics under 4. and the list of parameters of the worst intended conditions affecting the controllability and manoeuverability according to 5. and the performance data verified in accordance with Annex D (Definitions, requirements and compliance criteria related to operational and safety performance).

2.2 The information on operating limitations which shall be contained in the route operational manual shall include the characteristics under 2.1, 5.4 and 5.5.

3. Weight and centre of gravity

Compliance with each of the handling, controllability and performance requirements shall be established for all combinations of weight and centre of gravity position significant for the operational safety in the range of weights up to the all up weight.

4. Effect of failure

The effect of any likely failure in handling and control devices, services or components (e.g. power operation, power assistance, trimming and stability augmentation) shall be assessed in order that a safe level of craft operation can be maintained. Effects of failure identified as being critical according to Section 11 shall be verified during prototype tests.

5. Controllability and manoeuvrability

5.1 Instructions to crew members shall be provided in the craft operating manual regarding required actions and craft limitations subsequent to prescribed failures.

5.2 It is necessary to ensure that the effort required to operate the controls in the worst intended conditions is not such that the person at the control will be unduly fatigued or distracted by the effort necessary to maintain the safe operation of the craft.

5.3 The craft shall be controllable and be capable of performing those manoeuvres essential to its safe operation up to the critical design conditions.

5.4 When determining the operating limitations of a craft, particular attention shall be paid to the following aspects during normal operation and during and subsequent to failures:

.1 turning in ground effect mode

.2 automatic heading/track control

.3 stopping (from cruise speed in ground effect mode to a complete stop in displacement mode) in normal and emergency conditions;

.4 stability in transitional, skimming and take-off/landing modes about three axes and in heave;

.5 stability in ground effect mode about three axes and in height above ground;

5.5 The term "Turning" in 5.4.1 is defined as follows:

"Turning" is the rate of change of direction of a craft at cruise speed in specified wind and sea conditions.

6. Change of operating mode

There shall be no unsafe change in the stability, controllability or attitude of the craft during transition from one type of operating mode to another. Information on change in the behaviour characteristics of the craft during transition shall be available to the master.

7. Acceleration and deceleration

It shall be demonstrated that the worst likely acceleration or deceleration of the craft, due to any likely failure, emergency stopping procedures or other likely causes, would not hazard the persons on the craft. Reference is made to Section 1, B.10.

8. Speeds

Safe maximum speeds shall be determined, taking account of the limitations from Section 3, C.3.1, modes of operation, wind force and direction and the effects of possible failures of any one propulsion system over calm and rough water including the worst intended conditions.

9. Minimum depth of water

The minimum depth of water and other appropriate information required for operations in displacement mode shall be determined.

10. Night operation

The schedule of tests shall include sufficient operation to evaluate the adequacy of internal and external lighting and visibility under conditions of normal and emergency electrical power supply during service, cruising and docking manoeuvres.

C. Anchoring, Towing and Berthing

1. General

1.1 A primary assumption made in this Section is that WIG will only need an anchor for emergency purposes.

1.2 The arrangements for anchoring, towing and berthing and the local craft structure, the design of the anchor, towing and berthing arrangements and the local craft structure shall be such that risks to persons carrying out anchoring, towing or berthing procedures are kept to a minimum.

1.3 Non-crush and antiskid areas of adequate size shall be arranged, if areas of the deck and the upper surface of the wings need to be accessible for the handling of the craft (anchoring, towing, berthing). If required by the structure of the craft, accessible and non-accessible areas shall be highlighted by suitable optical marks, similar to aviation practice.

1.4 The anchoring gear comprises of anchors, anchor cables and windlasses or other equivalent equipment for laying out and heaving up the anchors and for keeping the craft at anchor.

1.5 All anchoring equipment, towing bitts, mooring bollards, fairleads cleats and eyebolts shall be so constructed and attached to the hull that in use up to design loads, the watertight integrity of the craft will not be impaired. Design loads and any directional limitations assumed shall be listed in the Craft Operating Manual.

1.6 Windlasses (and chain stoppers, if provided) shall comply with BKI Rules for Machinery Installations, Volume III, Section 14, D.

1.7 If the owner of a craft intends to install an anchor equipment of a lower standard than required by Table 9.1, such equipment is subject to approval by BKI in each individual case. In the Class Certificate and in the Register the Class Notation "Special Equipment" will be assigned to such craft.

1.8 Only anchoring equipment is considered for the purposes of classification.

2. Anchoring

2.1 A WIG shall be provided with at least one bow anchor with its associated cable or cable and warp and means of recovery. Every craft shall be provided with adequate and safe means for releasing the anchor, its cable and warp.

2.2 Good engineering practice shall be followed in the design of any enclosed space containing the anchor recovery equipment to ensure that persons using the equipment are not put at risk. Particular care shall be taken with the means of access to such spaces, the walkways, the illumination and protection from the cable and the recovery machinery.

2.3 Adequate arrangements shall be provided for two-way voice communication between the operating compartment and persons engaged in dropping, weighing or releasing the anchor.

2.4 The anchoring arrangements shall be such that any surfaces against which the cable may chafe (for example, hawse pipes and hull obstructions) are designed to prevent the cable from being damaged and fouled. Adequate arrangements shall be provided to secure the anchor under all operational conditions.

2.5 The craft shall be protected so as to minimize the possibility of the anchor and cable damaging the structure during normal operation.

3. Towing

3.1 Adequate arrangements shall be provided to enable the craft to be towed in the critical design conditions. Where towage is to be from more than one point a suitable bridle shall be provided.

3.2 The towing arrangements shall be such that any surfaces against which the towing cable may chafe (for example, fairleads), is of sufficient radius to prevent the cable being damaged when under load.

3.3 The maximum permissible speed at which the craft may be towed shall be included in the operating manual.

3.4 Each WIG shall be provided with a device suitable for fastening the towing line to or near the stem. Suitable devices are:

– eyebolts fastened to the stem of small boats

– two belaying cleats either side on the foredeck, wings, sponsons or winglets

– a bollard mounted amidships on the foredeck Bollards, cleats and eyes are to be positively joined to the hull.

4. Berthing

4.1 Where necessary, suitable fairleads, bitts and mooring ropes shall be provided.

4.2 Adequate storage space for mooring lines shall be provided such that they are readily available and secured against the high relative wind speeds and accelerations which may be experienced.

4.3 Any WIG craft shall have on board at least two securing lines. The length of line shall be 1.5 times the length of the craft.

4.4 It is recommended that each WIG craft be equipped with 4 securing lines.

5. Equipment

5.1 General

5.1.1 The anchoring equipment required in 5.2 is intended for temporary, occasional mooring of a craft within a harbour or sheltered area when the craft is awaiting berth, tide, etc.

5.1.2 The equipment is therefore not designed to hold a craft off fully exposed coasts in rough weather or to stop a craft which is moving or drifting. In this condition the loads on the anchoring equipment increase to such a degree that its components may be damaged or lost owing to the high energy forces generated, particularly in large craft.

5.1.3 For craft where frequent anchoring in open sea is expected, the owner's and shipyard's attention is drawn to the fact that anchoring equipment should be provided in excess of the requirements of these Rules.

5.1.4 The anchoring equipment required in 5.2 is designed to hold a WIG in good holding ground in conditions such as to avoid dragging of the anchor. In poor holding ground the holding power of the anchors will be significantly reduced.

5.1.5 The Equipment Number (EN) formula for anchoring equipment, as stipulated in 5.2, is based on an assumed current speed of 2.5 m/s, wind speed of 25 m/s and a scope of cable equal to 10, the scope being the ratio between length of cable paid out and water depth.

5.1.6 For small craft, with a length $L \leq 25$ m, some partial exemption from these Rules may be accepted especially for what concerns anchor operation; in particular, where proper and safe anchor operation is assured, hand-operated machinery and/or absence of hawse pipe may be accepted.

5.1.7 For anchors weighing less than 25 kg no windlass is to be provided. In this case however

– the craft shall be equipped with suitable means to fasten the anchor rope (or anchor chain; and

– a driving anchor is to be provided (readily available)

5.2 Equipment number

Each craft is to be provided with an anchor and a relevant steel wire rope according to its equipment number EN. The equipment number is to be calculated as follows:

$$EN = K_M D^{0.67} + 2\, A_{trans}\, C_D + 0.1\, A_{lat}$$

where:

A_{trans} = the projected area, in m², in front view of the WIG

C_D = specific total resistance coefficient of the WIG (if unknown, $C_D = 0.5$)

A_{lat} = the projected area, in m², in profile view of the WIG

$$K_m = \frac{(B_H T)^{0.67} + 2\sum_{i=1}^{n}(B_i T_i)^{0.67}}{\left(B_H T + 2\sum_{i=1}^{n} B_i T_i\right)^{0.67}}$$

n is the number of lateral hulls and/or sponsons on one side of the longitudinal symmetry plane of the WIG

B_i, and T_i are, respectively, the projected breadth and the draught of the mid hull (if any) and of the lateral hulls and/or sponsons/floaters, measured amidships (see Section 1, Fig. 1.2)

5.3 Anchors

5.3.1 Mass of anchors

.1 A "very high holding power anchor" (VHHP) is an anchor having a holding power equal to, at least, four times that of an ordinary anchor. The mass of a VHHP anchor M_{VHHP}, in kg, is not to be less than

$$M_{VHHP} = 0.003\,(EN + 70)^2 - 13.7$$

.2 "High holding power anchors" (HHP), are anchors having a holding power greater than that of an ordinary anchor, may be used.

.3 Normally VHHP or HHP anchors are to be used. Possible use of ordinary anchors would be specially considered by **BKI**.

.4 The actual mass of each anchor may vary within (+ 7, – 3) per cent of the value shown in the table.

.5 The mass of a HHP anchor is to be not less than 1.5 of the mass required for the VHHP anchor it replaces.

5.3.2 Anchor design

.1 Anchors shall have appropriate shape and scantlings and are to be constructed and tested in compliance with BKI-Rules.

.2 A high or very high holding power anchor is to be suitable for use on board without any prior adjustment or special placement on the ground.

.3 For approval and/or acceptance as a high or very high holding power anchor, the anchor is to have a holding power equal, respectively, to at least twice or four times that of an ordinary stockless anchor of the same mass.

5.4 Steel wire ropes for anchors

5.4.1 Anchors are preferably to be used in connection with steel wire ropes whose construction and steel grades are to be in accordance with the requirements of BKI.

5.4.2 The length L_W, in m, of steel wire rope is to be not less than

$$L_W = 0.73\, EN + 49$$

5.4.3 The effective breaking load P_w, in kN, of the steel wire rope is to be not less than

$$P_W = M_{VHHP} + 12$$

5.4.4 The ends of the steel wire ropes shall be jammed or integrated in sleeves, clamps or thimbles. The steel wire shall be connected with the anchor by an end shackle of proven design and of BKI approved type.

5.4.5 A short length of chain cable having scantlings complying with 5.6 may be fitted between the steel wire rope and the bow anchor.

5.5 Synthetic fibre ropes for anchors

5.5.1 Synthetic fibre ropes may be used as an alternative to steel wire ropes provided that the following requirements are complied with:

– Fibre ropes are to be made of polyamide or other equivalent synthetic fibres, excluding polypropylene.

– The length L_f of the synthetic fibre rope is equal to the length of steel wire rope determined by the formula given in 5.4.2.

– The effective breaking load P_f, in kN, of the synthetic fibre rope is to be not less than the following value:

$$P_f = 2.2\,P_W^{0.89}$$

where P_W, in kN, is the required breaking load of the steel wire rope replaced by the synthetic fibre rope.

– The ends of the fibre ropes shall be integrated in a thimble.

– A short length of steel wire rope (chain cable) having scantlings complying with 6.4 (6.6) is to be fitted between the synthetic fibre rope and the bow anchor. The length of this cable part is to be 10 m or the distance from the anchor in its stowed position to the windlass, whichever is the lesser.

5.6 Chain Cables

Chain cables may be used as an alternative to steel wire ropes required in 5.4, provided that the following requirements are complied with:

– Normally grade 2 or grade 3 stud link chain cables are to be used with HHP anchors. In case of VHHP anchors grade 3 chain cables are to be used.

– Proposal for use of grade 1 chain cables connected to ordinary anchors will be specially considered by BKI.

– The length L_{ch} of chain cable may be reduced to:

$$L_{CH} = L_W \frac{900}{(EN + 850)}$$

when $50 < EN < 100$.

– The effective breaking load of the chain cable is to be not less than the required breaking load of the steel wire rope it replaces.

– The method of manufacture of chain cables and the characteristics of the steel used are to be approved by BKI for each manufacturer. The material from which chain cables are manufactured and the completed chain cables them- selves are to be tested in accordance with the appropriate requirements.

– Chain cables are to be made of unit lengths ("shots") of 27.5 m minimum joined together by Dee or lugless shackles.

– Studless short link chain cables may be used provided that:

  – steel grade of the studless chain is to be equivalent to the steel grade of the stud chains it replaces

  – equivalence in strength is to be based on proof load (not on breaking load)

  – the studless chain cable meets the requirements of BKI.

– The proof loads PL and breaking loads BL, in kN, required for the stud (index stud) and studless link (index less) chain cables are given by the following formulae, where d, in mm, is the respective diameter of chain cables:

grade 1: $PL_1 = 6.9\ F'$

$BL_{1,stud} = 9.8\ F'$

$BL_{1,less} = 13.7\ F'$

grade 2: $PL_2 = 9.8\ F'$

$BL_{2,stud} = 13.7\ F'$

$BL_{2,less} = 19.6\ F'$

grade 3: $PL_3 = 13.7\ F'$

$BL_{3,stud} = 19.6\ F'$

$BL_{3,less} = 27.5\ F'$

with $F' = d^2\,(44 - 0.08\,d)\,10^{-3}$

5.7 Attachment pieces

Both attachment pieces and connection fittings for chain cables are to be designed and constructed in such a way as to offer the same strength as the chain cable and are to be tested in accordance with the appropriate requirement.

5.8 Arrangement of anchors and chain cables

5.8.1 The bow anchor, connected to its own cable, is to be so stowed as to always be ready for use.

5.8.2 Hawse pipe is to be of a suitable size and so arranged as to create, as far as possible, an easy lead for the cable and efficient housing for the anchor.

5.8.3 For this purpose chafing lips of suitable form with ample lay-up and radius adequate for the size of the cable are to be provided at the shell and deck. The shell plating at the hawse pipes as well as of the bulb bow is to be reinforced as necessary.

5.9 Windlass

5.9.1 The windlass is to be power driven and suitable for the size of the rope or the chain cable, and is to have the characteristics stated below.

5.9.2 The windlass is to be fitted in a suitable position in order to ensure an easy lead of the cable to and through the hawse pipe; the deck, at the windlass, is to be suitably reinforced.

5.9.3 The windlass is to be able to supply, for at least 30 minutes, a continuous duty pull Pc, in N, corresponding to the grade of the cables, given by the following formulae:

– for grade 2 chain cables: $Pc = 42{,}5\ d^2$
– for grade 3 chain cables: $Pc = 47{,}5\ d^2$

where d is the stud link chain cable diameter of the intended steel grade, in mm.

5.9.4 The windlass unit prime mover is to provide the necessary temporary overload capacity for breaking out the anchor.

5.9.5 The temporary overload capacity or "short term pull" is to be not less than 1,5 times the continuous duty pull Pc for at least two minutes.

5.9.6 The speed in this overload period may be lower than the nominal speed specified in 5.9.7.

5.9.7 The nominal speed of the chain cable when hoisting the anchor and cable may be a mean speed only and is to be not less than 0,15 m/s.

The speed is to be measured over two shots of chain cable (55 m) during the entire trip; the test is to commence with 3 shots (82,5 m) of chain fully submerged, or with the longest practicable submerged chain length where the chain length does not allow 3 shots to be paid out.

5.9.8 The windlass is to be provided with a brake having sufficient capacity to stop chain cable and anchor when paying out, even in the event of failure of the power supply.

Windlass and brake not combined with a chain stopper have to be designed to withstand a pull of 80 % of the breaking load of the chain cable without any permanent deformation of the stressed parts and without brake slip.

Windlass and brake combined with a chain stopper have to be designed to withstand a pull of 45 % of the breaking load of the chain cable.

5.9.9 The stresses on the parts of the windlass, its frame and brake are to be below the yield point of the material used.

The windlass, its frame and the brakes are to be efficiently anchored to the deck.

Performance criteria and strength of windlasses are to be verified by means of work be verified by means of workshop testing according to Society Rules.

5.10 Chain Stopper

5.10.1 A chain stopper is normally to be fitted between the windlass and the hawse pipe in order to relieve the windlass of the pull of the rope or the chain cable when the ship is at anchor.

5.10.2 A chain stopper is to be capable of withstanding a pull of 80 % of the breaking load of the chain cable; the deck at the chain stopper is to be suitably reinforced. However, fitting of a chain stopper is not compulsory.

5.10.3 Chain tensioners or lashing devices supporting the weight of the anchor when housed in the anchor pocket are not to be considered as chain stoppers.

5.10.4 Where the windlass is at a distance from the hawse pipe and no chain stopper is fitted, suitable arrangements are to be provided to lead the chain cable to the windlass.

5.11 Chain Locker

5.11.1 The chain locker is to be of a capacity adequate to stow all (chain) cable equipment and provide an easy direct lead to the windlass.

5.11.2 Where two anchor lines are fitted, the port and starboard chain cables are to be separated by a steel bulkhead in the locker.

5.11.3 Where the chain locker is arranged aft of the collision bulkhead, its boundary bulkheads are to be watertight.

5.11.4 A sufficient drainage system of the chain locker is to be provided.

5.11.5 The inboard ends of chain cables are to be secured to the structure by a fastening able to withstand a force not less than 15% nor more than 30% of the breaking load of the chain cable.

5.11.6 In an emergency, the attachments are to be easily released from outside the chain locker.

5.12 Anchoring sea trials

5.12.1 The anchoring sea trials are to be carried out on board in the presence of a BKI Surveyor.

5.12.2 The test is to demonstrate that the windlass complies with the anchoring procedure laid out in the craft operating manual.

5.12.3 The brake is to be tested during lowering operations.

Section 10

Provisions for Operation, Inspection and Maintenance

Note:

This section of the Rules is not applicable for the purpose of classification. The certification of operational, inspection and maintenance provisions falls under the responsibility of the Administration and is based on international safety requirements. Presently, no such international requirements exist for WIG craft. The IMO Sub-Committee on Design and Equipment, however, has established a Correspondence Group dealing with Guidelines for the Safety of WIG craft. The following text reflects the current state as per 31.01.2001 of deliberations in the Correspondence Group related to Category A passenger WIG craft of type A and cargo WIG craft of type A and is here reproduced for information only. It may serve as a basis for discussions with the Administration. The current status can be provided by BKI.

A. Documents to be submitted

– Craft operating manual;

– Route operational manual;

– Training manual;

– Maintenance manual; and

– Servicing schedule

B. Operational Provisions

1. Craft operational control

1.1 *The WIG Craft Safety Certificate, the Permit to Operate WIG Craft or certified copies thereof, and copies of the route operational manual, craft operating manual, and a copy of such elements of the maintenance manual as the Administration may require shall be carried on board.*

1.2 *The craft shall not be intentionally operated outside the worst intended conditions and limitations specified in the Permit to Operate WIG Craft, in the WIG Craft Safety Certificate, or in documents referred to therein.*

1.3 *The Administration shall issue a Permit to Operate WIG Craft when it is satisfied that the operator has made adequate provisions from the point of view of safety generally, including the following matters specifically, and shall revoke the Permit to Operate if such provisions are not maintained to its satisfaction:*

.1 *the suitability of the craft for the service intended, having regard to the safety limitations and information contained in the route operational manual;*

.2 *the suitability of the operating conditions in the route operational manual;*

.3 *the arrangements for obtaining weather information on the basis of which the commencement of a voyage may be authorized;*

.4 *provision in the area of operation of a base port fitted with facilities in accordance with 1.4;*

.5 *the designation of the person responsible for decisions to cancel or delay a particular voyage, e.g. in the light of the weather information available;*

.6 *sufficient crew complement required for operating the craft, deploying and manning survival craft, the supervision of passengers and cargo in both normal and emergency conditions as defined in the Permit to Operate. The crew complement shall be such that two officers are on duty in the operating compartment when the craft is under way, one of whom may be the master;*

.7 *crew qualifications and training, including competence in relation to the particular type of craft and service intended, and their instructions in regard to safe operational procedures;*

.8 *restrictions with regard to working hours, rostering of crews and any other arrangements to prevent fatigue, including adequate rest periods;*

.9 *the training of crew in craft operation and emergency procedures;*

.10 *the maintenance of crew competence in regard to operation and emergency procedures;*

.11 *safety arrangements at terminals and compliance with any existing safety arrangements, as appropriate;*

.12 *traffic control arrangements and compliance with any existing traffic control, as appropriate;*

.13 *restrictions and/or provisions relating to position fixing and to operation by night or in restricted visibility, including the use of radar and/or other electronic aids to navigation, as appropriate;*

.14 *additional equipment which may be required, due to the specific characteristics of the service intended, for example, night operation;*

.15 *communication arrangements between craft, coast radio stations, base ports radio stations, emergency services and other ships, including radio frequencies to be used and watch to be kept;*

.16 *the keeping of records to enable the Administration to verify:*

- *that the craft is operated within the specified parameters,*
- *the observance of emergency and safety drills/procedures;*
- *the hours worked by the operating crew;*
- *the number of passengers on board;*
- *compliance with any law to which the craft is subject;*
- *craft operations; and*
- *maintenance of the craft and its machinery in accordance with approved schedules;*

.17 *arrangements to ensure that equipment is maintained in compliance with the Administration's requirements, and to ensure co- ordination of information as to the service- ability of the craft and equipment between the operating and maintenance elements of the operator's organization;*

.18 *the existence and use of adequate instructions regarding:*

- *loading of the craft so that weight and centre of gravity limitations can be effectively observed and cargo is, when necessary, adequately secured;*
- *the provision of adequate fuel reserves;*
- *action in the event of reasonable foreseeable emergencies; and*

.19 *provision of contingency plans by operators for foreseeable incidents including all land based activities for each scenario. The plans shall provide operating crews with information regarding search and rescue (SAR) authorities and local administrations and organizations which may complement the tasks undertaken by crews with the equipment available to them, in accordance with the "IMO Search and Rescue Manual (IMOSAR)", adopted by the International Maritime Organization by resolution A.439(XI), and "Use of Radar Transponders for Search and Rescue Purposes", adopted by resolution A.530(13).*

1.4 *The Administration shall determine the maximum allowable distance from a base port or place of refuge after assessing the provisions made under 1.3.*

2. Craft documentation

The company shall ensure that the craft is provided with adequate information and guidance in the form of technical manual(s) to enable the craft to be operated and maintained safely. The technical manual(s) shall consist of a craft operating manual, route operational manual, training manual, maintenance manual and servicing schedule. Arrangements shall be made for such information to be updated as necessary.

2.1 Craft operating manual

The craft operating manual shall contain at least the following information:

.1 *leading particulars of the craft;*

.2 *description of the craft and its equipment;*

.3 *craft characteristics and behaviour relating to:*

- *manoeuvrability in all operational modes and in all environmental conditions up to the worst intended conditions;*
- *start procedures in all sea states up to a significant waveheight of H_{S0};*
- *landing procedures in all sea states up to a significant waveheight of H_{S1};*

– *speed in air in relation to flight altitude and pitch angle;*

.4 *operating limitations, including the worst intended conditions;*

.5 *limiting values of all machinery parameters requiring compliance for safe operation;*

.6 *information relating to:*

– *indication of emergency situations or malfunctions jeopardizing safety, required actions to be taken and any consequential restrictions on operation of the craft or its machinery;*

– *evacuation procedures;*

– *communication procedures for emergency situations*

.7 *procedures for checking the integrity of buoyancy compartments;*

.8 *details arising from compliance with the requirements of Section 2 likely to be of direct practical use to the crew in an emergency;*

.9 *damage control procedures;*

.10 *description and operation of machinery systems;*

.11 *description and operation of auxiliary systems;*

.12 *description and operation of remote control and warning systems;*

.13 *description and operation of electrical equipment;*

.14 *loading procedures and limitations, including maximum take-off weight, centre of gravity position and distribution of load, including any cargo or car securing arrangement and procedures depending on operational restrictions or damaged conditions. Such arrangement and procedures shall not be included as a separate Cargo Securing Manual as required by Chapter VI of the International Convention for the Safety of Life at Sea (SOLAS), 1974, as amended;*

.15 *description and operation of fire-detection and fire-extinguishing equipment;*

.16 *drawings indicating the structural fire protection arrangements;*

.17 *description and operation of radio equipment and navigational aids;*

.18 *information regarding the handling of the craft as determined in accordance with* Section 9, B. *(Handling, controllability and performance)*

.19 *procedures for lowering and hoisting the anchor;*

.20 *procedure for establishing a towing link with on-board equipment, including; maximum permissible towing speeds and towing loads, where applicable;*

.21 *procedure for dry-docking or lifting, including limitations;*

In regard to information on machinery or system failures, data shall take into account the results of the System Safety Assessment developed during the craft design.

2.2 Route operational manual

The route operational manual shall include at least the following information:

.1 *rescue procedures;*

.2 *specific requirements/limitations of the operational area including start/landing areas;*

.3 *procedures for operation of the craft within the limitations of .2;*

.4 *the elements of applicable contingency plans for primary and secondary rescue assistance in the case of foreseeable incidents, including land-based arrangements and activities for each incident;*

.5 *arrangements for obtaining weather information;*

.6 *identification of the "base port(s)";*

.7 *identification of the person responsible for decisions to cancel or delay voyages;*

.8 *identification of crew complement, functions and qualifications;*

.9 *restrictions on working hours of crew;*

.10 *safety arrangements at terminals;*

.11 *traffic control arrangements and limitations, as appropriate;*

.12 *specific route conditions or requirements relating to position fixing, operations by night and in restricted visibility, including the use of radar or other electronic aids to navigation; and*

.13 *communication arrangements between craft, coast radio stations, base ports radio stations, emergency services and other ships, including radio frequencies to be used and watch to be kept;*

.14 *list of tasks to be performed as part of the pre and post-flight checks.*

2.3 Training manual

The training manual shall contain instructions and information, in easily understood terms, illustrated wherever possible, on evacuation, fire and damage control appliances and systems and on the best methods of survival. Any part of such information may be provided in the form of audio-visual aids in lieu of the manual. Where appropriate, the contents of the training manual may be included in the craft operating manual. The following shall be explained in de- tail:

.1 *donning lifejackets and immersion suits, as appropriate;*

.2 *assemble at the assigned stations;*

.3 *boarding, launching and clearing the survival craft and rescue boats;*

.4 *method of launching from within the survival craft;*

.5 *release from launching appliances;*

.6 *methods and use of devices for protection in launching areas, where appropriate;*

.7 *illumination in launching areas;*

.8 *use of all survival equipment;*

.9 *use of all detection equipment;*

.10 *with the assistance of illustrations, the use of radio life-saving appliances;*

.11 *use of drogues;*

.12 *use of engine and accessories;*

.13 *hazards of exposure and the need for warm clothing;*

.14 *best use of the survival craft facilities in order to survive;*

.15 *methods of retrieval, including the use of helicopter rescue gear (slings, baskets, stretchers).*

.16 *all other functions contained in the muster list and emergency instructions;*

.17 *instructions for emergency repair of the life-saving appliances;*

.18 *instructions in the use of fire protection and fire-extinguishing appliances and systems;*

.19 *use of alarms and communications associated with fire safety;*

.20 *methods for surveying damage;*

.21 *use of damage control appliances and systems, including operation of watertight doors and bilge pumps; and*

.22 *for passenger craft, control of and communication with passengers in an emergency.*

2.4 Maintenance manual and servicing schedule.

The craft maintenance manual and servicing schedule shall contain as a minimum:

.1 *inspection and maintenance charts approved by BKI;*

.2 *detailed, illustrated description of all craft structure, machinery installations and all installed equipment and systems required for safe operation of the craft;*

.3 *specifications and quantities of all replenishable fluids and of structural materials which may be required for repairs;*

.4 *operational limitations of machinery in terms of values of parameters, vibration and consumption of replenished fluids;*

.5 *limitations of wear of structure or machinery components, including lives of components requiring calendar or operating time replacement;*

.6 *detailed description of procedures, including any safety precautions to be taken or special*

equipment required, to remove and install main and auxiliary machinery, transmissions, propulsion devices. and flexible structure components;

.7 *test procedures to be followed subsequent to replacement of machinery or system components or for malfunction diagnosis;*

.8 *procedure for lifting or dry-docking the craft, including any weight or attitude limitations;*

.9 *procedure for weighing the craft and establishing the position of longitudinal centre of gravity (LCG);*

.10 *where craft may be dismantled for transportation, instructions shall be provided for dismantling, transport and re-assembly;*

.11 *a servicing schedule, included in the maintenance manual or published separately, detailing the routine servicing and maintenance operations required to maintain the operational safety of the craft and its machinery and systems.*

2.5 Information on passengers

.1 *All persons on board craft shall be counted prior to departure.*

.2 *Details of persons who have declared a need for special care or assistance in emergency situations shall be recorded and communicated to the master prior to departure.*

.3 *The names and gender of all persons on board, distinguished between adults, children and infants shall be recorded for search and rescue purposes.*

.4 *The information required by 2.5.1, 2.5.2 and 2.5.3 shall be kept ashore and made readily available to search and rescue services when needed.*

.5 *The Administration may exempt from the requirements of 2.5.3 passenger craft operating on voyages having a duration of 2 h or less between each port of call.*

3. Qualifications and training

3.1 *The level of competence and the training considered necessary in respect of the master and each crew member shall be laid down and demonstrated in the light of the following Rules to the satisfaction of the company in respect of the particular type and model of craft concerned and the service intended. More than one crew member shall be trained to perform all essential operational tasks in both normal and emergency situations.*

3.2 *The Administration shall specify an appropriate period of operational training for the master and each member of the crew and, if necessary, the periods at which appropriate retraining shall be carried out.*

3.3 *The Administration shall issue a type rating certificate to the master and all officers having an operational role following an appropriate period of operational/simulator training and on the conclusion of an examination including practical test commensurate with the operational tasks on board the particular type and model of craft concerned and the route followed. The type rating training shall cover at least the following items:*

.1 *knowledge of all on-board propulsion and control systems, including communication and navigational equipment, steering, electrical, hydraulic and pneumatic systems and bilge and fire pumping;*

.2 *the failure mode of the control, steering and propulsion systems and proper response to such failures;*

.3 *handling characteristics of the craft and the limiting operational conditions;*

.4 *bridge communication and navigation procedures;*

.5 *intact and damage stability and survivability of the craft in damage condition;*

.6 *location and use of the craft's life-saving appliances, including survival craft equipment;*

.7 *location and use of escapes in the craft and the evacuation of passengers;*

.8 *location and use of fire protection and fire-extinguishing appliances and systems in the event of fire on board;*

.9 *location and use of damage control appliances and systems, including operation of watertight doors and bilge pumps;*

.10 *cargo stowage securement systems;*

.11 *methods for control of and communication with passengers in an emergency; and*

.12 *location and use of all other items listed in the training manual.*

3.4 *The type rating certificate for a particular type and model of craft shall only be valid for service on the route to be followed when it is so endorsed by the Administration following the completion of a practical test over that route.*

3.5 *The type rating certificate shall be revalidated every two years and the Administration shall lay down the procedures for re-validation.*

3.6 *All crew members shall receive instructions and training, as specified in 3.3.6 to .12.*

3.7 *The Administration shall specify standards of physical fitness and frequency of medical examinations, having regard to the route and craft concerned.*

3.8 *The Administration of the country in which the craft is to operate, if other than the flag State, shall be satisfied with the training, experience and qualifications of the master and each crew member. A valid type rating certificate appropriately endorsed and held by a master or crew member, in conjunction with the current and valid license or certificate is- sued by a flag State which is signatory to the International Convention on Standards of Training, Certification and Watch keeping (STCW) in force for those who are required to hold such a license or certificate, shall be acceptable as evidence of satisfactory training, experience and qualification to the Administration of the country in which the craft is to operate.*

4. Manning of survival craft and supervision

The company and the master shall ensure that:

.1 *a sufficient number of trained persons are on board for assembling and assisting untrained persons.*

.2 *a sufficient number of crew members, who may be deck officers or certificated persons, are on board for operating the survival craft, rescue boats and launching arrangements required for abandonment by the total number of persons on board.*

.3 *a deck officer or certificated person is placed in charge of each survival craft to be used. Recognizing however, that the Administration, having due regard to the nature of the voyage, the number of persons on board and the characteristics of the craft, may permit a deck officer, certificated person or persons practised in the handling and operation of liferafts to be placed in charge of each liferaft or group of liferafts;*

.4 *the person in charge of survival craft has a list of the survival craft crew and sees that those crew members are acquainted with their duties;*

.5 *every rescue boat has a person assigned who is capable of operating the engine and carrying out minor adjustments, and*

.6 *persons referred to in 4.1 to 4.3 are equitably distributed among the craft's survival craft.*

5. Emergency instructions and drills

5.1 *On or before departure, passengers shall be instructed in the use of lifejackets and the action to be taken in an emergency. The attention of the passengers shall be drawn to the emergency instructions required by* Section 6, D.1 *and* D.3.

5.2 *Emergency fire and evacuation drills for the crew shall be held on board the craft at intervals not exceeding one week for passenger craft and one month for cargo craft.*

5.3 *Each member of each crew shall participate in at least one evacuation, fire and damage control drill per month.*

5.4 *On-board drills shall, as far as practicable, be conducted to simulate an actual emergency. Such simulations shall include instruction and operation of the craft's evacuation, fire and damage control appliances and systems.*

5.5 *On-board instruction and operation of the craft's evacuation, fire and damage control appliances and systems shall include appropriate cross- training of crew members.*

5.6 *Emergency instructions including a general diagram of the craft showing the location of all exits, routes of evacuation, assigned assembly station, emergency equipment, life-saving equipment and appliances and illustration of lifejacket donning shall be available to each passenger and crew member in appropriate languages. It shall be placed near each passenger and crew seat and conspicuously displayed at assembly stations.*

5.7 Records

The date when musters are held, details of abandon craft drills and fire drills, drills of other life-saving appliances and on-board training shall be recorded in such log-book as may be prescribed by the Administration. If a full muster, drill or training session is not held at the appointed time, an entry shall be made in the log-book stating the circumstances and the extent of the muster, drill or training session held.

A copy of such information shall be forwarded to the operator's management.

5.8 Evacuation drills

5.8.1 *Evacuation drill scenarios shall vary each week so that different emergency conditions are simulated.*

5.8.2 *Each evacuation craft drill shall include:*

.1 *summoning of crew to assembly stations with the alarm required by* Section 6, B.2.2 *and ensuring that they are made aware of the order to abandon craft specified in the muster list;*

.2 *reporting to stations and preparing for the duties described in the muster list;*

.3 *checking that crew are suitably dressed;*

.4 *checking that lifejackets are correctly donned;*

.5 *donning of immersion suits or thermal protective clothing by appropriate crew members;*

.6 *testing of emergency lighting for mustering and abandonment; and*

.7 *giving instructions in the use of the craft's life-saving appliances and in survival at sea.*

5.8.3 Rescue boat drill

.1 *As far as is reasonable and practicable, rescue boats shall be launched each month as part of the evacuation drill, with their as- signed crew aboard, and manoeuvred in the water. In all cases this requirement shall be complied with at least once every three months.*

.2 *If rescue boat launching drills are carried out with the craft making headway, such drills shall, because of the dangers involved, be practised in sheltered waters only and under the supervision of an officer experienced in such drills, in accordance with resolution A.624(15) of the International Maritime Organization, concerning Guidelines on training for the purpose of launching lifeboats and rescue boats from ships making headway through the water.*

5.8.4 *Individual instructions may cover different parts of the craft's life-saving system, but all the craft's life-saving equipment and appliances shall be covered within any period of one month on passenger craft and two months on cargo craft. Each member of the crew shall be given instructions which shall include but not necessarily be limited to:*

.1 *operation and use of the craft's inflatable liferafts;*

.2 *problems of hypothermia, first-aid treatment of hypothermia and other appropriate first-aid procedures; and*

.3 *special instructions necessary for use of the craft's life-saving appliances in severe weather and severe sea conditions.*

5.9 Fire drills

5.9.1 *Fire drill scenarios shall vary each week so that emergency conditions are simulated for different vessel compartments.*

5.9.2 *Each fire drill shall include:*

.1 *summoning of crew to fire stations;*

.2 *operation of fire pumps and fire-fighting equipment;*

.3 *operation of communication equipment, emergency signals and general alarm;*

.4 *operation of fire-detection system; and*

.5 *instruction in the use of the craft's fire-fighting equipment and sprinkler systems.*

5.10 Damage control drills

5.10.1 *Damage control drill scenarios shall vary each week so that emergency conditions are simulated for different damage conditions.*

5.10.2 *Each damage control drill shall include:*

.1 *summoning of crew to damage control stations;*

.2 *reporting to stations and preparing for the duties described in the muster list;*

.3 *operation of watertight doors and other watertight closures;*

.4 *operation of bilge pumps and testing of bilge alarms and automatic bilge pump starting systems; and*

.5 *instruction in damage survey, use of the craft damage control systems and passenger control in the event of an emergency.*

5.11 *Special training involving collision avoidance and application of COLREG shall be provided.*

6. Type rating training for passenger craft crew

6.1 *The company shall ensure that the type rating training is implemented. For all crew members, the type rating training shall cover the control and evacuation of passengers additionally to 3.6.*

6.2 *When a craft carries cargoes, the craft shall comply with the requirements of 8.*

7. Emergency instructions and drills for passenger craft crew

The company shall ensure that the emergency instructions are implemented and the master shall be responsible for communicating the provisions of the emergency instructions to passenger upon boarding.

8. Type rating training for cargo craft crew *The company shall ensure that type rating training is implemented as provided in 3. For all crew members, the type rating training shall cover knowledge of cargo securement systems.*

C. Inspection and Maintenance Provisions

1. *The Administration shall be satisfied with the operator's organization or any organization on which he may call in the maintenance of his craft and shall specify the scope of the duties which any part of the organization may carry out, having regard to the number and competence of its staff, facilities available, arrangements for calling on specialist assistance shall it be necessary, record-keeping, communication and allocation of responsibilities.*

2. *The craft and equipment shall be maintained to the satisfaction of the Administration; in particular:*

.1 *routine preventive inspection and maintenance shall be performed to a schedule approved by the Administration, which shall have regard at least in the first instance to the manufacturer's schedule;*

.2 *in the performance of maintenance tasks, due regard shall be paid to maintenance manuals, service bulletins acceptable to the Administration and to any additional instructions of the Administration in this respect;*

.3 *all modifications shall be recorded and their safety aspects investigated. Where it could have any effect on safety, the modification, together with its installation, shall be to the satisfaction of the Administration;*

.4 *appropriate arrangements shall be provided for informing the master of the serviceability state of his craft and its equipment;*

.5 *the duties of the operating crew in respect of maintenance and repairs and the procedure for obtaining assistance with repairs when the craft is away from the base port shall be clearly defined;*

.6 *the master shall report to the maintenance organization any defects and repairs which are known to have occurred during operations;*

.7 *records of defects and their correction shall be maintained and those defects of recurrent nature, or those which adversely affect craft or personal safety, shall be reported to the Administration.*

3. *It is the Owner's responsibility to report to BKI any modification, damage or repair affecting the class of the ship.*

4. *The Administration shall be satisfied that arrangements are provided for ensuring adequate inspection, maintenance and recording of all life-saving appliances and distress signals carried.*

Section 11

Safety Assessment

The Safety Assessment process described in this Section complements the range of requirements set forward in the other Sections of these Rules. It provides a rational basis for the assessment of the safety of a WIG craft by applying basic objective requirements for craft functions and for those systems installed onboard the craft that perform these functions. Moreover, specific requirements are generated in the assessment process where the risk associated with particular failure conditions warrants this.

This Section is organized as follows:

The scope of the documentation required is outlined in Subsection A. Subsection B ("Application") describes for which craft and for which systems a Safety Assessment is required. A brief summary of the underlying probability concept and some basic definitions are given in Subsection C to ensure consistency in the application of the assessment process. The Safety Assessment process itself is described in Subsections D, while Subsection E provides a brief overview of the relevant methods employed in the various stages of the assessment process. Finally, Subsection F is concerned with Safety Management covering the operational phase.

A. Documents to be submitted

The owner shall submit a time schedule for the performance of the Safety Assessment. In consultation with the owner, BKI will integrate into the time schedule its review and approval tasks relating to the FHA, PSSA, SSA and to survey activities.

The results of the Safety Assessment shall be documented in a report addressing the three main elements of the assessment process: (i) Functional Hazard Assessment, (ii) Preliminary System Safety Assessment, and (iii) System Safety Assessment. The report shall be submitted in triplicate for approval and pro- vide the following information so that there is trace- ability of the steps taken in developing the analysis:

1. Functional Hazard Assessment (FHA)

– FHA input function list covering all craft systems (see example in Table 11.1)

– Environmental and emergency/abnormal configuration list

– For each system:

  – System definition (block diagram, boundaries, interfaces, operational limits)

  – System description (operational procedures, maintenance regime)

  – Functional description (top-down description: system ⟶ components)

  – Functional relationship with external systems

  – FHA worksheets (see example in Table 11.2)

  – Supporting material for classification of failure conditions

  – Verification methods and requirements

  – System summary

– Conclusions

2. Preliminary System Safety Assessment (PSSA)

– Planned compliance method with FHA requirements

– List of Failure Conditions for further analysis

– Fault Trees or Dependence Diagrams

– Lower level safety requirements

– Updated list of verification methods and requirements

– Operational requirements (maintenance tasks, checks, etc.)

3. System Safety Assessment (SSA)

– Updated Failure Condition list, including classifications

– Fault Trees or Dependence Diagrams showing compliance with safety requirements

– Documentation showing how requirements for the design of the system item's installation (segregation, separation, protection, etc.) have been incorporated.

– Verification that safety requirements from the PSSA are incorporated into the design and/ or testing process.

– Results of the non-analytic verification process, for example tests, simulations, demonstrations, inspection activities.

B. Application

Safety assessment provides for a systematic examination of the craft functions and craft systems associated with the safe performance of these functions. A safety assessment shall be conducted for each WIG craft, before entry into service.

For craft of the same design and having the same equipment one safety assessment on the lead craft will be sufficient, but each of the craft shall be subject to the same trial programme.

If in the course of the service life of the craft changes are made to the design or operation of the craft or its systems, the effect of these changes on the results of the safety assessment shall be examined, documented and reported to BKI.

The safety assessment shall be conducted for the craft itself and for systems installed on the craft. The systems considered shall include, but not be limited to:

– Propulsion system

– Electrical system

– Auxiliary systems

– Directional and altitude control systems

– Obstacle detection system, if provided

– Navigational equipment

C. Probability Concept

1. General

The Safety Assessment process is based on the principle that an inverse relationship shall exist between the probability of an occurrence and the severity of its effect. The principle itself, as illustrated in Table 11.3, is well documented in the literature; guidance on the correlation between safety level and acceleration levels is given in Table 11.4.

To ensure a level of consistency in its application it is helpful to define the terminology used in the assessment process.

2. Definitions

"Common Cause" means an occurrence that affects several elements which are otherwise considered independent or redundant.

"Failure" means a loss of function or a malfunction of a system or part of a system.

"Failure Condition" means a condition with an effect on the craft, its occupants or the environment caused by one or more failures, taking into account relevant adverse operation or environmental conditions. A Failure Condition may be detected or undetected and is classified according to the severity of its effects as follows[1)]:

"Minor Effect" means the effect of failure conditions that does not significantly reduce craft safety, and which involve crew actions that are well within their capabilities. Failure conditions with a minor effect may include, for example, a slight reduction in safety margins or functional capabilities, a slight increase in crew workload, or some inconvenience to occupants.

"Major Effect" means the effect of failure conditions that reduces the capability of the craft or the ability of the crew to cope with adverse operating conditions to the extent that there would be, for example, a significant reduction in safety margins or functional capabilities, a significant increase in crew work load or in conditions impairing crew efficiency, or discomfort to occupants, possibly including injuries.

"Hazardous Effect" means the effect of failure conditions that reduces the capability of the craft or the ability of the crew to cope with adverse operating conditions to the extent that there would be, for example, a large reduction in safety margins or functional capabilities, physical distress or higher work-load such that the flight crew cannot be relied upon to perform their tasks accurately or completely, or serious or fatal injuries to a relatively small number of occupants.

"Catastrophic Effect" means the effect of failure conditions that leads to a loss of the craft and/ or multiple fatalities.

"Hazard" is a potentially unsafe condition resulting from failures, malfunctions, external events, errors, or a combination of these.

"Risk" means the frequency (probability) of occurrence and the associated level of hazard.

"Safety Assessment" means a systematic evaluation of the craft functions and the design of systems performing these functions. It uses recognized

[1)] Refer to JAR-25, AMJ 25.1309

methods to identify failure conditions, establish safety objectives and requirements, and evaluate the implemented system.

"Safety requirement" means a statement in a specification that can be validated and against which an implementation can be verified.

D. Safety Assessment Process

1. General

The basic principles described below are based on established procedures outside the marine industry[2]. They provide the methods to evaluate the craft functions and the design of systems performing these functions. The safety assessment process shall ensure that all relevant failure conditions are identified and that all significant combinations of failures, which could cause those failures conditions, are taken into account.

The safety assessment is conducted in parallel to the design and construction of the craft. Accordingly, three phases may be distinguished:

.1 Generation of requirements

Depending on the criticality of functional failures at craft and system level, safety objectives are assigned to the various failure conditions identified. These safety objectives are expressed as probability levels and probability budgets that must be met by the implemented system, item and hardware/software configuration.

.2 Design implementation

During implementation account shall be taken of the failure rate budgets assigned to hardware and software items.

.3 Verification

In the verification phase it shall be demonstrated that the hardware and software actually implemented meets the relevant safety requirements.

Different processes are employed in the phases of the development cycle as illustrated in Table 11.5:

– Functional Hazard Assessment (FHA);

– Preliminary System Safety Assessment (PSSA); and

– System Safety Assessment (SSA).

There is likely to be some overlap between the phases and the assessment process is iterative in nature. Individual activities will hence be re-visited as the design evolves and becomes more defined.

The Functional Hazard Assessment (FHA) is conducted at the beginning of the development cycle. It shall clearly identify and classify failure conditions associated with the craft's functions. These failure condition classifications establish the safety objectives. In Table 11.3, the failure condition classifications (Category of Effect) are related to the safety objectives, expressed as levels of probability. The output of the FHA forms the starting point for the Preliminary System Safety Assessment (PSSA).

The Preliminary System Safety Assessment (PSSA) is a systematic analysis of the proposed system architecture. Its purpose is to show how failures at a lower hierarchical level can lead to the functional hazards identified in the FHA. The PSSA shall provide the designer with all necessary safety requirements of the system and demonstrate that the pro- posed architecture can meet the safety objectives identified by the FHA.

The PSSA is an interactive process and conducted at different development stages. At the lowest level, the PSSA determines the safety related design requirements of hardware and software. The PSSA usually takes the form of a Fault Tree Analysis (Dependence Diagram and Markov Analysis may also be used). It shall also address safety issues arising from Common Cause considerations.

The System Safety Assessment (SSA) is a systematic assessment of the actual system to demonstrate that safety objectives from the FHA and derived safety requirements from the PSSA are actually met. The SSA is usually based on the PSSA Fault Tree Analysis.

Activities typically performed in the FHA, PSSA and SSA are described below under the respective headings.

2. Functional Hazard Analysis (FHA)

2.1 Scope of analysis

2.1.1 The scope of a safety assessment varies depending on factors such as system complexity, level of service experience, and criticality of system failures. Before starting a detailed analysis of system failures it is therefore necessary to make a preliminary assessment in order to establish the required depth of analysis.

2.1.2 An FHA is performed at two levels, i.e. at craft level and at system level.

.1 The craft level FHA is a high level, qualitative assessment of the basic functions of the craft.

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[2] Refer to SAE Aerospace Recommended Practice, ARP 4761, Guidelines and Methods for Conducting the Safety Assessment Process on Civil Airborne Systems and Equipment (1996)

A craft level FHA shall identify and classify the failure conditions associated with the craft level functions. The classification of these failure conditions establishes the safety objectives that a craft shall meet (cf. Table 11.3).

.2 The system level FHA is also a qualitative assessment which is iterative in nature and becomes more defined as the development progresses. It considers a failure or combination of failures that affect a craft function. Lower level hardware or software items are not assessed in the system level FHA.

2.1.3 The output of the craft level FHA is the starting point for craft level fault trees, while the system level FHA is used to generate top level events for PSSA fault trees. In both cases the fault trees (Dependence Diagrams may also be used) can be used to derive lower level safety requirements.

2.2 Procedures for FHA

2.2.1 FHA carried out at craft and at system level use the same principles. The FHA process is a top down approach for identifying functional failure conditions and assessing their effects. This assessment is made following the steps listed below. A description of the FHA method following these steps is provided in Subsection E.

.1 Identification of all craft and system functions

.2 Identification and description of failure conditions associated with these functions

.3 Determination of the effects of the failure condition

.4 Classification of failure condition effects

.5 Assignment of safety objectives/ probability requirements

.6 Identification of means of compliance

2.2.2 The analysis shall take account of the environmental conditions the craft is likely to encounter en route.

2.2.3 A list shall be compiled describing:

– the craft configuration following the loss of systems examined in the FHA;

– resulting operational limitations; and

– the action required by the crew.

2.2.4 The results of the FHA shall be documented following the format given in Subsection A 1. They represent the input data and information for the PSSA process.

3. Preliminary System Safety Assessment (PSSA)

3.1 Scope of analysis

3.1.1 For each significant failure condition identified in the FHA, a PSSA shall be performed. Significant failure conditions are those classified as catastrophic, hazardous, or major. Catastrophic and hazardous failure conditions shall be subject to a qualitative and quantitative analysis. For failure conditions identified as major a less thorough qualitative analysis is sufficient when the systems are not complex or when relevant service experience is available.

3.1.2 The PSSA process examines the proposed system architecture with a view to identifying individual failures and combinations of failures that can cause the functional hazards identified by the FHA. The main purpose of the PSSA is to determine whether the chosen design can meet the safety objectives identified by the FHA and to derive safety requirements for systems and equipment associated with the function under consideration. The PSSA process is iterative in nature and continuous through- out the design cycle.

3.1.3 Since each significant failure condition shall be analysed by a PSSA, there are likely to be several PSSA's performed for a craft.

3.2 Procedures for PSSA

3.2.1 The PSSA process shall identify the sequence of events resulting from individual failures or combinations of failures that can lead to the functional hazards identified by the FHA. It shall also show how the FHA requirements can be satisfied by the chosen design. The process uses a top-down approach that seeks to identify all basic events that contribute to the functional hazards.

The assessment draws on established risk assessment methods of which the following shall be applied in the PSSA process:

– Zonal Hazard Analysis (ZHA),

– Failure Modes Effect and Criticality Analysis (FMECA),

– Failure Modes and Effects Summary (FMES), and

– Fault Tree Analysis (FTA) or Dependence Diagrams (DD).

These methods are described in more detail in Sub-section E.

The objective of a ZHA is to identify potential areas of risk arising from the design of the installation (segregation, separation, protection, etc.) and the operation (maintenance tasks, etc.).

An FMECA provides for a systematic examination of potential failure modes of equipment. It seeks to identify causes, analyze effects on system operation, quantify occurrence probabilities (failure rates), and identify corrective actions, i.e. design modifications.

The FMES summarizes lower level failure modes with the same effect derived from previously performed FMECAs.

FTA, or DD, is a top-down approach that allows the logic representation of many basic events (e.g. failure modes from FMECA) that combine to produce events at higher levels (e.g. failure conditions from FMES, ZHA or FHA). Its main purpose is to derive safety requirements for the basic events.

3.2.2 The results of the PSSA shall be documented following the format given in Subsection A.2. The outputs from the PSSA are the inputs for the SSA process.

4. System Safety Assessment (SSA)

The System Safety Assessment is the final step in the assessment process. It integrates results of the previously performed FHA, PSSA and flight/performance tests. While FHA and PSSA are used during the de- sign process to derive safety requirements, an SSA is a verification tool to show that the implemented design satisfies the requirements established by the FHA and PSSA. For each PSSA there shall be a corresponding SSA.

The verification process shall be supported by data sheets of which an example is shown in Table 11.6. In these data sheets requirements for specific failure conditions generated in the FHA and PSSA process are correlated with the results obtained in the SSA for the implemented design.

The results of the SSA shall be documented following the format given in Subsection A.3. The ‘inspection activities’ referred to in the documentation (Sub-section A.3.) relate to scope and intervals of safety related checks to be performed by the operator and BKI during the service life of the craft. The documentation shall include those activities (regular checks by the crew, maintenance tasks, inspections by BKI) necessary to satisfy the safety requirements established by the PSSA.

Means of verification include tests, analysis, demonstration and inspection.

E. Safety Assessment Methods

The assessment process described in Subsection D. employs a number of standard risk assessment techniques. The present Subsection provides some guidance on how the different types of analysis shall be applied to WIG craft systems. As all methods are well established, further background information can readily be found in the literature.

1. Functional Hazard Assessment (FHA)

The starting point for a Functional Hazard Assessment is a comprehensive description of the craft and its systems. This includes a complete breakdown of all systems and subsystems. The FHA is a function driven process that can be performed at an early design stage where system knowledge is still incomplete and subject to change.

The Functional Hazard Assessment comprises six main steps as outlined below:

.1 Identification of all craft and system functions

A function list is created at craft and at system level, taking into account both internal and external functions. Table 11.1 gives an example of an input function data sheet.

.2 Identification and description of failure conditions associated with these functions

Multiple failures have to be considered, especially then the effect of a certain failure depends on the availability of another system.

Failure conditions to be considered include:

– Loss of function (detected/ undetected)

– Malfunction (detected/ undetected)

  – incorrect function

  – reduced performance

  – interrupted function

  – inadvertent function

.3 Determination of the effects of failure conditions

Failure conditions are examined with respect to their effect at craft and system level and with respect to the effect on the crew, occupants and the environment. All operational modes, environmental conditions and emergency/abnormal situations are taken into account when evaluating the effect of failure conditions. If effects cannot be determined by the analyst, the associated failure condition shall be further examined using simulation techniques, model tests, or full scale tests.

.4 Classification of failure condition effects

The effect of failure conditions is classified according to the following categories: catastrophic, hazardous, major, minor, no safety effect (see C.2. and Table 11.3). Material used to support the classification must be documented. The need for further supporting material (e.g. simulations or tests) shall be identified.

.5 Assignment of safety objectives / probability requirements

For each failure condition, probability requirements (see Table 11.3) and qualitative design requirements are assigned and documented. The design requirements may relate to the craft, systems, and items.

.6 Identification of means of compliance

For each failure condition, the measures foreseen to comply with the safety objectives are identified.

2. Zonal Hazard Analysis (ZHA)

Starting point for a ZHA is the definition of specific zones within the craft that are, for example, separated by bulkheads or other parts of the structure. The analysis is performed initially based on design drawings and later on mock-ups or the final craft. For each of the zones four aspects are addressed in the analysis:

.1 Compliance with installation rules

Compliance with the provisions in these Rules relating to equipment installation must be demonstrated.

.2 Interaction between systems

The analysis shall identify intrinsically hazardous items (e.g. fuel lines) and show that failures (e.g. fuel leakage) do not cause cascade type failures in neighbouring systems.

.3 Maintenance errors

Improper equipment installation may increase the likelihood of maintenance errors. The analysis shall identify such areas and recommend alternative designs.

.4 Environmental effects

Consideration shall be given to the effect of environmental conditions such as lightning strike, bird strike, water ingress, etc.

Details of the analysis technique are e.g. given in ARP 4761.

Results of the analysis shall be recorded in data sheets, as shown in Table 11.7.

3. Failure Modes Effect and Criticality Analysis (FMECA)

An FMECA is performed for components or items that contribute to functional failures identified as hazardous or catastrophic. These are, for example, parts associated with basic events in fault trees. Procedures for FMECA are documented in the literature, for example British Standard 5760, Part 5. The level of detail must correspond to the level of indenture in the system hierarchy at which functional failures are postulated. The analysis is an iterative process that evolves as the design becomes more defined.

The FMECA process is facilitated by worksheets as shown in Table 11.8. An important and difficult aspect of an FMECA is concerned with obtaining reliable data for failure mode rates under similar environmental and operational conditions to those envisaged for the system being analysed. Failure rate data may be obtained from handbooks in the public domain, for example RAC-NPRD and Failure Mode/Mechanism Distributions[3)], from industry sources, or by computational methods.

4. Failure Modes and Effects Summary (FMES)

The FMES summarises all failure modes with the same effect from previously performed FMECAs. Its purpose is to combine into a single event all item failures with the same effect on the system, thereby simplifying the fault tree. Compared to an FMECA, it is a higher level type of analysis where the failure effects of the FMECAs are failure modes for the FMES. The FMES failure rates are obtained by adding the individual failure rates of contributing low level, independent, failure modes.

The FMES process is facilitated by worksheets as shown in Table 11.9.

5. Fault Tree Analysis (FTA)

Fault Tree Analysis is employed in the PSSA process to determine the causes leading to undesirable top events identified in the FHA. It is a graphical representation of events, or more often combinations of events, that contribute to the top event. It provides the link between the different analysis methods described in the present Subsection by:

– using failure conditions identified as hazardous or catastrophic in the FHA as top event;

– generating basic events that may have to be further analysed in an FMECA;

3) Reliability Analysis Center: Non electronic Parts Reliability Data
Reliability Analysis Center: Failure Mode/ Mechanism Distributions

– demonstrating how combinations of basic events lead to failure conditions derived by FMES and ZHA;

– quantifying failure rate budgets for basic or intermediate events; and

– deriving permissible failure rates for basic events.

Instead of Fault Tree Analysis, Dependence Diagrams may also be used to achieve the same objectives.

In the SSA process, Fault Tree Analysis is used to demonstrate that the safety objectives for the top events are satisfied.

Principles and procedures for Fault Tree Analysis are well documented in the literature, for example in ARP 4761 or in British Standard 5760, Part 7.

F. Safety Management

The operator must implement a Safety Management System (SMS) which is in compliance with the International Safety Management (ISM) Code.

Results from the PSSA and SSA shall be incorporated in the SMS and included in the Craft Operating Manual, in particular with reference to:

– crew operational procedures;

– emergency procedures and actions;

– procedures related to the control of hazardous situations and accidents;

– maintenance procedures for equipment whose sudden failure may have a hazardous or catastrophic effect;

– inspection intervals and methods; and

– control of documents and data relevant for the SMS as well as the integrity and operation of the craft.

Table 11.1 Input Function List

List of Function Worksheet			Sheet __ of ___ Issue : Date :
Function No.	**Function**	**System Sub-system Equipment**	**Equipment-ID-No.**

Table 11.2 Functional Hazard Analysis Worksheet

Functional Hazard Analysis Worksheet						Sheet __ of ___ Issue : Date :
System : **Subsystem :**			**Function :**			
Item No.	**Failure Condition**	**Mission Phase**	**Failure Effect**	**Classification**	**Objectives**	**Remarks**

Table 11.3 Correlation between levels of probability and categories of effect

Probability (quantitative)	$10^{-0}\ \frac{1}{h}$	$10^{-3}\ \frac{1}{h}$	$10^{-5}\ \frac{1}{h}$	$10^{-7}\ \frac{1}{h}$	$10^{-9}\ \frac{1}{h}$
Probability (descriptive) FAA	**Probable**		**Improbable**		**Extremely Improbable**
JAA	**Frequent**	**Reasonably Probable**	**Remote**	**Extremely Remote**	
Category of Effect	**Minor**		**Major**	**Hazardous**	**Catastrophic**
Effect on craft, occupants and environment	– Slight reduction in safety margins or functional capabilities; or – Slight increase in crew workload ; or – Some inconvenience to occupants		– Significant reduction in safety margins or functional capabilities; or – Significant increase in crew workload; or – Discomfort to occupants; or – Possibly injuries to occupants; or – Localized structural damage; or – Moderate environmental pollution	– Large reduction in safety margins or functional capabilities; or – Large increase in crew workload, so that the crew may not be able to perform tasks accurately or completely; or – Serious or fatal injuries to a relatively small number of occupants; or – Large structural damage; or – Significant environment pollution	– Loss of craft; or – Multiple fatalities; or – Large environmental pollution with long-term effects
Safety Level	**1**		**2**	**3**	**4**

Table 11.4 Correlation between safety levels and acceleration levels

Effect	*Criteria not to be exceeded*	*Value*	*Comment*
	Type of load		
Level 1 *Minor Effect* *Moderate degradation of safety*	*Maximum acceleration measured horizontally* [1]	*0,20 g* [2]	*0,08 g and 0,20 g/s* [3]*: Elderly person will keep balance when holding* *0,15 g and 0,20 g/s: Mean person will keep balance when holding* *0,15 and 0,80 g/s: Sitting person will start holding*
Level 2 *Major Effect* *Significant degradation of safety*	*Maximum acceleration measured horizontally* [1]	*0,35 g*	*0,25 g and 2,0 g/s: Maximum load for mean person keeping balance when holding* *0,45 g and 10 g/s: Mean person falls out of seat when not wearing seat belts*
Level 3 *Hazardous Effect* *Large degradation of safety*	*Collision design condition calculated* *Maximum structural design load, based on vertical acceleration at centre of gravity*	*Ref. Section 3, C.3.3* *Ref. Section 3, C.3.1*	*Risk of serious or fatal injury to a relatively small number of occupants, safe emergency operation after collision.* *1,0 g: Degradation of passenger safety*
Level 4 *Catastrophic Effect*	--	--	*Loss of craft or/and fatalities*

1 *The recording instruments used shall be such that acceleration accuracy is better than 5 % of the real value and frequency response should be minimum 20 Hz. Antialiasing filters with maximum passband attenuation 1 ± 5 % should be used.*

2 *g = gravity acceleration* $(9{,}81\ m/s^2)$

3 *g-rate or jerk may be evaluated from acceleration/time curves.*

Table 11.5 Safety Assessment Process

Assessment process :	**Functional Hazard Assessment (FHA)**	**Preliminary System Safety Assessment (PSSA)**	**System Safety Assessment (SSA)**
Purpose of process :	– Identify and classify failure conditions; – Establish safety objective	– Establish system and item safety requirements – Development specifications for hardware procurement	– Verify that safety requirements defined in FHA and PSSA are met
Development cycle :	Concept development	Design Preliminary → Detailed	Design Validation

System knowledge :

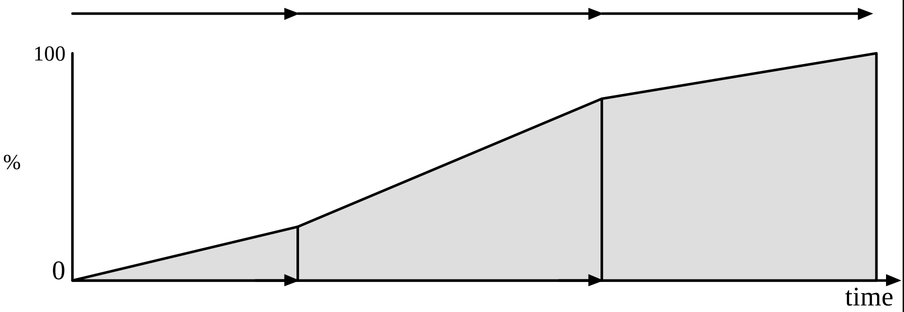

Table 11.6 SSA Verification Data sheet

SSA Verification Data Sheet					Sheet __ of ___ Issue : Date :
FHA / PSSA Requirement			Implemented Design		
No.	**Failure Condition**	**Objectives**	**Event**	**Probability**	**SSA FTA Reference**

Table 11.7 Zonal Hazard Analysis Data Sheet

ZHA: Hazard Identification Data Sheet						Sheet __ of ___ Issue : Date :
System : **Zone :** **Zone Number :**		**System :** **Equipment :**		**Subsystem :**		
ID	**Hazardous Element**	**Hazardous Condition**	**Initiator Event**	**Effects**	**Probability**	**Safety Measures/ Means of Compliance**

Table 11.8 Component FMECA Worksheet

Component FMECA Worksheet

Sheet __ of ___
Issue :
Date :

System :
Subsystem :

FTA Reference :

Item No.	Item	Item Failure Mode	Mode Failure Rate	Mission Phase	Failure Effects	Detection Method	Classification	Remarks

Table 11.9 FMES Worksheet

FMES Worksheet						Sheet __ of ___ Issue : Date :
System : **Subsystem :**						
Item No.	**Failure Mode**	**Failure Rate**	**Effects on System**	**Failure Cause (FMECA Ref.)**	**Detectability**	**Remarks**

Section 12

Requirements for the Design of Fibre Reinforced Plastics Structures and Components

A. General Requirements

The present version of requirements for fibre reinforced plastics components applied to Wing-In-Ground craft is a preliminary draft and subject to further revision.

1. Application

These requirements apply to Wing-In-Ground craft partly or fully made of fibre reinforced plastics. Exemptions from some of the requirements may be granted when particular circumstances warrant this, in the opinion of BKI Head Office.

These requirements are not applicable for piping systems.

2. Definitions

A glossary of terms used in fibre reinforced plastic fabrication is given in Annex G.

B. Quality System Requirements

Any contractor, supplier, or manufacturer involved in the design, supply, manufacture, testing, etc., shall have a documented quality system based on the appropriate ISO 9000 standard or approved equivalent. The effectiveness of an equivalent quality system shall be demonstrated in an appropriate manner.

A certificate issued by a second or third party may be accepted as objective evidence, however BKI reserves the right to check all relevant documents and audit the contract related areas.

If the contractor, supplier, or manufacturer has no evidence of an implemented quality management system, BKI will assess the competency by checking all relevant documents and performing own system audits as necessary.

C. Material Requirements

All materials to be used during the production of components from FRP for Wing-In-Ground craft shall first be assessed and approved by BKI.

Approval by other Societies can be recognised following agreement by BKI, provided that the tests required for approval are in accordance with BKI requirements.

Requirements given in [9] Part – 1, Section 2 (see Annex I) and [2] Section 3, C.3.2.6 shall be applied. Furthermore, the requirements listed below in paragraphs 1. to 5. have to be considered as far as applicable. For some cases supplementary demands may be necessary.

The manufacturer shall certify that all materials conform to the manufacturer's specifications for the product.

Concerning components or parts of the structure, which can be classified as safety critical (see F.1.1), the manufacturer shall certify that for all materials used, the minimum strengths R_k and moduli are not less than 95 % respectively 90 % of the manufacturer's published minimum values. Amongst others, this demand implies 100 % non destructive testing (see E.).

Concerning all other components or parts of the structure, it may be sufficient to specify characteristic values for strengths R_k and moduli based on random samples. Application of this procedure shall be approved by BKI. In such cases further parameters have to be specified, which shall be calculated by means of statistics methods from the sample. These parameters are

$\overline{x}$ the mean of the test values

ν variation coefficient

U_i i % fractile (percentile value) of the normal distribution

P probability (confidence interval).

In order to determine physical and mechanical properties, only standardised tests shall be used.

Standards, which will be recognised by BKI are given in Annex K as well as in [9].

A list of symbols is given in Annex L.

1. Fibres

Composite structures may consist of one or more of the following reinforcements embedded in a resin matrix:

- glass
- carbon
- aramid
- others

The following physical and mechanical properties shall be specified for each fibre type used:

- Young's modulus in longitudinal direction of fibre $E_{//}$
- Young's modulus in transversal direction of fibre $E_{\perp}$
- Shear modulus $G_{\perp //}$
- Poisson's ratio $\nu_{\perp //}$ $\nu_{// \perp}$
- Density ρ
- Coefficient of thermal expansion $\alpha_{\perp}$ $\alpha_{//}$
- Ultimate tensile strength Rm^{+}
- Ultimate tensile strain A^{+}

2. Resin system

The matrix shall consist of an epoxy, polyester, vinyl ester, or other resin system.

Each resin used shall be traceable by the name of its manufacturer and the trade name or number of that manufacturer. The resin materials used shall be the same as those specified in the procedure specification.

Each curing agent shall be traceable by the name of its manufacturer and the trade name or number of that manufacturer.

Each curing agent and resin-to-curing-agent ratio used during fabrication shall be as specified in the procedure specification and shall be recorded and become part of the quality control test report specification.

The fabricator shall define and document the method used to assure that proper laminate cure is attained. These methods have to be approved by the Society. The following physical and mechanical properties shall be specified for each resin system, curing agent, resin-to-curing-agent ratio, and curing procedure used in order to provide for calculation constants necessary to analyze the laminate:

- Young's modulus E
- Shear modulus G
- Poisson's ratio ν
- Density ρ
- Coefficient of thermal expansion α
- Temperature of deflection under load
- Ultimate tensile strength R_{m^+}
- Ultimate compression strength R_{m^-}
- Ultimate shear strength R_s
- Ultimate tensile strain A^{+}

3. Core material

The core manufacturer shall certify that the product conforms to the manufacturer's specifications.

The following physical and mechanical properties shall be specified for each core type used:

- Young's modulus in longitudinal direction $E_{//}$
- Young's modulus in transversal direction $E_{\perp}$
- Shear modulus $G_{\perp //}$
- Major Poisson's ratio $\nu_{\perp //}$
- Minor Poisson's ratio $\nu_{// \perp}$
- Density ρ
- Coefficient of thermal expansion in longitudinal direction $\alpha_{//}$
- Coefficient of thermal expansion in transversal direction $\alpha_{\perp}$
- Ultimate tension strength in longitudinal direction $R_{m//^+}$
- Ultimate compression strength in longitudinal direction $R_{m//^-}$
- Ultimate shear strength R_s
- Ultimate compression strain A^{-}

4. Layer specification

Each layer shall be specified in the procedure specification, including information regarding fibre content, material specifications of fibre and resin system, curing agent, resin-to-curing-agent ratio used, and curing procedure followed, as well as thickness, and orientation of each layer.

The following physical and mechanical properties have to be specified for each layer in order to provide for calculation constants necessary to analyze the laminate:

- Young's modulus in longitudinal direction of fibre $E_{//}$

- Young's modulus in transversal direction of fibre $E_{\perp}$
- Shear modulus $G_{\perp//}$
- Major Poisson's ratio $\nu_{\perp//}$
- Minor Poisson's ratio $\nu_{//\perp}$
- Density ρ
- Coefficient of thermal expansion in longitudinal direction of fibre $\alpha_{//}$
- Coefficient of thermal expansion in transversal direction of fibre $\alpha_{\perp}$
- Ultimate tensile strength in longitudinal direction of fibre $R_{m//^+}$
- Ultimate tensile strength in transversal direction of fibre $R_{m\perp^+}$
- Ultimate compression strength in longitudinal direction of fibre $R_{m//}-$
- Ultimate compression strength in transversal direction of fibre $R_{m\perp}-$
- Ultimate shear strength R_s
- Interlaminar shear strength $R_{//\perp}$
- Ultimate strain A

Concerning strengths and ultimate strain, optionally the corresponding laminate values listed under 5., may be specified.

5. Laminate specification

Each laminate shall be specified in the procedure specification, including information regarding layer stacking sequence and orientation of each layer (layer plan).

The following physical and mechanical properties have to be specified for each laminate in order to provide for calculation constants necessary to analyze the composite structure:

- Young's modulus in different directions E_x, E_y, E_z
- Shear modulus G_{xy}
- Poisson's ratio ν_{xy}, ν_{yz}, ν_{zx}
- Density ρ
- Coefficient of thermal expansion α_x, α_y, α_z
- Ultimate tensile strength in different directions R_{mx}^+, R_{mv}^+, R_{mz}^+
- Ultimate compression strength in different directions R_{mx}^-, R_{my}^-,R_{mz}^-
- Ultimate shear strength R_s
- Interlaminar shear strength R_{xy}
- Ultimate strain A

Concerning strengths and ultimate strain, optionally the corresponding laminate values listed under 4. may be specified.

D. Fabrication Requirements

Any work shop involved in the manufacture of FRP has to fulfill the requirements given in [9] Part - 1 Section 1 (see Annex H).

This has to be demonstrated due to a shop approval by BKI. Within the shop approval procedure the work shop is to be inspected by BKI for suitability of its production facilities and adequate qualifications of its personnel. The approval is documented by a statement of shop approval.

A certificate issued by a second or third party may be accepted as objective evidence, however BKI reserves the right to check all relevant documents and audit the contract related areas.

If the work shop has no evidence that the requirements given in [9] Part - 1, Section 1 (see Annex H) are fulfilled, BKI will assess the competency by checking all relevant documents and performing own system audits as necessary.

E. Quality Control Requirements

Each manufacturer shall be responsible for qualifying the design and the procedure specifications used in fabricating fibre-reinforced plastic structure components.

In order to check the structural behaviour of the component and also to check the margin of safety against the defined load conditions qualification tests shall be done (see 2.).

In order to guarantee the quality necessary for the composite structure component tests accompanying manufacturing shall be done (see 1.).

1. Quality control accompanying manufacturing

Requirements given in Section C.3.2.6.2 of [2] and [9] Part - 1 Section 1 (see Annex H) shall be applied.

- A check of manufacturer's written procedure specification shall verify that each process has been properly qualified as required by this document.

– It has to be checked that post cure times and temperatures used conforms the specifications given in the qualified procedure specification.

– It has to be demonstrated that operation of the heating system provides uniform heating over the entire surface of the composite structure to be cured. The temperature shall not differ by more than –3/+5 °C.

– It has to be verified that the adhesive used the preparation of the surfaces to be joined, and the application of the adhesive conform to the procedure specification for qualification of adhesive bonding.

– It has to be assured that all materials used in the fabrication comply with the given requirements. In order to guarantee this:

  – A sample shall be taken from every batch of thermosetting resin compound that is mixed, and this shall be labeled, cured and stored. These samples shall be subjected to random testing of the degree of their curing and the results shall be documented.

  – During production, laminate samples shall be prepared and shall be used for checking the characteristic values and the mechanical properties. The material strength values shall conform with the specified values. If no adequately-sized laminate samples can be obtained from cuttings or sections, then reference laminates produced in parallel to with dimensions of approx. 50 x 50 cm^2 shall be prepared. Their quantity depends either on the number of the components, or the number of production days (the lower number can be chosen).

– All parts to be incorporated into the Wing-In-Ground craft, shall be inspected before fabrication into the completed Wing-In-Ground craft for the purpose of detecting any imperfections which would not meet the requirements given in this document.

– Where possible both sides of the composite structure have to be examined for the following defects: indentations, cracks, voids, air bubbles, exposed fibres, lack of resin, excess resin, thin areas, wrinkling, uniformity of seal surface, and de-lamination.

– It has to be verified by suitable tests that the fabricated composite structure has been properly cured.

– It has to be checked whether the fibre weight of the composite structure conforms the given requirements.

– A non-destructive-test programme shall be defined with respect to each component.

All tests and any permitted re-tests shall be documented and certified by fabricator and have to be verified.

Additional tests of fabrication procedure can be called for if necessary.

1.1 Quality requirements for contact moulding (hand-lay)

It has to be checked whether the fibre reinforcements used conforms the given requirements.

A check of laminating sequence, cure system, method of component attachments, and overall quality shall verify conformity with qualified procedure specification.

1.2 Quality requirements for filament winding

It has to be verified that the fibre, resin and curing agent being used conforms the specifications given in the procedure specification.

It has to be verified that the speed of winding, uniformity of tension, and adherence are closely in conformity with predetermined patterns of the qualified procedure specification.

1.3 Quality requirements for bag-moulding

It has to be checked whether the form of fibre reinforcements used conforms the given requirements.

A check of resin injection pressure, processing temperatures during lay-up, and pumping procedures shall verify conformity with qualified procedure specification.

2. Qualification test

The following checks shall be applied to all prototypes of composite structure components:

– The structure components shall be visually checked for imperfections in the laminate.

– The percent of fibre and resin by weight shall be determined.

– The weight of the components shall be determined and compared with the values given in the Procedure Specification.

– The thickness of the components shall be checked and compared with the values given drawings and used in calculations.

– Thickness shall also be consistent with the fibre-resin ratio and number and thickness of individual layer specified in the procedure specification.

– All physical dimensions shall be checked for compliance with the drawings.

Characteristic tests shall be applied to all prototypes of composite structure components, e.g.:

– Barcol hardness test, to verify that laminate has been cured in accordance with the Procedure Specification

– Differential scanning calorimetry (DSC), to determine the glass transition temperature

– Volumetric expansion test, to verify that the laminate used has a modulus of elasticity within the range specified by the designer

– Suitable static tests utilising loads simulating the expected loads of the structure caused by any expected combination of loads.

– Suitable impact tests utilising impact loads simulating the critical as well as permissible impact loads of the structure.

– Cyclic tests utilising a dynamic load spectrum simulating the expected load spectrum of the structure. Realistic environmental conditions and superposed static load combinations have also to be applied if relevant.

Furthermore, requirements given in Section C.3.2.6.2 of [2] shall be considered.

Paragraphs 2.1 to 2.8 are foreseen to give qualification test requirements for special composite structure components.

All tests and any permitted re-tests shall be documented and certified by the fabricator and have to be verified.

Additional tests of fabrication procedure can be called for if necessary.

Static and/or cyclic testing based on a reduced scaled model has to be accepted by BKI.

2.1 Qualification test requirements for hull structures

To be specified considering individual case.

2.2 Qualification test requirements for struts

To be specified considering individual case.

2.3 Qualification test requirements for hydrofoils

To be specified considering individual case.

2.4 Qualification test requirements for wings

To be specified considering individual case.

2.5 Qualification test requirements for control surfaces

To be specified considering individual case.

2.6 Qualification test requirements for propulsion system components

To be specified considering individual case.

2.7 Qualification test requirements for auxiliary systems

To be specified considering individual case.

2.8 Qualification test requirements for other systems

To be specified considering individual case.

F. Design Requirements

1. General design requirements

The safety concept explained below is based on a close link between requirements related to:

– materials (C.)

– fabrication (D.) and quality control (E.)

– design (F.)

– inspection (G.)

Therefore, special regard has to be paid to

– analyses in parallel to tests (see 1.7.10), in order to realize a close link between tests and calculations, which is necessary because all other calculations have to be verified

– analyses of structural joints (see 1.7.11), because these are mostly the weak points of the structure.

Each component shall:

– perform its function for specified service life

– be capable of withstanding all design loads and load combinations

– be constructed of materials that are compatible with each other and compatible with the environment to which the materials are to be exposed

– conform to the corrosion control requirements

– conform to requirements for fire resistance

– conform to requirements for lightning protection

The present sub-section F. is divided into two parts. The first part, F.1. deals with general design requirements, covering all parts of the FRP-Structure and all components made of composite material. The second part, F.2. to F.9. deals with special design requirements for each part of FRP-Structure and each component mode of composite material.

The first part is organized in

- Safety concept
- Failure modes
- Safety margins and partial safety factors
- Load conditions
- Layer modeling
- Modeling of layered structure
- Numerical analysis of composite structure and components
- Fire safety
- Lightning protection

Within 1.7 the following calculations for design verification are described:

- Fatigue analysis
- Static analysis
- Impact analysis
- Buckling analysis
- Resonance analysis
- Dynamic response analysis
- Transient response analysis
- Analyses in parallel to tests
- Analyses of structural joints

The second part is foreseen to provide design requirements for components and special parts of the structure.

- Special design requirements for hull structures
- Special design requirements for wings
- Special design requirements for control surfaces
- Special design requirements for struts
- Special design requirements for hydrofoils
- Special design requirements for propulsion system components
- Special design requirements for auxiliary systems
- Special design requirements for other systems For each part all deviations from calculations for design verification given in general part are described.

1.1 Safety concept

The design of the structure and components shall be based on an safety assessment of the failure condition severity with regard to the whole Wing-In-Ground craft.

Therefore, the failure condition severity shall be estimated for the structure as well as for each component made of FRP (see Table 12.1).

Table 12.1 Failure Condition Severity as Related to Probability Objectives

Failure Condition Severity		**Minor**		**Major**	**Hazardous**	**Catastrophic**
Probability		**Probable**		**Improbable**		**Extremely Improbable**
(Descriptive)		**Frequent**	**Reasonably Probable**	**Remote**	**Extremely Remote**	**Extremely Improbable**
Probability (Quantitative)	1.0	1E-3	1E-5	1E-7	1E-9	

Concerning the structure, this estimation normally shall lead directly to a fail-safe design. Fail-safe design means that the composite structure shall be designed to be damage tolerant. If components of the structure fail due to overload, structural redundancy takes over the additional load. Structural redundancy cover component redundancy as well as load path redundancy. The fail-safe concept is based on the ability to detect cracks and other structural damage by inspections before the damage reaches an extent that may cause immediate total failure of the structure.

If non-redundant structures are used, it is not possible to apply the fail-safe concept. This concept is called safe-life design and requires the analysis of load and strength of the components including the linked uncertainties like variations in the material properties or variations of loads due to environmental conditions.

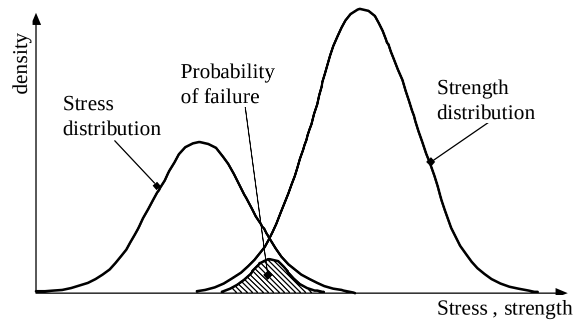

Fig. 12.1

The resulting distribution of loads and strength yields a probability of failure where the loads exceed the strength of the component (see Figure 12.1). The resulting probability of failure must be lower or equal to the safety objective (target probability, see Table 12.1) derived from Hazard identification analysis.

1.2 Failure modes

Analytical and numerical design calculations shall consider all possible failure modes, as a result of

– fatigue

– static loads

– impact loads

– buckling

– vibration

and shall include the critical as well as allowable effects of:

– environment

– service life (residual limit strength and stiffness demonstration)

– load path loss (fail-safe)

– standard fabrication process and its variability

– impact damage expected during service (up to the established threshold of detect-ability of the field inspection methods to be employed)

– point design and structural discontinuity considerations.

Concerning fatigue analyses, calculations shall show a failure probability lower than the estimated permissible value (see 1.7.1).

Concerning static, impact, and buckling analyses all critical, allowable load cases shall be analyzed having a greater probability than the estimated permissible failure probability (see 1.7.4 to 1.7.6).

Concerning vibration analyses, operating conditions shall be analyzed having a greater probability than the estimated permissible value. Generally, vibration analyses shall be divided into resonance analysis, dynamic response analysis, and transient response analysis (see 1.7.7 to 1.7.9).

The fail-safe design of composite structure and components made of FRP shall be assessed and appropriate inspection programs provided to prevent catastrophic failure from damage propagation.

For each component the design life shall be specified, which may be the same or lower than the design life of the whole Wing-In-Ground craft.

1.3 Safety margins and partial safety factors

Within the design process of each component every load case shall be analyzed taking into consideration specific safety margins γ_{FM} paying regard to the failure mode, factor of safety paying regard to the material γ_M, factor of safety paying regard to loads γ_F, and γ_{FC} paying regard to failure criterion.

The design methodology (i.e. safe-life, fail-safe, partially fail-safe, or non-fail-safe) has no influence on safety margins or partial safety factors. The only influence of design methodology is concerning with load cases to be investigated and/or permissible value of failure probability to be specified.

The verifications shall be carried out using guaranteed minimum values respective characteristic values R_k (see C.) divided by the safety margin for failure mode γ_{FM} and the partial safety factor for material γ_M. This leads to the design values R_d, which shall be greater than the load induced values S:

$$S \leq R_k / (\gamma_{FM} \cdot \gamma_M) = R_d$$

Which means, for each layer the design analysis shall verify that the design load effect of each relevant load combination is not greater than the corresponding design resistance.

The safety margins for failure modes γ_{FM} are listed in Table 12.2. Listed maximum values for normal analysis method shall be used. Usage of listed minimum values or values between listed minimum and maximum values shall be approved by BKI in each case. In general, lower values may be applicable in cases where

– sound engineering solutions are adopted, which are tested, well known and reliable or

– a high sophisticated analysis methods are adopted, which are generally accepted and show more reliable results than normal methods.

The safety factors for material γ_M are listed in Table 12.3. The partial safety factor for material γ_M shall be determined by multiplying appropriate factors C_{ij}. Factors verified by experiment may be used as an alternative. The reciprocal gradient k, used within

$C_{1f} = N^{1/k}$ for fatigue, applies without further verification for laminates with a fibre content of at least 40 % by volume (which implies that material behaviour is dominated by fibre). If a higher value for k shall be used, appropriate verification (a S-N curve) is required. The factors C_{2j} (temperature) apply for the influence of ambient temperatures between 30 °C and 60 °C, if the drop in shear or flexural moduli of the laminates at 60 °C compared with that at 23 °C is less than 20 %.

Partial safety factors γ_{FC} paying regard to failure criterion are listed in Table 12.5. The partial safety factor for failure criterion may be applied for

– components classified as non safety critical and
– special cases where it can be shown that inter fibre failure will rise no safety critical situations (these cases shall be approved by BKI).

This leads to the design values R_d, which shall be greater than the load induced values S:

$$S \leq R_k / (\gamma_{FM} \cdot \gamma_M * \gamma_{FC}) = R_d$$

Furthermore, partial safety factors γ_F given in Table 12.4 shall be considered by multiplying loads, which leads to design loads.

$$F_D = F \cdot \gamma_F$$

Compliance with the requirements shall be shown for each critical loading condition. Structural analysis may be used only if the structure conforms to those for which experience has shown this method to be reliable. In other cases, substantiating load tests shall be made. Where substantiating load tests are made these shall cover loads up to the ultimate load, unless it is agreed with BKI that in the circumstances of the case, equivalent substantiation can be obtained from tests to agreed lower levels.

When loading condition is prescribed in terms of ultimate loads, a factor of safety γ_F as well as γ_{FM} need not to be applied unless otherwise specified. Whereas, γ_M shall be considered according to verification test procedure.

Table 12.2 Safety margin for Failure Mode γ_{FM}

Safety margin for Failure Mode γ_{FM}			
Failure Mode		**Maximum value for normal analysis method**	**Minimum value for well known and reliable analysis method**
Fatigue		γ_{FMf} = 1.35	γ_{FMf} = 1.15
Static		γ_{FMs} = 1.35	γ_{FMs} = 1.05
Impact		γ_{FMi} = 1.5	γ_{FMi} = 1.2
Buckling		γ_{FMb} = 1.5	γ_{FMb} = 1.2
Vibration	Resonance	γ_{FMr} = 1.1	γ_{FMr} = 1.05
	Dyn. Resp.	γ_{FMd} = 1.35	γ_{FMd} = 1.15
	Trans. Resp.	γ_{FMt} = 1.35	γ_{FMt} = 1.15

Table 12.3 Partial Safety Factor for Material γ_M

Failure mode	Partial Safety Factor for Material γ_M	Effect having influence	Factors C_{ij} to be used
Fatigue	$\gamma_{Mf} = \Pi_i C_{if}$	fatigue strength at load cycle N and with gradient k = 9 for polyester matrix and k = 10 for epoxy matrix	$C_{1f} = N^{1/k}$
		temperature	$C_{2f} = 1.1$
		no water exposure water exposure of epoxy resin water exposure of polyester resin	$C_{3f} = 1.0$ $C_{3f} = 1.05$ $C_{3f} = 1.1$
		unidirectional (UD) reinforcement product non-woven fabrics and UD woven rovings all other reinforcement products	$C_{4f} = 1.0$ $C_{4f} = 1.1$ $C_{4f} = 1.2$
		post-cured laminate non post-cured laminate	$C_{5f} = 1.0$ $C_{5f} = 1.1$
Static	$\gamma_{Ms} = \Pi_i C_{is}$	ageing (fatigue, moisture)	$C_{1s} = 1.5$
		temperature	$C_{2s} = 1.1$
		laminate made from prepreg as well as semi automatically-manufactured laminates hand lay-up laminate	$C_{3s} = 1.1$ $C_{3s} = 1.2$
		post-cured laminate non post-cured laminate	$C_{4s} = 1.0$ $C_{4s} = 1.1$
Impact	$\gamma_{Mi} = \Pi_i C_{ii}$	ageing (fatigue, moisture)	$C_{1i} = 1.5$
		temperature	$C_{2i} = 1.1$
		laminate made from prepreg hand lay-up laminate	$C_{3i} = 1.1$ $C_{3i} = 1.2$
		post-cured laminate non-post-cured laminate	$C_{4i} = 1.0$ $C_{4i} = 1.1$
Buckling	$\gamma_{Mb} = \Pi_i C_{ib}$	ageing (fatigue, moisture)	$C_{1b} = 1.2$
		temperature	$C_{2b} = 1.1$
		massive laminates and skin layers of sandwich structures to account for the scattering of the moduli core materials, to account for the scattering of the moduli	$C_{3b} = 1.1$ $C_{3b} = 1.3$
		core materials, if verified minimum characteristics are used	$C_{4b} = 1.0$
Resonance	$\gamma_{Mr} = \Pi_i C_{ir}$ check also: $\gamma_{Mr} = 1.0$	ageing (fatigue, moisture)	$C_{1r} = 1.1$
		temperature	$C_{2r} = 1.1$
Dynamic Response	$\gamma_{Md} = \Pi_i C_{id}$ check also:	ageing (fatigue, moisture)	$C_{1d} = 1.5$
	$C_{1d} = C_{2d} = 1.0$	temperature	$C_{2d} = 1.1$
		laminate made from prepreg hand lay-up laminate	$C_{3d} = 1.1$ $C_{3d} = 1.2$
		post-cured laminate non post-cured laminate	$C_{4d} = 1.0$ $C_{4d} = 1.1$
Transient Response	$\gamma_{Mt} = \Pi_i C_{it}$ check also:	ageing (fatigue, moisture)	$C_{1t} = 1.5$
	$C_{1t} = C_{2t} = 1.0$	temperature	$C_{2t} = 1.1$
		laminate made from prepreg hand lay-up laminate	$C_{3t} = 1.1$ $C_{3t} = 1.2$
		post-cured laminate non post-cured laminate	$C_{4t} = 1.0$ $C_{4t} = 1.1$

Table 12.4 Partial Safety Factor for Loads γ_F

Failure mode	Partial Safety Factor for Loads γ_F			
Condition	**Normal**	**Extreme**	**Fault**	**Installation**
Gravity/Inertia forces unfavourable	1.35 – 1.1	1.35 – 1.1	1.0	1.35
Gravity/Inertia forces favourable	1.0	1.0	1.0	1.0
Initial stress due to pre-stress unfavourable	1.2	1.2	1.0	1.0
Initial stress due to pre-stress favourable	0.8	0.8	1.0	1.0
Aerodynamic forces	1.2	1.35	1.0	1.0
Hydrostatic forces	1.0	1.1	1.0	1.5
Hydrodynamic forces	1.2	1.35	1.0	1.0
Functional forces	> 1.0	> 1.0	1.0	> 1.0
Temperature	1.0	1.0	1.0	1.0
Fatigue	1.1			
Impact	1.0			
Buckling	see list above			
Resonance (Pre-stress calculation)	1.0			
Dynamic Response	1.0			
Transient Response	1.0			

Table 12.5 Safety margin for Failure Criterion γ_{FC}

Failure criterion	Safety margin for Failure Criterion γ_{FC}
Fibre-Failure (FF)	$\gamma_{FC} = 1.0$
Inter-Fibre-Failure Mode A (IFF-A)	$\gamma_{FC} = 1.0 / \gamma_M$
Inter-Fibre-Failure Mode B (IFF-B)	$\gamma_{FC} = 1.0 / \gamma_M$
Inter-Fibre-Failure Mode C (IFF-C)	$\gamma_{FC} = 1.35 / \gamma_M$

1.4 Load conditions

In order to determine the safety integrity of a component against all possible modes of failure, all relevant forces, displacements, etc., which may act on a part or the whole of the component, have to be evaluated. The following types of loads shall be taken in consideration:

– Operational, permanent and environmental loads

– Accidental loads

– Maintenance and transport

The operational and permanent loads include all loads based on the system's existence, use and treatment Transient operational effects shall be considered, if relevant.

Environmental loads shall take into account parameters such as the worst conditions of wind force allowable, significant wave height (including un-favourable combinations of length and direction of waves), minimum air temperature, visibility and depth of water for safe operation and such other parameters as the Administration may require in considering the type of craft in the area of operation.

Accidental loads are intended to cover unusual loads and damages resulting from accidents, such as collisions, and unusual operating conditions etc. An accidental load has to be considered if the probability of occurrence is relevant. The relevance has to be agreed by BKI. Accidental loads shall be combined with the least favourable permanent and operational loads.

A combination of an accidental load with other accidental loads or with extreme environmental loads is not required unless the probability of these loads occurring simultaneously is as high as the permissible value of failure probability.

Maintenance and transport loads include all loads and load combinations caused by maintenance and transport conditions. Furthermore, test load conditions shall be considered.

1.4.1 Operational Loads

The operational loads can be grouped into different operational modes:

– Ground-effect mode (main operating mode)

– Displacement mode

– Transitional mode

– Jump-up mode

– Flight mode

Analyses of parts of the structure or components made of fibre reinforced plastics, shall be based on load combinations considering relevant operation mode. These load combinations shall also pay regard to environmental loads or influences from hygrothermal effects.

.1 Ground-effect mode (main operating mode)

The Wing-In-Ground craft shall be designed to withstand loads induced during operating in ground-effect mode.

Analyses of parts of the structure or components made of fibre reinforced plastics, shall be based on load combinations considering

– Aerodynamic loads

– Inertia loads

– Propulsion system loads

.2 Displacement mode

The Wing-In-Ground craft shall be designed to withstand loads induced during operating in displacement mode.

Analyses of parts of the structure or components made of fibre reinforced plastics, shall be based on load combinations considering

– Aerodynamic loads

– Hydrostatic loads

– Hydrodynamic loads

– Inertia loads

– Propulsion system loads

.3 Transitional mode

The transitional modes can be grouped into different phases:

– Transient from displacement to skimming and back

– Skimming (step-taxi) (steady state)

– Transient from skimming to ground-effect operation

– Overcoming of the resistance hump

– Operation just before the separation from the water

Analyses of parts of the structure or components made of fibre reinforced plastics, shall be based on load combinations considering these different transitional phases.

.4 Jump-up mode

Analyses of parts of the structure or components made of fibre reinforced plastics, shall be based on load combinations considering

– Aerodynamic loads

– Hydrostatic loads

– Hydrodynamic loads

– Inertia loads

– Propulsion system loads

induced during jump-up mode.

.5 Flight mode

The Wing-In-Ground craft shall be designed to withstand flight loads.

Regarding the flight loads, requirements given in [10] Section 1 Subpart C and [10] Section 2 Subpart C are to be applied.

1.4.2 Accidental loads

The Wing-In-Ground craft shall be designed to withstand accidental loads, which have relevant probabilities of occurrence (e.g. impact, bird strike, emergency touch-down etc.).

1.4.3 Maintenance and transport loads

The Wing-In-Ground craft shall be designed to withstand all loads caused by activities during maintenance and transport.

Analyses of parts of the structure or components made of fibre reinforced plastics, shall be based on load combinations considering

– Anchoring

– Towing

– Mooring

– Docking

– Berthing

– Testing

– Others

These load combinations shall also pay regard to environmental and operational loads if necessary.

1.5 Layer modeling

In order to analyze a part of the structure or a component made of composite material, a mechanical model has to be defined which shall at least distinguish between different layers. The difference between two layers may be

– fibre angle,

– fibre material,

– fibre content,

– matrix material,

or other effects having an influence on physical or mechanical material properties.

1.5.1 Micromechanics

In order to analyze a composite structure, material properties of each layer are required. Material properties shall be reduced to 90 % for all analyses using dynamic boundary conditions. Material properties shall be set to 100 % for all analyses using kinematic boundary conditions. If the layer properties are not available from tests, then the constituent properties of fibre, resin material, in conjunction with fibre volume fraction, can be used in a micromechanics model to give the layer properties.

Micromechanics shall not be used for calculating strengths or material resistances.

1.5.2 Failure criteria

In order to check the design, only conservative, proven failure criteria shall be used [12].

Global failure criteria such as "Quadratic interaction criterion" may be used for identification of critical zones. In such case, "Maximum stress criterion" shall be used supplementary.

To show evidence that critical zones are well dimensioned, a combination of different failure criteria shall be used, for example the "Maximum stress criterion", "Maximum strain criterion" in addition to "Quadratic interaction criterion" or the criterion given by Puck [5]. This procedure shall enable to distinguish between different failure modes (FF, IFF-A, IFF-B, IFF-C).

1.6 Modeling of layered structure

In order to analyse a part of the structure or a component made of composite material, a mechanical model as well as a calculation technique has to be employed which shall at least allow for a calculation of stress and strain distribution in each layer.

1.6.1 Classical laminate theory

Laminate theory is a mathematical treatment of the mechanics governing the behaviour of a unidirectional orthotropic layer, and the interrelation between multiple layer as they act together to form a multidirectional laminate.

The laminate theory shall be used to:

– determine the in-plane and flexural modulus components that define the stress-strain and moment-curvature relationship for laminates;

– examine the strength of the laminate based on the strain state of individual layer reacting to imposed moment and stress resultants;

– determine the effective engineering constants of the laminate.

Within the laminate theory certain assumptions are to be made. The following assumptions usually will be necessary for this theory:

– interlaminar or transverse shear is not addressed;

– laminate stress resultants and moment resultants are taken as averages of ply stresses across the thickness of the laminate;

– ply stress is based on homogeneity within each ply where the fibre and matrix are not recognised as distinct phases;

– the laminate is assumed to consist of perfectly bonded layer, i.e. displacements are continuous across laminate boundaries and no layer slips relative to another;

– since the stress distribution across a multidirectional laminate is not constant due to the variation in ply modulus, the stress-strain relationship is defined in terms of an average stress.

In each case it has to be paid attention that the idealisation chosen is permissible. If necessary, a failure assessment has to be performed and/or another calculation method shall be used.

1.6.2 Finite element analysis

Finite-element-analysis is a calculation method which shall be chosen, if laminate theory is not applicable.

In general, analysis of structural discontinuities and details to obtain the geometric stress is not possible using analytical methods. Parametric formulae are rarely available. Thus, finite element (FEM) analysis is mostly applied.

The FEM mesh shall be fine enough near the critical point to enable the stress and the stress gradient to be determined.

In following, only some rough recommendations are given:

– Elements are to be selected on the basis of expected stress distribution. Selection shall be verified

– The ratio between the biggest and smallest dimension of an element must not exceed 3 in relevant areas.

– Transition of elements size shall be gradual.

1.7 Numerical analysis of composite structure and components

The design analysis shall be based on suitable calculation methods using programmes approved by BKI. For each layer the design analysis shall verify that the design load effect of each relevant load combination is not greater than the corresponding design resistance.

In the design calculation a change in material properties during the service life (ageing due to mechanical, chemical, and hygrothermal degradation) shall be taken into account, if the effect is not covered within the tested resistance properties.

Furthermore, realistic assumptions may be necessary regarding residual stresses, hygrothermal deformation, and pre-stress condition. Relevant effects have to pay regard to, if the effect is not covered within the tested resistance properties.

Alternatively the influence can be paid regard to in a more global manner using partial safety factor γ_M.

1.7.1 Fatigue analysis

A fatigue analysis shall be performed regarding each part of the structure and each component, which are subject to alternating loads, which can reduce the structural integrity in a safety critical manner during the lifetime.

In order to perform a fatigue analysis

– the lifetime has to be specified;

– all static and alternating loads and corresponding load cycles have to be specified;

– the stress distribution within the structure has to be analysed;

– a S-N-curve has to be determined considering the permissible failure probability (fail-safe);

– a damage calculation by PALMGREN-MINER summation shall be performed.

.1 Lifetime

For each component the design life shall be specified, which may be the same or lower than the design life of the whole Wing-In-Ground craft.

.2 Load spectrum

A long term distribution (load spectrum) shall be established in terms of complete cycles using a appropriate cycle counting method or the load spectrum shall be estimated synthetically.

Special care shall be taken to ensure that the considered load and load cycle number for each load effect are not underestimated.

Temporary situations shall be considered, if the contribution of the corresponding load cycles is relevant. The following effects shall normally be taken into account:

– Environmental loads

– Vibrations

– Transient operational effects.

.3 Stress spectrum

Fatigue assessment shall base on stress range

$$\Delta\sigma = \sigma_{max} - \sigma_{min}$$

The maximum and minimum values of the stresses shall be calculated from a superposition of all non permanent, i.e. fluctuating, actions:

– fluctuations in the magnitude of loads

– movement of loads on the structure

– changes in loading directions

– structural vibrations due to loads and dynamic response

– temperature transients

Fatigue analysis is based on the cumulative effect of all stress range occurrences during the anticipated service life of the structure. The stress range occurrences may be discretised giving a table of discrete blocks in terms of stress range level exceedances versus the number of cycles (stress spectrum). For each block the stress ratio $R = \sigma_{min}/\sigma_{max}$ shall also be considered.

.4 S-N curve

Fatigue verification is carried out using the design resistance S-N curve based on design resistance stresses, in which the characteristic resistance stress ranges have been divided by the partial safety factor γ_M and γ_{FM} for fatigue resistance.

Fatigue life verification of fail-safe structures or components depends largely on the design and operation parameters of the structure. The effectiveness of statically over-determined behaviour or redundancy, the possibility of detection of failures in individual structural part and the possibility of repair determine the level of safety in the individual component.

.5 Damage summation

If the maximum design stress range of the stress spectrum is lower than the design fatigue limit of the design fatigue resistance S-N curve at the maximum cycle number of the stress spectrum the life can be assumed to be infinite and no further damage calculation is necessary (see 1.7.2 Simplified Procedure). All other cases shall be treated in detail (see 1.7.3 Detailed Procedure).

1.7.2 Simplified Procedure

The simplified procedure is only applicable, if the stress spectrum is very simple, i.e. it can be discretised using only one discrete block. A simplification using $\Delta\sigma_{max}$ and n_{max} is allowed.

Given that case, it is possible to define a criterion as simple as for static case.

For safe-life design as well as for fail-safe design the life time has to be specified.

Based on the life time, normal operating conditions, extreme conditions, etc. as well as load combinations, and corresponding load cycles, which all shall be specified within the design basis, the load spectrum shall be estimated synthetically. All load conditions having a relevant number of load cycles and inducing relevant stresses shall be taken into consideration. The structure shall be analysed for each load condition using methods or programmes agreed by the Society. This leads at the end to a stress spectrum, which may be simplified in the above mentioned way.

Within the simplified procedure it has to be shown that the maximum of stress range spectrum is smaller than the permissible design resistance value at the maximum load cycle number of stress spectrum.

This criterion is fulfilled, if

$$\Delta\sigma_{max} \le R_k / (\gamma_{FMf}\ \gamma_{Mf}) = R_d$$

Values for γ_{FMf} are given in Table 12.2. Values for γ_{Mf} are given in Table 12.3. Partial Safety Factors γ_{Ff} given in Table 12.4 shall be considered by multiply-ing loads, which leads to design loads

$$F_{Df} = F\ \gamma_{Ff}$$

Realistic assumptions may be necessary regarding environmental condition, and hygrothermal deformation. Relevant effects have to be paid regard to.

Furthermore, it shall be checked, whether there is a significant influence from present pre-stress condition, i.e. residual stresses and/or additional stresses: In such cases the response amplitude shall be calculated taken into account the relevant pre-stress condition.

1.7.3 Detailed Procedure

For safe-life design as well as for fail-safe design the life time has to be specified.

Based on the life time, normal operating conditions, extreme conditions, etc. as well as load combinations, and corresponding load cycles, which all shall be specified within the design basis, the load spectrum shall be estimated synthetically. All load conditions having a relevant number of load cycles and inducing relevant stresses shall be taken into consideration. The structure shall be analysed for each load condition using methods or programmes approved by the Society. This leads at the end to a stress spectrum, which may be simplified in the above mentioned way.

Within the detailed procedure it has to be shown that the failure probability is smaller than the permissible failure probability. Therefore, the design resistance S- N curve shall be specified. The S-N curve shall be based on experimental data. In cases where no experimental data is available, the slope given in γ_{Mf} (C_{1f} in Table 12.3) may be used in combination with the characteristic resistance value for relevant static loading. Using a S-N curve based on experimental data, it depends on specimens specification, whether the resistance stress ranges shall be divided by the partial safety factor γ_{Mf} for fatigue resistance (Table 12.3). In any case the resistance stress ranges shall be divided by the partial safety factor γ_{FM} (Table 12.2). Using a S-N curve based on slope given in γ_{Mf} (C_{1f} in Table 12.3) the resistance stress ranges shall be divided by the partial safety factor γ_{Mf} for fatigue resistance (Table 12.3) but not using C_{1f} once again.

For fatigue verification it shall be shown that

$$\sum D = \sum_i \frac{n_i}{N_i} \le R_k$$

The safety margin for failure criterion γ_{FC} may be used in order to pay regard for different severity of failure criteria. partial safety Factors γ_{Ff} given in Table 12.4 shall be considered by multiplying loads, which leads to design loads

$$F_{Df} = F \cdot \gamma_{Ff}$$

Realistic assumptions may be necessary regarding environmental condition, and hygrothermal deformation. Relevant effects have to be paid regard to. Furthermore, it shall be checked, whether there is a significant influence from present pre-stress condition, i.e. residual stresses and/or additional stresses: In such cases the response amplitude shall be calculated taken into account the relevant pre-stress condition.

1.7.4 Static analysis

Normal operating conditions, extreme conditions, etc. as well as load combinations shall be specified within the design basis. Furthermore, an average exposure time probability as related to load condition shall be specified. All load conditions, which have to be classified as safety critical considering structural integrity and which show an average exposure time probability greater than related permissible failure probability have to be taken into consideration. For such load conditions the structure has to be analysed using methods or programmes approved by BKI.

It has to be shown that the load induced value S (related to the introduced failure criterion) is smaller than the permissible design value:

This criterion is fulfilled, if

$$S \le R_k / (\gamma_{FMs} \cdot \gamma_{Ms}) = R_d$$

Values for γ_{FMs} are given in Table 12.2. Values for γ_{Ms} are given in Table 12.3. Partial safety factors γ_{Fs} given in Table 12.4 shall be considered by multiplying loads, which leads to design loads

$$F_{Ds} = F \cdot \gamma_{Fs}$$

The safety margin for failure criterion γ_{FC} may be used in order to pay regard for different severity of failure criteria. Therefore the criterion becomes

$$S \le R_k / (\gamma_{FMs} \cdot \gamma_{Ms} \cdot \gamma_{FC}) = R_d$$

Realistic assumptions may be necessary regarding environmental condition and hygrothermal deformation. Relevant effects have to be paid regard to. Furthermore, it shall be checked, whether there is a significant influence from present pre-stress condition, i.e. residual stresses and/or additional stresses: In such cases the load induced value S shall be calculated taken into account the relevant pre-stress condition.

1.7.5 Impact analysis

Normal operating conditions, extreme conditions, etc. as well as load combinations shall be specified within the design basis. Furthermore, an average exposure time probability as related to load condition shall be specified. All load conditions, which have to be classified as safety critical considering impact loads and which show an average exposure time probability greater than related permissible failure probability have to be taken into consideration. For such load conditions the structure has to be analysed using methods or programmes approved by BKI.

It has to be shown that the load induced value S (related to the introduced failure criterion) is smaller than the permissible design value:

This criterion is fulfilled, if

$$S \le R_k / (\gamma_{FMi} \cdot \gamma_{Mi}) = R_d$$

Values for γ_{FMi} are given in Table 12.2. Values for γ_{Mi} are given in Table 12.3. Partial safety factors γ_{Fi} given in Table 12.4 shall be considered by multiplying loads, which leads to design loads

$$F_{Di} = F \cdot \gamma_{Fi}$$

The safety margin for failure criterion γ_{FC} may be used in order to pay regard for different severity of failure criteria. Therefore the criterion becomes

$$S \le R_k / (\gamma_{FMs} \cdot \gamma_{Ms} \cdot \gamma_{FC}) = R_d$$

Realistic assumptions may be necessary regarding environmental condition, and hygrothermal deformation. Relevant effects have to be paid regard to. Furthermore, it shall be checked, whether there is a significant influence from present pre-stress condition, i.e. residual stresses and/or additional stresses: In such cases the load induced value S shall be calculated taken into account the relevant pre-stress condition.

An impact analysis shall show a sufficient margin of safety for each component against nominal loading conditions. If necessary the margin of safety has to be shown based on a load combination which pay regard also to additional loads and environmental condition. Furthermore, realistic assumptions may be necessary regarding residual stresses, hygrothermal deformation, and pre-stress condition. Relevant effects have to be paid regard to.

1.7.6 Buckling analysis

Normal operating conditions, extreme conditions, etc. as well as load combinations shall be specified within the design basis. Furthermore, an average exposure time probability as related to load condition shall be specified. All load conditions, which have to be classified as safety critical considering buckling behaviour and which show an average exposure time probability greater than related permissible failure probability have to be taken into consideration.

For such load conditions the first buckling load has to be analysed using methods or programmes approved by BKI.

It has to be shown that the quotient given by first buckling load F_B and the load specified within the load condition F_D is sufficient. Sufficiency exist, if

$$F_B / F_{Db} < \gamma_{FMb} \cdot \gamma_{Mb}$$

Values for γ_{FMb} are given in Table 12.2. Values for γ_{Mb} are given in Table 12.3. Partial safety factors γ_{Fb} given in Table 12.4 shall be considered by multiplying loads, which leads to design loads

$$F_{Db} = F \cdot \gamma_{Fb}$$

Furthermore, realistic assumptions may be necessary regarding residual stresses and additional loads (i.e. pre-stress condition), environmental condition, and hygrothermal deformation. Relevant effects have to be paid regard to.

1.7.7 Resonance analysis

Normal operating conditions, extreme conditions, etc. as well as load combinations shall be specified within the design basis. Furthermore, an average exposure time probability as related to loading condition shall be specified. All load conditions, which have to be classified as safety critical considering resonance behaviour and which show an average exposure time probability greater than related permissible failure probability have to be taken into consideration.

For such load conditions all natural frequencies within the range of interest (i.e. excitation frequency) have to be analysed using methods or programmes approved by BKI.

It has to be shown that sufficient distances are given between natural frequencies and excitation frequencies. Sufficient distances exist, if

$$f_n < f_e / (\gamma_{FMr} \cdot \gamma_{Mr})$$

or

$$f_n > f_e \cdot \gamma_{FMr} \cdot \gamma_{Mr}$$

where f_n is the natural frequency and f_e is the excitation frequency. Values for γ_{FMr} are given in Table 12.2. Values for γ_{Mr} are given in Table 12.3. Furthermore, it shall be checked, whether there is a significant influence from

– present stress condition: In such cases the natural frequency f_n shall be calculated taken into account the relevant pre-stress condition; therefore, values for γ_{Fr} given in Table 12.4 have to be taken into account, which leads to pre-stress loads

$$F_{Pr} = F \cdot \gamma_{Fr};$$

– damping: In such cases the natural frequency f_n shall be calculated taken into account the relevant damping behaviour;

– environmental condition;

– hygrothermal deformation.

Relevant effects have to be paid regard to.

1.7.8 Dynamic response analysis

A dynamic response analysis may be necessary, if it is not possible to show sufficient distances between natural frequencies and excitation frequencies, or if there are specific requirements regarding the noise reduction.

In such cases a complete forced vibration analysis shall be performed using methods or programmes approved by the Society.

In order to show evidence that there are sufficient distances between natural frequencies and excitation frequencies, as an alternative to resonance analysis (see 1.7.7), the same loading conditions have to be taken into consideration. Moreover, it is necessary to specify the amplitudes for each load condition, which have to be classified as safety critical.

Sufficient distances exist, if

$$q < q_{crit} / (\gamma_{FMd} \cdot \gamma_{Md})$$

where q is the calculated maximum response amplitude for given condition and q_{crit} is the specified safety critical amplitude response amplitude for the given condition. Values for γ_{FMd} are given in Table 12.2. Values for γ_{Md} are given in Table 12.3. Partial safety factors γ_{Fd} given in Table 12.4 shall be considered by multiplying loads, which leads to design loads

$$F_{Dd} = F \cdot \gamma_{Fd}$$

Furthermore, realistic assumptions may be necessary regarding environmental condition, and hygrothermal deformation. Relevant effects have to be paid regard to.

In these calculations the damping behaviour has a significant influence and shall be estimated in a conservative manner.

Furthermore, it shall be checked, whether there is a significant influence from present pre-stress condition, i.e. residual stresses and/or additional stresses: In such cases the response amplitude shall be calculated taken into account the relevant pre-stress condition.

1.7.9 Transient response analysis

A transient response analysis may be necessary, if it is not possible to perform a dynamic response analysis. This case may be given, if there is no harmonic or at least periodic excitation frequency. In such cases a full transient analysis shall be performed using methods or programmes approved by BKI.

In order to show evidence that the deformation due to structural response is smaller than safety critical values, as an alternative to resonance analysis (see 1.7.7) respective dynamic response analysis (see 1.7.8), the same load conditions have to be taken into consideration. It is necessary to specify the safety critical values for structural response for each operating condition.

Evidence can be shown, if

$$q < q_{crit} / (\gamma_{FMt} \cdot \gamma_{Mt})$$

where q is the calculated maximum deformation due to structural response for given condition and q_{crit} is the specified safety critical deformation value for the given condition. Values for γ_{FMt} are given in Table 12.2. Values for γ_{Mt} are given in Table 12.3. Partial safety factors γ_{Ft} given in Table 12.4 shall be considered by multiplying loads, which leads to design loads

$$F_{Dt} = F_t \cdot \gamma_{Ft}$$

Furthermore, realistic assumptions may be necessary regarding environmental condition, and hygrothermal deformation. Relevant effects have to be paid regard to.

In these calculations the damping behaviour has a significant influence and shall be estimated in a conservative manner.

Furthermore, it shall be checked, whether there is a significant influence from present pre-stress condition, i.e. residual stresses and/or additional stresses: In such cases the response amplitude shall be calculated taken into account the relevant pre-stress condition.

1.7.10 Analyses in parallel to tests

Numerical analysis shall be done in parallel to the static and/or cyclic qualification tests (see E.2.) in order to realize a close link between tests and calculations, which is necessary because all other calculations have to be verified. Analyses explained in 1.7.1 to 1.7.9 shall be performed if necessary. Partial safety factors shall be used considering the circumstances given by tests.

Analyses in parallel to tests are absolutely necessary, when the integrity of a component shall be assessed using a down scaled test prototype.

1.7.11 Analyses of structural joints

Structural joints have to be analysed by detail if necessary, because these are often the critical points of the structure. Analyses explained in 1.71 to 1.7.9 shall be performed if necessary.

A coarse calculation, e.g. [6,13], may be used where the structure cannot be analyzed in detail. In such cases all assumptions and estimates made shall be of a strict conservative nature.

In contrast to a coarse calculation, a detailed analysis of a structural joint means often performing a FEM analysis. In this connection it may be necessary to analyse the global structure behaviour, in order to estimate the correct boundary conditions for the detailed analysis. Within a detailed analysis it may be necessary to pay regard to contact conditions, e.g. pre-stress, gaps, friction, etc.

1.8 Fire Safety

Regarding the fire safety, requirements given in [2] section 7 are to be applied.

1.9 Lightning protection

The Wing-In-Ground craft must be protected against catastrophic effects from lightning.

For FRP components compliance with this demand can be shownby

– Designing the components to minimise the effect of a strike; or

– Incorporating acceptable means of diverting the resulting electrical current so as not to endanger the Wing-In-Ground craft.

Protection shall be provided and substantiated using analysis and tests.

2. Special design requirements for hull structures

To be specified considering individual case.

3. Special design requirements for wings

To be specified considering individual case.

4. Special design requirements for control surfaces

To be specified considering individual case.

5. Special design requirements for struts

To be specified considering individual case.

6. Special design requirements for hydrofoils

To be specified considering individual case.

7. Special design requirements for propulsion system components

To be specified considering individual case.

8. Special design requirements for auxiliary systems

To be specified considering individual case.

9. Special design requirements for other systems

To be specified considering individual case.

G. Inspection and Maintenance

Regarding inspection and maintenance, requirements given in [2] , Section 19 are to be applied.

H. Repair

BKI shall be informed about repairs of any component faults relevant to the strength of the component, and the procedure used to carry out the repair shall be agreed on with BKI before work starts.

Furthermore, requirements given in [9] (see Annex J) are to be applied.

I. Documentation

Design and manufacturing particulars are to be submitted for approval well in advance of the commencement of manufacturing.

The documents are generally to include:

- Design basis
- Design report
- Detailed manufacturing drawings
- Manufacturing specification

1. Design basis

The design basis shall include all requirements for the design and analysis of the component. It shall include all information necessary before any detailed engineering is started. Where no information is available, values assumed shall be stated in the design basis. The design basis shall cover:

- all functional requirements,
- all relevant environmental conditions,
- all relevant load cases,
- all loads expected from accidental events, and
- all combinations of accidental events and other loads.

An independent verification of the accuracy and completeness of the information used for the design basis is essential.

2. Design Report

The design report shall include all relevant detailed engineering information. In detail it shall cover:

- a documentation of all material specifications according to C.1. to C.5.
- a documentation of all calculations carried out
- all information to fulfill requirements given in [2] Section 3, C.3.0
- a documentation of all tests done and tests to be performed
- the time schedule of manufacturing including an appointment list for survey plus milestones
- the layer plan of each specified laminate
- each laminate shall be specified in the procedure specification, including information regarding
  - fibre content,
  - layer stacking sequence including material specifications of
    - fibre and resin system,
    - curing agent,
    - resin-to-curing-agent ratio used, and
    - curing procedure followed, as well as
    - thickness, and
    - orientation of each layer

3. Manufacturing drawings

Manufacturing drawings of composite structure components shall give a clear local indication of each laminate specified within the structure. Where required, detailed drawings shall be attached.

Furthermore, detailed manufacturing drawings of all structural joints and adjacent components shall be submitted to BKI. Manufacturing drawings shall clearly reference detailed manufacturing drawings.

Manufacturing drawings shall include bills of material as well as details on tolerances, masses, operating parameters and operating limits.

4. Manufacturing specification

The manufacturing specification shall include all procedure specifications, material specifications according to [9] Part - 1, Section 2 as well as a quality control documentation.

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Annex A

Documents to be submitted

Depending on the design of the craft, the following drawings and documents are to be submitted, as applicable, at least in triplicate[1)] for approval. BKI reserves its right to ask for supplementary copies, if deemed necessary in particular cases. Further documentation may be required, if deemed necessary by BKI . The list corresponds to the requirements for documents to be submitted in the individual Sections. A time schedule of submission of documents is to be agreed upon between the company and BKI .

1. Buoyancy, stability and subdivision

- Hull, plotted and numerically
- Side contour, plotted and numerically
- Coordinates of non-watertight and non-weather tight openings
- Hydrostatic tables
- Cross curve tables
- Data of boundaries of all sub-compartments and a plan in which these compartments are stated
- Damage stability investigation, complete input and output data including initial loading conditions
- Damage control plan
- Inclining test report
- Intact stability booklet

2. Structures

Table A.1 lists the structural plans to be submitted.

3. Accommodation and escape measures

- Plan showing the arrangement of the passenger compartment containing the indication of seat characteristics, installation, and the characteristics of the safety belts
- Plan showing the means of escape and the means of access to the various craft spaces
- Plan showing the arrangement of means of communication
- Windows, arrangements and details
- Calculation of the collision load and collision length
- Plan showing the relevant arrangement of exits intended to be used in an emergency
- Evacuation procedure and evacuation time calculation

4. Directional and height control systems

- Assembly and general drawings of all directional and height control surfaces in connection with their control systems
- Diagram and description of the control systems architecture
- Detail drawings of all load-transmitting components
- Diagrams of hydraulic and electric equipment, if applicable
- Hardware and Software fault tolerance architectures, if applicable
- Plan showing design of pressure vessels
- Plan for verification and validation in accordance with IEC 1508, if applicable

The drawings and other documents shall contain all data necessary for verifying scantlings and power calculations and shall include material specifications.

[1)] For Indonesia Flag ship in quadruplicate (one for Indonesian Government)

Table A.1 Documents to be submitted for structural drawing approval / examination:

Plan	Containing information	Remarks
General Arrangement	- Overview - watertight transverse and longitudinal bulkheads compartments. - aerodynamic loads and distribution of wing and control surfaces.	3 x for information
Midship Section	- moulded dimensions, speeds, limit wave heights, position of center of gravity and gyration radii. - materials and alloys - structural details of hull at main step or x/L = 0.5 and wing spar - typical structural details.	3 x for approval / examination
Main Sections	- transverse and longitudinal structure details.	3 x for approval / examination
Longitudinal Sections	- position of centre of gravity	3 x for approval / examination
Shell Expansion	- hull, sponson and wing with openings - direction of laminate	3 x for approval / examination
Decks	- openings - static deck loads - structural details with seat rails and lashing points	3 x for approval / examination
Watertight Bulkheads	- openings - position of air vents - structural details	3 x for approval / examination
Machinery Space Structure	- machinery mass and position of center of gravity - joining details.	3 x for approval / examination
Tanks	- position, volumes, liquid densities, setting pressures. - structural details with foundations/substructure	3 x for approval / examination
Wing Sections	- openings - structural details	3 x for approval / examination
Control Surfaces	- openings, flaps - structural details	3 x for approval / examination
Equipment	- lateral and profile view of the craft - anchor equipment - calculation	3 x for approval / examination
Windows	- positions, dimensions - strength and specification	3 x for approval / examination
Appendages	- dimensions - loads, load distribution	3 x for approval / examination
Steering Arrangements	- loads - structural details	3 x for approval / examination
Seats	- structural details of crew and passenger seats - dynamic test reports - fire test reports	3 x for approval / examination 1 x for type approval 1 x for type approval
Trial and Test Procedure		1 x for information
Trial Reports		1 x for information
Materials	- specification - arrangement of laminate	1 x for information
Service Area	- sea area, routes	1 x for information
Manuals		1 x for information
Direct Calculation	- any performed direct calculations	1 x for information
Test and Measurements	- results	1 x for information
Weight Distribution		1 x for information

5. Fire safety

- Documents showing the measures of structural fire protection (fire-resisting subdivision, use of materials etc.)
- Plan showing the arrangement of the means of escape
- Schematic plan concerning the natural and mechanical ventilation, with indication of location of dampers and identification numbers of the fans serving each craft section
- Plan showing automatic fire detection systems, including fire alarm systems
- Plan relating to the fixed water fire-extinguishing system (pumps, piping, etc.)
- Plan relating to the arrangement of fixed foam, gas or water mist fire-extinguishing systems
- Plan relating to the arrangement of fixed pressure water-spraying system for special category spaces
- Constructional plans relevant to pressure vessels or bottles serving fixed fire extinguishing systems
- Plans of pumping and drainage means for the water delivered by fixed fire-extinguishing systems
- Fire control plan

6. Propulsion machinery systems

- Before the start of manufacture, plans showing the general arrangement of the machinery installation together with all drawings of parts and installations subject to testing, to the extent specified in the relevant sections of Rules of Machinery Installations, Volume III are to be submitted
- Plans and drawings showing the design and arrangement of transmission components such as shaftings, couplings, clutches and gears in propulsion, manouvering and lifting devices
- Plans showing the design and arrangement of propulsion devices
- The drawings must contain all the data necessary for approval. Where necessary, strength calculations according to recognised calculation procedures and descriptions of the plant are to be submitted
- Maintenance and inspection charts showing intervals and specifying tasks to be carried out
- Once the documents submitted have been approved by BKI they are binding. Subsequent modifications require BKI's approval before being put into effect

7. Auxiliary machinery systems

- Machinery arrangement plan showing the layout of machinery components such as engines, fans, heat exchangers, generators, switchboards, pumps, excluding pipes, valves and accessories
- Maintenance and inspection charts showing intervals and specifying tasks to be carried out

Drawings of:

- Tank arrangement for fuel and other flammable fluids
- Fuel systems (bunkering, transfer and service)
- Lubricating oil systems, including storage and distribution
- Hydraulic Systems
- Cooling water systems (seawater and fresh water)
- Starting arrangement for propulsion engines
- Exhaust gas systems
- Bilge pumping and drainage systems
- Air, overflow and sounding pipes
- Ballast systems
- Sanitary systems
- Fittings on side and bottom
- Arrangement of remote controlled valves
- Ventilation Systems for machinery spaces and other technical spaces

The drawings or accompanying lists are to include the following particulars:

- Outside diameters and wall thickness of pipes
- Materials for pipes, valves and fittings
- Type and capacity of pumps
- Type of pipe connection, flexible hose assemblies and expansion elements
- Maximum working pressures
- Temperature ranges
- Equipment list

8. Remote control, alarm and safety systems

- Layout diagrams showing the location of individual components, input and output devices, control cabinets and interconnection lines between the components
- Wiring and piping diagrams including details of their material and connecting units

- Plans and specifications showing the working principles of the system with comprehensive description
- List of instruments stating name of manufacturers, types, working ranges, set points and application with regard to their environmental conditions
- Plans of control and monitoring panels with details on their instrumentation and control devices
- List of operating values of machinery and limits for alarm and safety action threshold
- Diagrams of electric and non-electric power supply
- System analysis of programmable electronic systems including hardware configuration algorithms
- Plan for verification and validation in accordance with IEC 1508, if applicable

9. Electrical installations

- Single line general diagram of the electrical power generating and distribution with description of the operation modes (including emergency installation)
- Data sheets of generators
- Data sheets and circuit diagrams of UPS units
- Electrical power balance
- List of circuits including, for each supply and distribution circuit, data concerning the nominal current, the cable type, length and cross-section, nominal and setting values of the protective and control devices
- Diagram of the main cable runs showing cables for duplicated equipment and the location of the main and emergency switchboards
- Functional circuit diagram of the main switchboard and a list with the main components
- Functional circuit diagram of the emergency switchboard and a list with the main components
- Diagram of the most important section boards
- Diagram of the supply, monitoring and control systems of the steering and stabilization gear
- Diagram of the supply, monitoring and control systems of the propulsion plant
- Diagram of the general alarm system
- Diagram of the navigation-light switchboard
- Electrical diagram of the engines fire alarm and fire extinguishing system
- Electrical diagram of the compartments fire alarm and fire extinguishing system
- Electrical diagram of the explosion suppression in the tank ventilation
- Diagram and description of the horizontal measuring unit
- Diagram of the public address system or other inter-communication systems
- Electrical diagram of the ice and rain protection system
- Description of the lightning protection in case of plastic steering rudders and flaps
- Diagram of EMC measurements for essential electronic installations
- Diagrams of switchboards for control, indication and alarm of watertight doors
- Diagram of the emergency lighting system

10. Navigation equipment

- Visibility from the control station in the operating compartment
- Arrangement of navigation equipment in the operating compartment
- Configuration of consoles, including equipment
- List of equipment, including type, manufacturer and type approval authority
- Block diagrams showing the functionally connected appliances, as well as their power supply

11. Radio communication

- Antenna drawings (location of antennas and EPIRB)
- Radio equipment arrangement drawings (layout on control station)
- Cable diagrams (antenna connections, power connection, interface connection)
- List of radio equipment (product description, type, manufacturer, approval no., approval authority)
- Battery capacity calculation for the reserve source of energy (with list of connected consumers and their load)

12. Anchoring, Towing and Berthing

- A detailed drawing, showing all the elements necessary for the evaluation of the equipment number of the craft, is to be submitted together with the calculations of the EN number

– The anchoring equipment to be fitted on the concerned craft is to be specified

– Windlass, brake and stopper are subject to approval by BKI . The relevant documentation is to be submitted

– Description of the anchoring procedure and associated equipment

– Description of the towing procedure and associated equipment

– Description of the berthing procedure and associated equipment

13. Operation, inspection and maintenance

– Craft operating manual

– Route operational manual

– Training manual;

– Maintenance manual; and

– Servicing schedule

14. Safety assessment

The owner shall submit a time schedule for the performance of the Safety Assessment. In consultation with the owner, BKI will integrate into the time schedule its review and approval tasks relating to the FHA, PSSA, SSA and to survey activities.

The results of the Safety Assessment shall be documented in a report addressing the three main elements of the assessment process: (i) Functional Hazard Assessment, (ii) Preliminary System Safety Assessment, and (iii) System Safety Assessment. The report shall be submitted in triplicate[2)] for approval and provide the following information so that there is traceability of the steps taken in developing the analysis:

14.1 Functional Hazard Assessment (FHA)

– FHA input function list covering all craft systems

– Environmental and emergency/ abnormal configuration list

– For each system:

  – System definition (block diagram, boundaries, interfaces, operational limits)

  – System description (operational procedures, maintenance regime)

  – Functional description (top-down description: system ⟶ components)

  – Functional relationship with external systems

  – FHA worksheets

  – Supporting material for classification of failure conditions

  – Verification methods

  – System summary

  – Conclusions

14.2 Preliminary System Safety Assessment (PSSA)

– Planned compliance method with FHA requirements

– List of Failure Conditions for further analysis

– Fault Trees or Dependence Diagrams

– Lower level safety requirements

– Operational requirements (maintenance tasks, checks, etc.)

14.3 System Safety Assessment (SSA)

– Updated Failure Condition list

– Fault Trees or Dependence Diagrams showing compliance with safety requirements

– Documentation showing how requirements for the design of the system item's installation (segregation, separation, protection, etc.) have been incorporated.

15. Tests

– Schedule detailing the scope and time frame of demonstration and verification tests

16. Design of fibre reinforced plastics structures and components

Design and manufacturing particulars are to be submitted for approval well in advance of the commencement of manufacturing. The documents are generally to include:

– Design basis

– Design report

– Detailed manufacturing drawings

– Manufacturing specification

16.1 Design basis

The design basis shall include all requirements for the design and analysis of the component. It shall include all information necessary before any detailed engineering is started. Where no information is available, values assumed shall be stated in the design basis. The design basis shall cover:

– all functional requirements,

– all relevant environmental conditions,

2) For Indonesia Flag ship in quadruplicate (one for Indonesian Government)

– all relevant load cases,

– all loads expected from accidental events, and

– all combinations of accidental events and other loads.

An independent verification of the accuracy and completeness of the information used for the Design Basis is essential.

16.2 Design Report

The Design Report shall include all relevant detailed engineering information. In detail it shall cover:

– a documentation of all material specifications according to C.1 to C.5 of Section 12

– a documentation of all calculations carried out

– all information to fulfill requirements given in Rules of High Speed Craft (HSC) Section 3.C.3.0

– a documentation of all tests done and tests to be performed

– the time schedule of manufacturing including an appointment list for survey plus milestones

– the layer plan of each specified laminate

– each laminate shall be specified in the Procedure Specification, including information regarding

– fibre content,

– layer stacking sequence including material specifications of

  – fibre and resin system,

  – curing agent,

  – resin-to-curing-agent ratio used, and

  – curing procedure followed, as well as

  – thickness, and

  – orientation of each layer

16.3 Manufacturing Drawings

Manufacturing drawings of composite structure components shall give a clear local indication of each laminate specified within the structure. Where required, detailed drawings shall be attached. Furthermore, detailed manufacturing drawings of all structural joints and adjacent components shall be submitted to the Society. Manufacturing drawings shall clearly reference detailed manufacturing drawings.

Manufacturing drawings shall include bills of material as well as details on tolerances, masses, operating parameters and operating limits.

16.4 Manufacturing Specification

The Manufacturing Specification shall include all Procedure Specifications, Material Specifications according to Rules of Non Metallic Material Part-1, Part-2, Part-3 as well as a Quality Control Documentation.

Annex B

Ice Accretion

1. Icing allowances

1.1 For craft operating in areas where ice accretion is likely to occur, the following icing allowance shall be made in the stability calculations.

.1 30 kg/m² on exposed weather decks and gangways;

.2 7.5 kg/m² for projected lateral area of each side of the craft above the waterplane;

.3 the projected lateral area of discontinuous surfaces of rail, sundry booms, spars (except masts) and rigging and the projected lateral area of other small objects shall be computed by increasing the total projected area of continuous surfaces by 5 % and the static moments of this area by 10 %;

.4 reduction of stability due to asymmetric ice accumulations in cross-structure.

1.2 For craft operating in areas where ice accretion may be expected:

.1 Within the areas defined in 2.1, 2.3, 2.4 and 2.5 known to have icing conditions significantly different from those in 1.1, ice accretion requirements of one half to twice the required allowance may be applied.

.2 Within the area defined in 2.2, where ice accretion in excess of twice the allowance required by 1.1 may be expected, more severe requirements than those given in 1.1 may be applied.

1.3 Information shall be provided in respect of the assumptions made in calculating the condition of the craft in each of the circumstances set out in this annex for the following:

.1 duration of the voyage in terms of the period spent in reaching the destination and returning to port; and

.2 consumption rates during the voyage for fuel, water, stores and other consumables.

2. Areas of icing conditions

In the application of 1., the following icing areas shall apply:

.1 The area north of latitude 65°30'N, between longitude 28°W and the west coast of Iceland; north of the north coast of Iceland; North of the rhumb line running from latitude 66°N, longitude 15°W to latitude 73°30' N, longitude 15 E, north of latitude 73°30' N between longitude 15°E and 35°E, and east of longitude 35°E, as well as north of latitude 56°N in the Baltic Sea.

.2 The area north of latitude 43°N bounded in the west by the North American coast and the east by the rhumb line running from latitude 43°N, longitude 48°W to latitude 63°N, longitude 28°W and thence along longitude 28°W.

.3 All sea areas north of the North American continent, west of the areas defined in sub-paragraphs .1 and .2 of this paragraph.

.4 The Bering and Okhotsk Seas and the Tartary Strait during the icing season.

.5 South of latitude 60°S.

A chart to illustrate the areas is attached.

3. Special requirements

Craft intended for operation in areas where ice accretion is known to occur shall be:

.1 designed to minimize the accretion of ice; and

.2 equipped with such means for removing ice as the Administration may require.

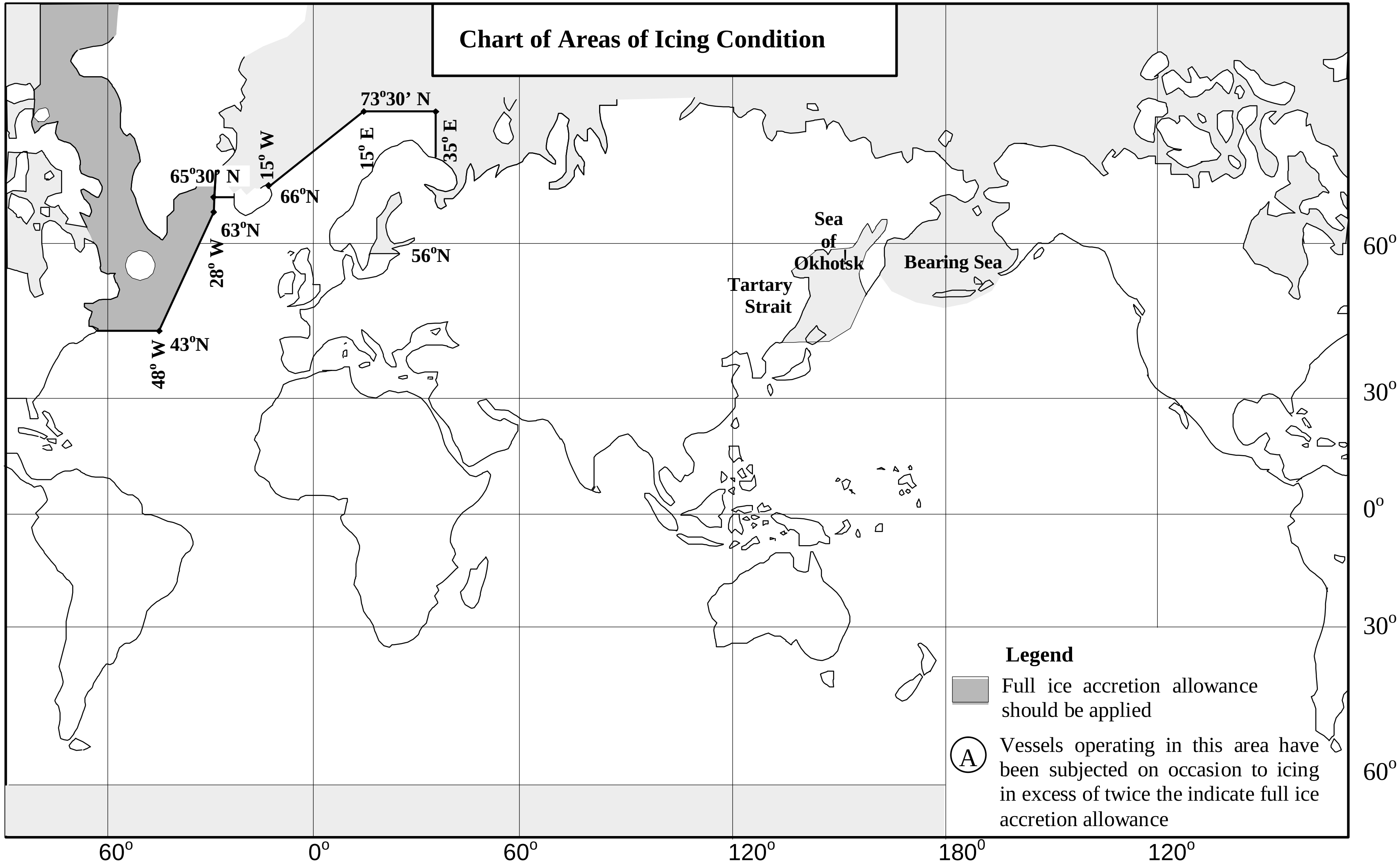
Chart of Areas of Icing Condition
73°30' N
15° E
35° E
15° W
65°30' N
66°N
63°N
56°N
28° W
43°N
48° W
Sea of Okhotsk
Tartary Strait
Bearing Sea
60°
30°
0°
30°
60°
60°
0°
60°
120°
180°
120°
Legend
Full ice accretion allowance should be applied
A
Vessels operating in this area have been subjected on occasion to icing in excess of twice the indicate full ice accretion allowance

Fig.B.1

Annex C

Residual Stability

1. Stability criteria in the intact condition

A WIG craft, in the intact condition and in displacement mode, shall have sufficient stability when rolling in a seaway to successfully withstand the effect of either passenger crowding or high-speed turning as described in 1.4. The craft's stability shall be considered to be sufficient provided compliance with this paragraph is achieved.

1.1 Area under the GZ curve

The area (A1) under the GZ curve up to an angle θ shall be at least:

$$A1 = 0.055 \cdot 30°/\theta \ [\text{m} \cdot \text{rad}]$$

where θ is the least of the following angles:

.1 the down flooding angle;

.2 the angle at which the maximum GZ occurs; and

.3 30°

1.2 Maximum GZ

The maximum GZ value shall occur at an angle of at least 10°.

1.3 Heeling due to wind

The wind heeling lever shall be assumed constant at all angles of inclination and shall be calculated as follows:

$$HL_1 = \frac{P_i . A . Z}{9800 D} \quad [\text{m}] \quad (\text{see Fig. C.1})$$

$$HL_2 = 1.5\ HL_1 \quad [\text{m}] \quad (\text{see Fig. C.1})$$

where:

P_i[1)] = 500 [Pa]

A = projected lateral area of the portion of the ship above the lightest service waterline [m^2]

Z = vertical distance from the centre of A to a point one half the lightest service draught [m]

D = Displacement [t]

1.4 Heeling due to passenger crowding or high-speed turning

Heeling due to the crowding of passengers on one side of the craft or to high-speed turning, whichever is the greater, shall be applied in combination with the heeling lever due to wind (HL_2).

1.4.1 Heeling due to passenger crowding

When calculating the magnitude of the heel due to passenger crowding, a passenger crowding lever shall be developed using the assumptions stipulated in Section 2, F.1. of this Rule.

1.4.2 Heeling due to high-speed turning

When calculating the magnitude of the heel due to the effects of high-speed turning, a high-speed turning lever shall be developed using the following formula:

$$TL = \frac{1}{g}\frac{V_o^2}{R}\left(KG - \frac{d}{2}\right)[\text{m}]$$

where:

TL = turning lever [m]

V_0 = speed of craft in the turn [m/s]

R = turning radius [m]

KG = height of vertical centre of gravity above keel [m]

D = mean draught [m]

g = acceleration due to gravity [m/s^2]

1.5 Rolling in waves (Fig. C.1 and C.2)

The effect of rolling in a seaway upon the craft's stability shall be demonstrated mathematically. In doing so, the residual area under the GZ curve (A_2), i.e. beyond the angle of heel (θh), shall be at least equal to 0.028 m·rad up to the angle of roll θr. In the absence of model test or other data θr shall be taken as 15° or an angle of (θd – θh), whichever is less.

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1) The value of *Pi* for ships in restricted service may be reduced, subject to the approval by BKI.

2. Criteria for residual stability after damage

2.1 The method of application of criteria to the residual stability curve is similar to that for intact stability except that the craft in the final condition after damage shall be considered to have an adequate standard of residual stability provided:

.1 the required area A_2 shall be not less than 0.028 m · rad (Fig. C.2 refers); and

.2 there is no requirement regarding the angle at which the maximum GZ value shall occur.

2.2 The wind heeling lever for application on the residual stability curve shall be assumed constant at all angles of inclination and shall be calculated as follows:

$$HL_3 = \frac{P_d.A.Z}{9800D}$$

where:

P_d = 120 [Pa]

A = projected lateral area of the portion of the ship above the lightest service waterline [m²]

Z = vertical distance from the centre of A to a point one half of the lightest service draught [m]

D = displacement [t]

2.3 The same values of roll angle shall be used as for the intact stability.

2.4 The downflooding point is important and is regarded as terminating the residual stability curve. The area A_2 shall therefore be truncated at the down-flooding angle.

2.5 The stability of the craft in the final condition after damage shall be examined and shown to satisfy the criteria, when damaged as stipulated in Section 2, D.1.6 and D.1.7 of this Rule.

2.6 In the intermediate stages of flooding, the maximum righting lever shall be at least 0.05 m and the range of positive righting lever shall be at least 7°. In all cases, only one breach in the hull and only one free surface need to be assumed.

3. Application of heeling levers

3.1 In applying the heeling levers to the intact and damaged curves, the following shall be considered:

3.1.1 for intact condition:

.1 wind heeling lever - steady wind (HL_1); and

.2 wind heeling lever (including gusting effect) plus either the passenger crowding or speed turning levers whichever is the greater (HTL).

3.1.2 for damage condition:

.1 wind heeling lever – steady wind (HL_3); and

.2 wind heeling lever plus heeling lever due to passenger crowding (HL_4)

3.2 Angles of heel due to steady wind

3.2.1 The angle of heel due to steady wind when the heeling lever HL_1, obtained as in 1.3, is applied to the intact stability curve shall not exceed 16°; and

3.2.2 The angle of heel due to steady wind when the heeling lever HL_3, obtained as in 2.2, is applied to the residual stability curve after damage, shall not exceed 20°.

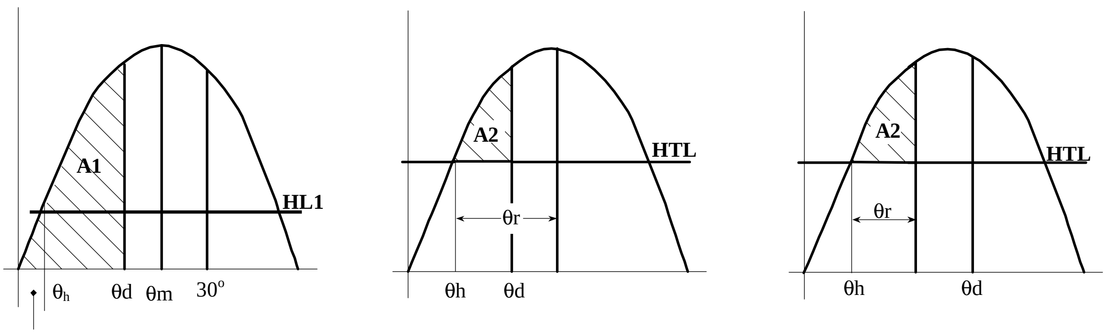

Fig.C.1: Intact Stability

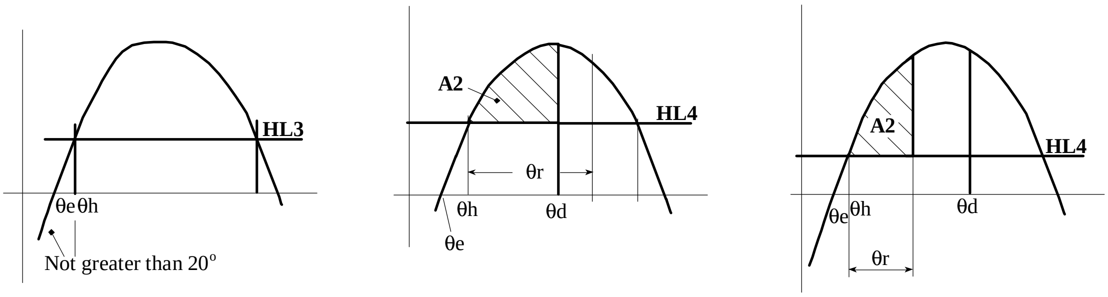

Fig.C.2: Damage Stability

HL_1	=	Heeling lever due to wind
HL_2	=	Heeling lever due to wind + gusting
HTL	=	Heeling lever due to wind + gusting + (passenger crowding or turning)
HL_3	=	Heeling lever due to wind
HL_4	=	Heeling lever due to wind + passenger crowding
θm	=	Angle of maximum GZ

θd	=	Angle of downflooding
θr	=	Angle of roll
θe	=	Angle of equilibrium, assuming no wind, passenger crowding or turning effects
θh	=	Angle of heel due to heeling lever HL1,HTL,HL3 or HL4
A1	=	Area required by 1.1
A2	≥	0.028 m.rad

Annex D

Definitions, Requirements and Compliance Criteria Related to Operational and Safety Performance

This Annex applies to WIG craft as defined in Section 1, D.1. Tests to evaluate operational safety shall be conducted on the prototype craft of a new design or of a design incorporating new features which may modify the results of a previous testing. The tests shall be carried out to a schedule agreed between the Administration and the manufacturer. Where conditions of service warrant additional testing (e.g., low temperature), the Administration or base port state authorities as appropriate may require further demonstrations. Functional descriptions, technical and system specifications relevant to the understanding and evaluation of craft performance shall be available.

The objective of these tests is to provide essential information and guidance to enable the craft to be operated safely under normal and emergency conditions within the design speed and environmental envelope.

The following procedures are outlined as requirements in dealing with verification of craft performance.

1. Performance

1.1 General

1.1.1 The craft shall meet the applicable operational requirements in Section 8 of these Rules and this Annex for all extremes of passenger and load configurations for which certification is required. The limiting sea state related to the different modes of operation shall be verified by tests and analyses of a craft of the type for which certification is requested.

1.1.2 Operational control of the craft shall be in accordance with procedures established by the applicant for operation in service. Procedures to be established shall be start, take-off, cruise, safety and emergency landing and stop and (harbour) manoeuvre procedures.

1.1.3 The procedures established under 1.1.2 shall:

.1 demonstrate that normal manoeuvres and craft responses to failures are consistent in performance;

.2 use methods or devices that are safe and reliable; and

.3 include allowance for any time lag in the execution of procedures that may reasonably be expected in service.

1.1.4 Procedures required by this Annex shall be conducted over water of sufficient depth such that craft performance will not be affected.

1.1.5 Tests shall be conducted at minimum practicable weight and additional testing shall be conducted at maximum weight sufficient to establish the need for additional restrictions and for testing to examine the effect of weight.

2. Start and take-off

2.1 These tests are to establish the acceleration experienced when taking-off the craft in calm water with no passenger load or cargo load during the following conditions:

.1 start from manoeuvre and displacement speed to skimming speed

.2 take-off from skimming speed including the end of the start procedure where the required start power is reduced to cruise speed power.

3. Stopping

3.1 These tests are to establish the acceleration experienced when stopping the craft in calm water with no passenger load or cargo load during the following conditions:

.1 safety landing and stop from cruise speed in ground-effect mode.

.2 emergency landing (incl. crash stop) cruise speed in ground-effect mode.

3.2 The tests referred to in 3.1.1 and 3.1.2 shall document that the accelerations do not exceed safety level 2 of Table 11.4 in Section 11, when control levers are used in accordance to written procedures as given in the craft operating manual or in an automatic mode. Should safety level 2 be exceeded during safety landing and stop, control systems shall be modified in order to avoid exceedance. Shall safety level 2 be exceeded during emergency landing and stop, then written procedures in the craft operating manual shall include detailed information of how to avoid exceedance or the control system shall be modified to avoid exceedance. Otherwise the g_{coll} described in Table 11.4 of Section 11 is to be increased in every direction by the greatest ratio of measured/listed acceleration.

3.3 Other tests shall be repeated during craft turning in all modes of operation to establish the need or otherwise to impose any speed-related restrictions during manoeuvres.

4. Cruise performance

4.1 This test is to establish the craft performance and accelerations experienced during cruise modes with no passenger load or cargo load during the following conditions:

.1 normal operation conditions are those in which the craft will safely cruise at any heading while manually operated, auto-pilot assisted operated or operated with any automatic control system in normal mode; and

.2 worst intended conditions, referred to in Section 1, E.67. of these Rules, are those in which it shall be possible to maintain safe cruise without exceptional piloting skill. However, operations at all headings relative to the wind and sea may not be possible. The performance and accelerations shall also be established in displacement and in skimming mode during operation in the worst intended condition.

4.2 Operation levels, as defined in 4.1, shall be established and documented by full-scale tests in at least two relevant sea conditions and in head, beam and following seas. Test periods shall be at least 5 minutes. Model tests and mathematical simulations could be used to verify the performance in the worst intended conditions.

Limits for normal operation condition shall be documented by measurements of craft speed, heading to the wave and interpolation of measurements of maximum horizontal accelerations in accordance with Table 11.4 of Section 11 Measurement of wave height and period shall be made to the maximum extent practicable.

Limits for worst intended condition shall be documented by measurements of craft speed, wave height and period, heading to the wave and by root mean square (RMS) values of horizontal accelerations in accordance with Table 11.4 of Section 11 and of vertical accelerations close to the craft longitudinal centre of gravity. RMS values could be used for extrapolation of peak values. To obtain the expected peak values related to structural design load and safety levels (one per 5-min exceedance), multiply the RMS values by 3.0 or

$$C = \sqrt{2 \ln N}$$

where N is the number of successive amplitudes within the relevant period.

If not otherwise verified by model tests or by mathematical calculations, it might be assumed a linear relation between wave height and accelerations based on measurements in the two sea conditions. Limits for worst intended condition shall be documented both related to passenger safety in accordance with Table 11.4 of Section 11 and related to the actual structural design load of the craft.

4.3 The tests and verification process shall document the limiting seas for safe operation of the craft:

.1 in normal operation at cruise speed the accelerations shall not exceed safety level 2 of Table 11.4 of Section 11 with an average of one per 5-min period. The craft operating manual shall include detailed description of the effects of speed reduction, increase of speed or change of heading to the waves in order to prevent exceedance;

.2 in the worst intended conditions, with suitable speed as necessary, the accelerations shall not exceed safety level 2 of Table 11.4 of Section 11 with an average of one per 5-min period, nor shall any other craft characteristic motion as pitch, roll and yaw exceed levels that could impede the safety of passengers. In worst intended conditions, with suitable speed as necessary, craft shall be safely manoeuvrable and provide adequate stability in order that the craft can continue safe operation to the nearest place of refuge, provided caution is exercised in handling.; and

.3 within the actual structural design load for the craft, with reduced speed and change of heading, as necessary.

4.4 Turning and manoeuvrability

The craft shall be safely controllable and manoeuvrable when operating in the harbour area and the adjacent take-off and landing area with reduced main propulsion or with auxiliary propulsion in the displacement, transitional or skimming mode and during berthing operation. The craft operating manual shall include particulars of safe operation at low speed.

5. Weight and balance report

Craft shall be weighed at intervals not exceeding 2 years or at such other times as the Administration may require i.e. after a significant loss of performance, major modification, or repair. The equipment used in weighing the craft shall be satisfactory for its intended purpose and shall have been calibrated or tested as appropriate, within the previous 12 month. The procedures used for weighing the craft and for establishing the basic weight and c.g. shall be acceptable to the Administration.

The weight and balance report shall include the following items:

– Designation and serial number of the craft and the identification or registration marks.

– A copy of the actual weighing record or note of the results, including the corrections used for the weighing equipment and a statement as to when the equipment was last calibrated.

– The calculations made, to correct for the actual craft build standard at weighing, in order to determine the craft Basic Weight and corresponding c.g. position.

6. Loading Information

The loading information scheduled in the Operating Manual shall include, as appropriate:

– The lever arms to be used for items of Disposable Load such as fuel and oil, baggage, cargo and seated passengers in the various seating layouts obtainable. NOTE: For loading purposes the average weight of both passengers and crew may be assumed to be 75 kg per person. This value includes an allowance of 9 kg per person for hand baggage.

– The maximum total usable capacities and weights of the fuel and oil in their appropriate tanks and if critical, the effect of fuel burn-off on the c.g. position.

– The maximum weights allowed in each baggage compartment, cargo by or passenger cabin, as applicable.

– The lever arms to be used and the weights of moveable ballast.

– Instructions and advice in loading procedures and methods, e.g. for loading and lashing cars.

– An example of a loading and c.g. calculation typical for the craft.

7. Trials reports

Reports shall contain the following information in such depth and scope as to enable the Administration to check the limitations, approved information and handling procedure quoted in the Technical Manuals:

– Details of the test methods employed and the relevant craft behaviour.

– The relevant test conditions (e.g. weight, c.g., nominal cushion c.p., environmental conditions) for each aspect of the trials.

– The relevant test results.

– Any significant failures or problems experienced during the programme.

– The final conclusions and recommendations.

– Each report shall have a reference number and be signed by a suitably qualified person.

– The structure shall be capable of supporting the Ultimate Load. During application of loads up to and including the Proof Load, and after the removal of such loads, resultant elastic and permanent deformation shall not interfere with the safe operation of the craft.

– The stiffness of the craft structure shall be such that vibrations which can occur on the craft do not unduly impair the integrity of the structure itself, the functioning of machinery and equipment or the ability of the operating crew to carry out its duties.

Unless otherwise stated each structural requirement shall be complied with:

– at all practical weights up to the Maximum Permissible Weight,

– when the centre of gravity is in the most adverse position compatible with the weight assumed, within the centre-of-gravity range for which certification is sought, and

– when the weight is distributed in the most adverse practical manner, within the operating limitations for which certification is sought.

Where the weight of the craft is to be established by calculation and this is not subsequently to be confirmed by an acceptable means of weight determination, items of Primary Structure the loading of which is sensitive to weight shall have an additional factor applied to the standard bare weight of the craft.

8. Further requirements

8.1 General

Compliance with the structural requirements shall be established by calculation and where necessary by static and/or dynamic model or full scale tests.

8.2 Test instrumentation

Instrumentation shall be provided to enable suitable measurements to be made during certification trials to support the assumptions made in establishing the design loading conditions used for meeting the static and fatigue strength requirements of Section 3, B. The standard of instrumentation shall be agreed with the Administration.

8.3 Wind loads

The craft structure shall have Proof and Ultimate Factors of 1.0 and 1.5 respectively under the loads from the full dynamic pressure of a horizontal wind of 148 km/h (80 knots) in any direction. The following conditions shall be taken into consideration:

– craft moored at the pier; and

– craft lashed on land.

8.4 Fail-safe structure

Where a fail-safe concept is chosen, guidance shall be included in the Technical Manual as to the frequency and extent of the inspections necessary to ensure that any failures will be found within a reasonable period.

9. Effects of failures or malfunction

9.1 General

The limits of safe operation, special handling procedures and any operational restrictions shall be examined and developed as a result of full-scale trials conducted by simulating possible equipment failures.

The failures to be examined shall be those leading to major or more severe effects as determined from evaluation of System Safety Analysis.

Failures to be examined shall be agreed between the craft manufacturer and the Administration and each single failure shall be examined in a progressive manner.

9.2 Objects of tests

Examination of each failure shall result in:

.1 determining safe limits of craft operation at the time of failure, beyond which the failure will result in degradation beyond safety level 2 or beyond the increased g_{coll} as defined in 3.2;

.2 determining crew member's actions, if any, to minimize or counter the effect of the failure; and

.3 determining craft or machinery restrictions to be observed to enable the craft to proceed to a place of refuge with the failure present.

9.3 Failures to be examined

Equipment failures shall include, but not be limited to, the following:

.1 total loss of propulsion power;

.2 total failure of control of one propulsion system;

.3 involuntary application of full propulsion thrust (positive or negative) on one system;

.4 failure of control of one directional control system;

.5 involuntary full deflection of one directional control system;

.6 failure of control of trim control system;

.7 involuntary full deflection of one trim control system element; and

.8 total loss of electrical power.

Failures shall be fully representative of service conditions and shall be simulated as accurately as possible in the most critical craft manoeuvre where the failure will have maximum impact.

9.4 "Dead ship" test

In order to establish craft motions and direction of laying to wind and waves, for the purposes of determining the conditions of a craft evacuation, the craft shall be stopped and all main machinery shut down for sufficient time that the craft's heading relative to wind and waves has stabilized. This test shall be carried out on an opportunity basis to establish patterns of the design's "dead ship" behaviour under a variety of wind and sea states.

Annex E

Criteria for Testing and Evaluation of Revenue and Crew Seats

1. Purpose and scope

The purpose of these criteria is to provide requirements for revenue and crew seats, seat anchorages and seat accessories and their installation to minimize the possibility of occupant injury and/or disruption of egress/ingress if the craft suffers a collision.

2. Dynamic seat tests

2.1 The requirements of this Section are applicable for crew and revenue seats..

2.2 All seats for which this Section applies, the seat supporting structure, the attachment to the deck structure, the lap belt, if installed, and shoulder harness, if installed, shall be designed to withstand the maximum acceleration force that can be imposed upon them during a design collision. Consideration shall be given to the orientation of the seat relative to the acceleration force (i.e. whether the seat is forward, aft, or side-facing).

2.3 The acceleration pulse to which the seat is subjected shall be representative of the collision time-history of the craft. If the collision time-history is not known, or cannot be simulated, the acceleration time-history envelope shown in the figure can be used.

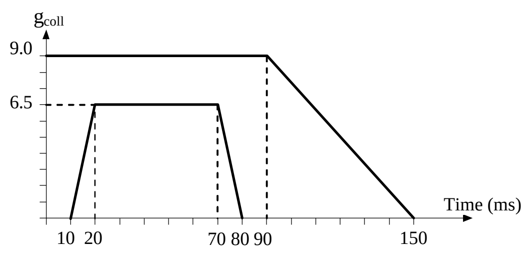

Fig. E.1

2.4 In the test frame, each seat unit and its accessories (e.g., lap belts and shoulder harnesses) shall be attached to the support structure similar to the manner in which it will be attached to the deck structure in the craft. The support structure can be a rigid surface; however, a support structure having the same strength and stiffness as the support structure in the craft is preferred. Other seats and/or tables with which an occupant may come in contact during a collision shall be included in the test frame in an orientation and with a method of attachment typical of that in the craft.

2.5 During the dynamic seat test, a fiftieth percentile anthropomorphic test dummy, corresponding to the Hybrid II or Hybrid III (preferred) human surrogate (unless a more advanced test dummy is available), shall be placed in the seat in an upright seating position. If a typical seating unit is composed of more than one occupant seat, a test dummy shall be placed in each occupant seat in the unit. The dummy, or dummies, shall be secured in the seat unit in accordance with procedures of recognized national standards[1)] and be secured using only the lap belt and shoulder harness if they are installed. Tray tables and other such devices shall be placed in the position that would cause the greatest potential for an occupant to become injured.

2.6 The test dummy shall be instrumented and calibrated, in accordance with the requirements of a recognized national standard, so as to permit calculation of the head injury criterion, calculation of the thoracic trauma index, measurement of force in the femur, and measurement, if possible, of extension and flexion of the neck, measurement of the maximum relative pelvis acceleration, and measurement of the maximum pelvis load in the direction of the spine.

2.7 If more than one dummy is used in the tests, the dummy located in the seat having the highest potential for an occupant to be injured shall be the one instrumented. The other dummy or dummies need not be instrumented.

2.8 The tests shall be conducted and the instrumentation shall be sampled at a rate sufficient to reliably show response of the dummy in accordance with the requirements of a recognized national standard.

2.9 The seat unit tested in accordance with the requirements of this Section shall be considered acceptable if:

.1 The seat unit and tables installed in the seat unit or area do not become dislodged from the supporting deck structure and do not deform in manner that would cause the occupant to become trapped or injuried.

[1)] *Recognized national standards include ECE 80 with addendum 79, ADR 66/00 from Australia and NCHRIP Report 350 from the United States. Other national standards equivalent to these standards may be considered acceptable*

.2 The lap belt, if installed, remains attached and on the test dummy's pelvis during the impact. The shoulder harness, if installed, remains attached and in the immediate vicinity of the test dummy's shoulder during the impact. After the impact, the release mechanisms shall be operative.

.3 The following acceptability criteria are met:

– the head injury criterion (HIC), calculated in accordance with the formula, does not exceed 500

$$HIC = (t_2 - t_1)\left[\frac{1}{t_2 - t_1}\int_{t_1}^{t_2} a(t)\ dt\right]^{2.5}$$

where :

t_1 and t_2 are the beginning and ending times (in seconds) of the interval in which the HIC is a maximum. The term a(t) is the resultant measured acceleration in the head of the dummy in g's;

– the thoracic trauma index (TTI), calculated in accordance with the formula, does not exceed 30 g except for periods totaling less than 3 ms

$$TTI = \frac{g_R + g_{LS}}{2}$$

or acceleration at the centre of gravity

where:

g_R is the acceleration in g of either the upper or lower rib; and

g_{LS} is the acceleration in g of the lower spine;

– the maximum pelvis acceleration does not exceed 13 g;

– the maximum pelvic load does not exceed 6.7 kN measured in the axis of the spine;

– neck flexion does not exceed 88 N m, if measured;

– neck extension does not exceed 48 N m, if measured; and

– the force in the femur does not exceed 10 kN except that it cannot exceed 8 kN for periods totaling more than 20 ms.

.4 Loads on the upper torso harness straps do not exceed 7.8 kN or a total of 8.9 kN if dual straps are used.

Annex F

Open Reversible Liferafts

1. General

1.1 All open reversible liferafts shall:

.1 be constructed with proper workman ship and materials;

.2 not be damaged in stowage throughout the air temperature range of –18°C to +65°C;

.3 be capable of operating throughout an air temperature range of –18°C to +65°C and a seawater temperature range of –1°C to +30 °C;

.4 be rot-proof, corrosion-resistant and not be unduly affected by seawater, oil or fungal attack;

.5 be stable and maintain their shape when inflated and fully laden; and

.6 be fitted with retro-reflective material, where it will assist in detection, and in accordance with the "Recommendation on the Use and Fitting of Retro-Reflective Materials on Life-Saving Appliances", adopted by the International Maritime Organization by resolution A.658(16).

2. Construction

2.1 The open reversible liferaft shall be so constructed that when it is dropped into the water in its container from a height of 10 m, the liferaft and its equipment will operate satisfactorily. If the open reversible liferaft is to be stowed at a height of more than 10 m above the waterline in the lightest seagoing condition, it shall be of a type which has been satisfactorily drop-tested from at least that height.

2.2 The open reversible floating liferaft shall be capable of withstanding repeated jumps on to it from a height of at least 4.5 m.

2.3 The open reversible liferaft and its fittings shall be so constructed as to enable it to be towed at a speed of 3 knots in calm water when loaded with its full complement of persons and equipment, with the sea-anchor deployed.

2.4 The open reversible liferaft when fully inflated shall be capable of being boarded from the water whichever way up it inflates.

2.5 The main buoyancy chamber shall be divided into:

.1 not less than two separate compartments, each inflated through a non return inflation valve on each compartment; and

.2 the buoyancy chambers shall be so arranged that in the event of one of the compartments being damaged or failing to inflate, the intact compartment shall be able to support, with positive freeboard over the open reversible liferaft's entire periphery, the number of persons which the liferaft is permitted to accommodate, each having a mass of 75 kg and seated in their normal positions.

2.6 The floor of the open reversible liferaft shall be waterproof.

2.7 The open reversible liferaft shall be inflated with a non-toxic gas by an inflation system complying with the requirements of regulation III/39 of the Convention. Inflation shall be completed within the period of one minute at an ambient temperature of between 18 °C and 20 °C and within a period of three minutes at an ambient temperature of –18 °C. After inflation the open reversible liferaft shall maintain its form when loaded with its full complement of per- sons and equipment.

2.8 Each inflatable compartment shall be capable of withstanding a pressure equal to at least three times the working pressure and shall be prevented from reaching a pressure exceeding twice the working pressure either by means of relief valves or by a limited gas supply. Means shall be provided for fitting the topping-up pump or bellows.

2.9 The surface of the buoyancy tubes shall be of non-slip material. At least 25 % of these tubes shall be of a highly visible colour.

2.10 The number of persons which an open reversible liferaft shall be permitted to accommodate shall be equal to the lesser of:

.1 the greatest whole number obtained by dividing by 0.096 the volume, measured in cubic metres, of the main buoyancy tubes (which for this purpose shall not include the thwarts, if fitted) when inflated; or

.2 the greatest whole number obtained by dividing by 0.372 the inner horizontal cross-sectional area of the open reversible liferaft measured in square metres (which for this purpose may include the thwart or thwarts, if fitted) measured to the innermost edge of the buoyancy tubes; or

.3 the number of persons having an average mass of 75 kg, all wearing lifejackets, that can be seated inboard of the buoyancy tubes without interfering with the operation of any of the liferaft's equipment.

3. Open reversible liferaft fittings

3.1 Lifelines shall be securely becketed around the inside and outside of the open reversible liferaft.

3.2 The open reversible liferaft shall be fitted with an efficient painter of a length suitable for automatic inflation on reaching the water. For open reversible liferafts accommodating more than 30 persons an additional bowsing in line shall be fitted.

3.3 The breaking strength of the painter system, including its means of attachment to the open reversible liferaft, except the weak link required by regulation III/39 of the Convention, shall be:

.1 7.5 kN for open reversible liferafts accommodating up to 8 persons;

.2 10.0 kN for open reversible liferafts accommodating 9 to 30 persons; and

.3 15.0 kN for open reversible liferafts accommodating more than 30 persons.

3.4 The open reversible liferaft shall be fitted with at least the following number of inflated ramps to assist boarding from the sea whichever way up the raft inflates:

.1 one boarding ramp for open reversible liferafts accommodating up to 30 persons; or

.2 two boarding ramps for open reversible liferafts accommodating more than 30 persons; such boarding ramps shall be 180° apart.

3.5 The open reversible liferaft shall be fitted with water pockets complying with the following requirements:

.1 the cross-sectional area of the pockets shall be in the shape of an isosceles triangle with the base of the triangle attached to the buoyancy tubes of the open reversible liferaft;

.2 the design shall be such that the pockets fill to approximately 60 % of capacity within 15 s to 25 s of deployment;

.3 the pockets attached to each buoyancy tube shall normally have aggregate capacity of between 125 *l* and 150 *l* for inflatable open reversible liferafts up to and including the 10 person size;

.4 the pockets to be fitted to each buoyancy tube on liferafts certified to carry more than 10 persons shall have, as far as practicable, an aggregate capacity of 12 N litres, where N is the number of persons carried;

.5 each pocket on a buoyancy tube shall be attached so that when the pocket is in the deployed position it is attached along the full length of its upper edges to, or close to, the lowest part of the lower buoyancy tube; and

.6 the pockets shall be distributed symmetrically round the circumference of the liferaft with sufficient separation between each pocket to enable air to escape readily.

3.6 At least one manually controlled lamp complying with the requirements shall be fitted on the upper and lower surfaces of the buoyancy tubes.

3.7 Suitable automatic drain arrangements shall be provided on each side of the floor of the liferaft in the following manner:

.1 one for open reversible liferafts accommodating up to 30 persons; or

.2 two for open reversible liferafts accommodating more than 30 persons.

3.8 The equipment of every open reversible liferaft shall consist of:

.1 one buoyant rescue quoit, attached to not less than 30 m of buoyant line with a breaking strength of at least 1 kN;

.2 two safety knives of the non-folding type, having a buoyant handle, shall be fitted attached to open reversible liferaft by light lines.

They shall be stowed in pockets so that, irrespective of the way in which the open reversible liferaft inflates, one will be readily available on the top surface of the upper buoyancy tube in a suitable position to enable the painter to be readily cut;

.3 one buoyant bailer;

.4 two sponges;

.5 one sea-anchor permanently attached to the open reversible liferaft in such a way as to be readily deployable when the open reversible liferaft inflates. The position of the sea-anchor shall be clearly marked on both buoyancy tubes;

.6 two buoyant paddles;

.7 one first-aid outfit in a waterproof case capable of being closed tightly after use;

.8 one whistle or equivalent sound signal;

.9 two hand flares;

.10 one waterproof electric torch suitable for Morse signalling together with one spare set of batteries and one spare bulb in a waterproof container;

.11 one repair outfit for repairing punctures in buoyancy compartments; and

.12 one topping-up pump or bellows.

3.9 The equipment specified in 3.8 is designated an HSC Pack.

3.10 Where appropriate, the equipment shall be stowed in a container which, if it is not an integral part of, or permanently attached to, the open reversible liferaft, shall be stowed and secured to the open reversible liferaft and be capable of floating in water for at least 30 min without damage to its contents. Irrespective of whether the equipment container is an integral part of, or is permanently attached to, the open reversible liferaft, the equipment shall be readily accessible irrespective of which way up the open reversible liferaft inflates. The line which secures the equipment container to the open reversible liferaft shall have a breaking strength of 2 kN or a breaking strength of 3:1 based on the mass of the complete equipment pack, whichever is the greater.

4. Containers for open reversible inflatable liferafts

4.1 The open reversible liferafts shall be packed in a container that is:

.1 so constructed as to withstand conditions encountered at sea;

.2 of sufficient inherent buoyancy, when packed with the liferaft and its equipment, to pull the painter from within and to operate the inflation mechanism shall the craft sink; and

.3 as far as practicable, watertight, except for drain holes in the container bottom.

4.2 The container shall be marked with:

.1 maker's name or trademark;

.2 serial number;

.3 the number of persons it is permitted to carry;

.4 non-SOLAS reversible;

.5 type of emergency pack enclosed;

.6 date when last serviced;

.7 length of painter;

.8 maximum permitted height of stowage above waterline (depending on drop-test height); and

.9 launching instructions.

5. Markings on open reversible inflatable liferafts

The open reversible liferafts shall be marked with:

.1 maker's name or trademark;

.2 serial number;

.3 date of manufacture (month and year);

.4 name and place of service station where it was last serviced; and

.5 number of persons it is permitted to accommodate on the top of each buoyancy tube, in characters not less than 100 mm in height and of a colour contrasting with that of the tube.

6. Instructions and information

Instructions and information required for inclusion in the craft's training manual and in the instructions for on-board maintenance shall be in a form suitable for inclusion in such training manual and instructions for on-board maintenance. Instructions and information shall be in a clear and concise form and shall include, as appropriate, the following:

.1 general description of the open reversible liferaft and its equipment;

.2 installation arrangements;

.3 operational instructions, including use of associated survival equipment; and

.4 servicing requirements.

Annex G

Glossary of Terms Related to Fibre-Reinforced Plastics

accelerator - a material which, when mixed with a catalyzed resin, will speed up the chemical reaction between the catalyst and resin

adhesive - substance capable of holding two surfaces together

ambient conditions - prevailing environmental conditions, such as the surrounding temperature, pressure, and relative humidity

angle ply laminate - possessing equal plies with positive and negative angles. This bi-directional laminate is orthotropic. Typical examples of an angle ply laminate would be cross-ply [0/90] or [+/–45]

anisotropy - material properties that vary with the orientation or direction of the reference coordinates. Having different material properties in all directions

aramidfiber - an aromatic nylon fiber having a high modulus and strength

A-stage - an early stage in the reaction of certain thermosetting resins, in which the material is still soluble in certain liquids and fusible

axial winding - in filament-wound composites, a winding with the filaments parallel to the longitudinal axis (0 deg. helix angle)

balanced design - in filament-wound reinforced plastics, a winding pattern designed so as to have equal stresses in all filaments

balanced-in-plane contour - in a filament-wound part, a head contour in which the filaments are oriented within a plane and the radii of curvature are adjusted to balance the stresses along the filaments with the pressure loading

balanced laminate - where plies with positive angles are balanced by equal plies with negative angles. A balanced laminate is orthotropic in in-plane behaviour but anisotropic in flexural behaviour

band density - in filament winding, the quantity of fiber reinforcement per inch of bandwidth, expressed as strands (or filaments) per inch

band thickness - in filament winding, the thickness of the reinforcement as it is applied to the mandrel

bandwidth - in filament winding, the width of the reinforcement as it is applied to the mandrel

batch - a quantity of material produced in a single, separate production run which is identifiable by a unique number

biaxial load - a loading condition whereby a laminate is stressed in at least two different directions in the plane of the laminate. The loading condition of a pressure vessel under internal pressure and with unrestrained ends

biaxial winding - a type of winding in which the helical band is laid in sequence, side by side, eliminating crossover of the fibers

bidirectional laminate - a reinforced plastic laminate with the fibers oriented in various directions in the plane of the laminate (see also unidirectional laminate

bladder - a flexible liner with independent burst strength not greater than 10 % of the vessel design pressure, temporarily installed in a fiber-reinforced pressure vessel prototype in order to prevent leakage through the wall (to facilitate attainment of the required qualification pressure)

bleedout - in filament-wound composites, the excess liquid resin that migrates to the surface of a winding B-stage – an intermediate stage in the reaction of certain thermosetting resins in which the material swells when in contact with certain liquids and softens when heated, but may not entirely dissolve or fuse. The resin in an uncured prepreg or premix is usually in this stage.

bulk molding compound - a blend of resin and chopped fibers used for compression and injection molding

catalyst - see initiator

catenary - the tendency of some strands in a taut horizontal roving to sag lower than the others; a measure of the evenness of length (of winding tension indirectly) of strands in a specified length of roving. The distance between the strands at the mid- point of a roving draped in a catenary in a specified manner (see also strand length differential)

circs - see circumferential winding

circuit - one complete traverse of the fiber feed mechanism of a winding machine; in filament-wound, fiber reinforced plastics, one complete traverse of a winding band from one arbitrary point along the winding path to another point on a plane through the starting point and perpendicular to the axis

circumferential (circs) winding - in filament-wound composites, a winding with the filaments essentially perpendicular to the axis (90 deg. or level winding)

compatibility - usually refers to the suitability of a sizing or finish for use with certain general resin types. For instance, polyester compatible roving, epoxy compatible roving, etc.

compliance - measurement of softness as opposed to stiffness of a material. It is a reciprocal of the Young's modulus, or an inverse of the stiffness matrix

composite - material that is made of two or more constituent materials

constituent materials - individual materials that make up the composite material, such as glass fibers and epoxy

contact molding - a process for molding reinforced plastics in which reinforcement and resin are placed on a mold; cure is either at room temperature using a catalyst-promoter system or by heat in an oven, and no additional pressure is used

coupling agent - in fibers for composites, that part of a surface treatment or finish which is designed to provide a bonding link between the surface and the laminating resin

crazing - in a composite, the appearance of fine cracks in the resin, usually as a result of excessive resin shrinkage or some external loading condition

creel - an apparatus for holding a number of pack-ages of strand, yam, roving, tape, etc. Tensioning devices are sometimes included in the creel

creep - the special case of inelasticity that relates to the stress-induced time-dependent deformation under load. Small time-dependent deformations may occur after the removal of all applied loads

critical buckling stress - least value of stress that will cause buckling

cross-ply laminate - special laminate that contains only 0 deg. and 90 deg. Plies

C-stage - the final stage in the reaction of certain thermosetting resins in which the material is relatively insoluble and infusible. The resin in a fully cured thermoset molding is in this stage

cure - to change the properties of a plastic by chemical reaction, which may be condensation, polymerization, or addition; usually accomplished by the action of heat or catalyst or both, with or without pressure

curing agent - substance added to thermoset resin to cause curing reaction. See initiator

deformation - deformation of a component part is an alteration of its shape or size

delamination - the physical separation or loss of bond between laminate plies

displacement angle - in filament winding, the advancement distance of the winding ribbon on the equator after one complete circuit

doubler - in a filament-wound part, a local area with extra-wound reinforcement, wound integrally with the part, or wound separately and fastened to the part

dry laminate - a laminate containing insufficient resin for complete bonding of the reinforcement

dry spot - in a laminate, an area containing insufficient resin for complete bonding of the reinforcement

dry winding - filament winding with dry strands of fiber, often used to confirm the winding pattern

dwell - in filament winding, the time that the traverse mechanism is stationary while the mandrel continues to rotate to the appropriate point for the traverse to begin a new pass

E-glass - a borosilicate glass; the type most used for glass fibers for reinforced plastics. Suitable for electrical laminates because of its high resistivity

engineering constants - measured directly from uniaxial tensile, compressive, and pure shear test applied to unidirectional as well as laminated composites. Typical constants are the effective Young's modulus, Poisson's ratio, and shear modulus; each constant is accompanied by letter or numerical subscripts designating the direction associated with the property

epoxy - synthetic resin containing a reactive group in which an oxygen atom is joined to each of two carbonatoms which are already united in some other way (see sketch below)

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equator - in a filament-wound pressure vessel, the-line described by the juncture of the cylindrical portion and the end dome

expansion stresses - stresses resulting from restraint of free expansion and displacement of the piping system

fabric - a planar structure produced by interfacing yams, rovings, etc.

fiber - single filament, rolled or formed in one direction, and used as the principal constituent of woven and non woven composite materials. Most common fibers are glass and graphite

fiber content - percent by volume, or percent by weights, of the fiber component in a composite material. See loss-on-ignition

fiber stress - in a filament-wound part, usually a pressure vessel, the stress calculated using the load and the cross-sectional area of the reinforcement only

filament winding - a process for fabricating a composite structure in which continuous reinforcements (filament, tape, or other), either previously impregnated with a matrix material or impregnated during winding, are placed over a rotating and removable form or mandrel in a previously prescribed way to meet certain stress conditions. Generally, the shape is a surface of revolution and may or may not include end closures

filler - a relatively inert nonfibrous material added to a plastic to modify its strength, permanence, working properties, or other qualities, or to lower costs

finish - a material applied to the surface of fibers used to reinforce plastics and intended to improve the physical properties of such reinforced plastics over that obtained using glass reinforcement without finish (see surface treatment)

free end displacement - the relative motions that would occur between an attachment and connected structure or equipment if the two members were separated. Examples of such motions are those that would occur because of relative thermal expansion of piping, equipment, and equipment supports, or because of rotations imposed upon the equipment by sources other than piping

fuzz - accumulation of short broken filaments after passing fiber strands, yarns, or rovings over a contact point. Often weighted and used as an inverse measure of abrasion resistance

gap - in filament winding, the space between successive windings, which windings are usually intended to lie next to each other

gel - the initial jellylike solid phase that develops during the cure of a thermosetting resin

gel coat - a resin applied to the surface of a mold and gelled prior to lay-up. The gel coat becomes an integral part of the finished laminate and is usually used to improve surface appearance, etc.

gel time - time lapsed as read on the actual exotherm curve between 150 °F and 10 °F above the 180 °F bath temperature (hence 190 °F). This definition applies for any desired reference (bath) temperature

geodesic - the shortest distance between two points on a surface

geodesic isotensoid - see geodesic ovaloid. Isotensoid refers to constant stress level in any given filament at all points in its path

geodesic isotensoid contour - in filament-wound, fiber-reinforced plastic pressure vessels, a dome contour in which the filaments are placed on geodesic paths so that the filaments will exhibit uniform tensions throughout their length under pressure loading

geodesic ovaloid - a contour for end domes, the fibers forming a geodesic line (the shortest distance between two points on a surface of revolution). Ile forces exerted by the filaments are proportioned to match the hoop and meridional stresses at any point

geodesic ovaloid contour - see geodesic isotensoid contour

glass fiber - a glass filament that has been cut to a measurable length. Staple fibers of relatively short length and suitable for spinning into yam

glass filament - a form of glass that has been drawn to a small diameter and extreme length

graphite filament - made from organic precursor filament after high temperature exposure and mechanical stretching

gross structural discontinuity - a source of stress or strain intensification which effects a relatively large portion of a structure and has a significant effect on the overall stress or strain pattern or on the structure as a whole. Examples of gross structural discontinuities are head-to-shell and flange-to-shell junctions, nozzles, and junctions between shells of different diameters or thicknesses

hand lay-up - the process of placing and working successive plies of the reinforcing material or resinimpregnated reinforcement in position on a mold by hand. See contact molding

hardener - see curing agent

head - the end closure(s) of a cylindrical container

helical winding - in filament-wound composites, a winding in which a filament band advances along a helical path, not necessarily at a constant angle, except in the case of a cylinder

high pressure molding - a molding process in which the pressure used is greater than 200 psi

hoop winding - see circumferential winding

hybrid - composite with more than two constituents, such as a graphite/glass/epoxy composite hybrid

impregnate - in fiber-reinforced plastics, saturation of the reinforcement with a resin

inelasticity - inelasticity is a general characteristic of material behavior in which material does not return to its original (undeformed) shape and size after removal of all applied loads

inhibitor - a material added to a catalyzed resin to slow down cure at approximately room temperature. Usually used in prepreg or premix resins

initiator - a material which, when mixed with a resin, will react chemically with the resin to produce a cured thermoset

interface - on fibers, the contact area between fiber and surface treatment (or finish). In a laminate, the contact area between the fiber surface treatment, or finish, and the laminating resin

interlaminar shear strength - the maximum shear stress existing between layers of a laminated material

interlaminar stresses - the three stress components associated with the thickness direction of a plate. Interlaminar stresses are significant only if the thickness is greater than 10 % of the length or width of the plate. These stresses can also be significant in areas of concentrated loads and abrupt change in material and geometry. The effects of these stresses are difficult to assess because three-dimensional stress analysis and the failure criterion are not well understood

invariant - constant values for all orientations of the coordinate axis. Components of stress, strain, stiffness, and compliance all have linear and quadratic invariants. For composite materials they represent directionally independent properties, and the bounds of stiffness and strength of multidirectional laminates

isotensoid - constant tension

isotropic laminate - a laminate in which the strength properties are equal in all directions

knitted matrix fabric - a structure produced by inserting reinforcing fibers into a knitted matrix. The matrix fibers are non-reinforcing and serve only to hold the reinforcing fibers in place

knuckle area - the area in an end dome region near the juncture with the cylindrical portion; in a filament-wound part, the area of transition between different general shapes, e.g., the transition from a central cylindrical portion to the end dome

lamina - ply or layer of unidirectional composite or fabric

laminate - a product made by bonding together two or more layers of material or materials

laminate ply - one layer of a product made by bonding together two or more layers of material

lamination theory - the most common method for the analysis and design of composite laminates; each ply or ply group is treated as a quasi-homogeneous material. Linear strain across the thickness is assumed

lap - in filament winding, the amount of overlay between successive windings, usually intended to minimize gapping

lay - in filament winding, the orientation of the ribbon with some reference, usually the axis of rotation

lay-up - (a) a laminate that has been assembled, but not cured; (b) a description of the component materials, geometry, etc., of a laminate

level winding - see circumferential winding

liner - in a pressure vessel, the continuous, usually flexible, coating on the inside surface of the vessel used to protect the laminate from chemical attack or to prevent leakage under stress

load stress - the stress resulting from the application of a load, such as internal pressure or the effects of gravity, as distinguished from thermal stress

local primary membrane stress - a membrane stress produced by pressure or other mechanical loading and associated with a primary and/or a discontinuity effect which would, if not limited, produce excessive distortion in the transfer of load to other portions of the structure. Conservatism requires that such a stress be classified as a local primary membrane stress even though it has some characteristics of a secondary stress. An example of a local primary membrane stress is the membrane stress in a shell produced by external load and moment at a permanent support or at a nozzle connection

local structural discontinuity - a source of stress or strain intensification which affects a relatively small volume of material and does not have a significant effect on the overall stress or strain pattern or on the structure as a whole. Examples are small fillet radii and small attachments

longitudinal modulus - elastic constant along the fiber direction in a unidirectional composite, such as longitudinal Young's modulus

longos - low-angle helical or longitudinal windings

loops and snarls - a place in a roving where one or more short lengths of strand have doubled back on themselves

loss-on -ignition - weight loss, usually expressed in percent of total, after burning off an organic surface treatment from fibers or an organic resin from a fiber laminate

low-pressure molding - molding or laminating in which the pressure used is between 15 psi and 200 psi

mandrel - in filament winding, the mold on which the laminating material is wound

mat - a fiber material for composite laminates consisting of randomly oriented chopped strands or swirled strands with a binder and available in blankets of various widths and lengths

mat binder - a resin which is applied to fiber strands and cured during the manufacture of a mat to hold strands in place and maintain the shape of the mat

matrix - see resin

matrix - mathematical entity, consisting of rows and columns of numbers. In two dimensions, stress and strain are I x 3 matrices, and stiffness and compliance are 3 x 3 matrices

matrix inversion - algebraic operation to obtain compliance matrix from stiffness matrix, or vice versa. It is analogous to obtaining the reciprocal of a number

membrane stress - the component of normal stress which is uniformly distributed and equal to the average value of stress across the thickness of the section under consideration

midplane - middle surface of a laminate thickness; usually the z = 0 plane

modulus - elastic constants such as the Young's modulus or shear modulus

moment - stress couple that causes a plate or beam to bend or twist

multicircuit winding - in filament-wound composites, a winding that requires more than one circuit before the band repeats by laying adjacent to the first, band

multidirectional - having multiple ply orientations in a laminate

netting analysis - the analysis of filament-wound structures which assumes that the stresses induced in the structure are carried entirely by the filaments, and the strength of the resin is neglected; and also that the filaments possess no bending or shearing stiffness and carry only axial loads

nol ring - a parallel filament-wound test specimen used for measuring various mechanical strength properties of the material by testing the entire ring, or segments of it. The ring is usually 5.750 in. in inside diameter by 0.250 in. wide by either 0.060 in. or 0.125 in. in wall thickness

normal stress - the component of stress normal to the plane of reference (this is also referred to as direct stress). Usually the distribution of normal stress is not uniform through the thickness of a part, so this stress is considered to be made up in turn of two components, one of which is uniformly distributed and equal to the average value of stress across the thickness of the section under consideration, and the other of which varies with the location across the thickness

off-axis - not coincident with the symmetry axis; also called off-angle

orthotropy - having three mutually perpendicular planes of symmetry. Unidirectional plies, fabric, crossply, and angle-ply laminates are all orthotropic

ovaloid - a surface of revolution symmetrical about the **polar axis which forms the end closure** for a filament-wound cylinder

part - a portion of a vessel that is fabricated by an operation or process requiring inspection by the "Inspector"

peak stress - the basic characteristic of a peak stress is that it does not cause any noticeable distortion. A stress which is not highly localized falls into this category if it is of a type which cannot cause noticeable distortion. Examples of peak stress are: (a) the thermal stress in the wall of a vessel or pipe caused by a rapid change in temperature of the contained fluid; (b) the stress at a local structural discontinuity

phenolic - synthetic condensation resins of aldehyde and phenols. The common reactants are formaldehyde, phenol, and cresol

planar helix winding - a winding in which the filament path on each dome lies on a plane which inter- sects the dome, while a helical path over the cylindrical section is connected to the dome paths

planar winding - a winding in which the filament path lies on a plane which intersects the winding surface

plasticizer - a material added to a resin to facilitate compounding and improve flexibility and other properties of the finished product

plied yarn - a yam formed by twisting together two or more single yams in one operation

ply group - group formed by contiguous plies with the same angle

ply strain - those components in a ply which, by the laminate plate theory, are the same as those in the laminate

ply stress - those components in a ply which vary from ply to ply depending on the materials and angles in the laminate

polar piece - in a pressure vessel, the metal reinforcements placed at both ends of the major axis of the vessel. Their extension into the end dome depends on stress conditions

polar winding - a winding in which the filament path passes tangent to the polar opening at one end of the chamber, and tangent to the opposite side of the polar opening at the other end. A one-circuit pattern is inherent in the system

polyester

- basically a class of thermosetting resins produced by esterification of polybasic organic acids (or anhydrides) with polyhydric alcohols;
- for Code purposes, polyester may be any type of liquid resin which comprises a mixture of polymerizable unsaturated ester and a co-polymerizable monomeric substance that contains at least one active ethylene double bond; this liquid resin shall be capable of gelling and

curing to infusible polymer by free radical initiation at ordinary temperatures with negligible change in weight;

– commonly, the unsaturated ester is a polymer of maleic anhydride, phthalic anhydride, and glycol; the copolymerizable monomer (which also serves as solvent) is styrene, and the free radical initiator is an organic peroxide;

– any resin which is handled and cured in a similar manner can be considered acceptable as polyester

post cure - additional oven cure, usually without pressure, after initial cure to improve final properties of reinforced plastic laminates

pot life - the length of time a resin system retains a viscosity low enough to be used in laminating

preform - a matlike structure of chopped fibers bonded together and approximating the shape of the structure

preform binder - a resin applied to the chopped strands of a preform, usually during its formation, and cured so that the preform will retain its shape and can be handled

premix - see bulk molding compound

prepreg - in reinforced plastics, the mixture of resin, catalyst, reinforcements, fillers, etc., in web or filamentous form, to provide a complete mix ready for molding

pressure - unless otherwise defined, means gage pressure

pressure bag molding - a process for molding reinforced plastics in which a tailored flexible bag is placed over the contact lay-up on the mold, sealed, and clamped in place. Fluid pressure (usually compressed air) is placed against the bag, and the part is cured

primary stress - a normal stress or a shear stress developed by the imposed loading which is necessary to satisfy the simple laws of equilibrium of external and integral forces and moments. The basic characteristic of a primary stress is that it is not self-limiting. Primary stresses which considerably exceed the stress at onset of cracking will result in failure or, at least, in gross distortion. A thermal stress is not classified as a primary stress. Examples of primary stress are:

– general membrane stress in a circular cylindrical or a spherical shell due to internal pressure or to distributed live loads;

– bending stress in the central portion of a flat head due to pressure

principal direction - specific coordinate axes orientation when stress and strain components reach maximum and minimum for the normal components and zero for the shear

principal stress - the stress component normal to the plane on which the shearing stress is zero

promoter - see accelerator

random pattern - a winding with no fixed pattern. If a large number of circuits is required for the pattern to repeat, a random pattern is approached

reinforced plastic - see composite

reinforcement - material which is applied to a resin matrix in order to strengthen and improve the properties of the resin

release agent - material which is applied in a thin film to the surface of a mold to keep the laminating resin from bonding to the mold

resin - in composites, the material used to bind together the reinforcement material; also known as matrix

resin applicator - in filament winding, the device which deposits the liquid resin onto the reinforcement band

resin content - the amount of resin in a laminate, expressed as a percent of either total weight or total volume

resin flexibilizer - see plasticizer

ribbonization - the degree of flattening of a sized roving, expressed as the ratio of ribbon width to thickness

ribbon width - see bandwidth

ring punchout shear strength - the interlaminar shear strength of a filament-wound cylinder at a predetermined shear plane

roving - an assemblage of a number of strands orends, roughly parallel and with very little twist

roving ball - package, usually cylindrically wound, of continuous roving

roving ball build - the geometry of a roving ball, including a description of the waywind

roving integrity - the degree of bond between strandsin a roving

S-glass - magnesia-alumina-silicate glass, especially designed to provide very high tensile strength glass filaments

secondary bonding - the joining of two or more FRP subassemblies by adhesive bonding, laminate overlay, or other suitable means to form a larger component

secondary stress - a normal stress or a shear stress-developed by the constraint of adjacent parts or by self constraint of a structure. The basic characteristic of a secondary stress is that it is self-limiting. Local inelastic deformation and minor distortions can satisfy the conditions which cause the stress to occur. Examples of secondary stress are:

– general thermal stress;

– bending stress at a gross structural discontinuity

sequential winding - see biaxial winding

shakedown – in a structure, occurs during the first few cycles of load application. The subsequent structural response is elastic, and progressive incremental inelastic deformation is absent. Elastic shakedown is the case in which the subsequent response is elastic

shear stress - the component of stress tangent to the plane of reference

shelf life - length of time a material can be stored under specified environmental conditions without failure to meet specifications

shelling - a term applied to loops of roving failing to the base of a roving ball as the roving is payed out from the ball on end

short beam shear strength - the interlaminar shear strength of a parallel composite as determined by threepoint flexural loading of a short segment cut from a ring-type specimen

silicone - semiorganic polymers made up of a skeleton structure of alternate silicon and oxygen atoms with various organic groups attached to the silicon

single circuit winding - winding in which the filament path makes a complete traverse of the chamber, after which the following traverse lies immediately adjacent to the previous one

size - to apply compounds to a strand, which compounds form a more or less continuous film around the strand and individual fibers

sizing content - the percent of the total strand weight made up by the sizing, usually determined by burning off the organic sizing (see also loss-on-ignition)

sizing extractables - the percent of the total sizing weight that can be extracted with acetone or some other applicable solvent, measured primarily on certain reactive sizings to determine degree of cure

skein - a continuous strand, yam, roving, etc., wound up to some measurable length and usually used to measure various physical properties of the material

skirt - a non-pressurized shell of revolution supporting a pressure vessel

splice - the joining of two ends of glass fiber yam or strand, usually by means of an air drying glue

spray-up - a process for laying up reinforced plastics in which a special "gun" chops fiber roving and sprays resin and a curing agent or catalyst-accelerator on the mold. The lay-up is then usually worked by hand (see contact molding)

stacking sequence - ply ordering in a laminate. Stacking sequence does not affect the in-plane properties of a symmetric laminate. Only the ply number and ply angles are important. But stacking sequence becomes critical for the flexural properties, and the interlaminar stresses for any laminate, symmetric or not. Stacking sequence is important for asymmetric and hybrid laminates

stiffness - ratio between the applied stress and the resulting strain. Young's modulus is the stiffness of a material subjected to uniaxial stress. For composite materials, stiffness and other properties are dependent on the orientation of the material

strain - geometric measurement of deformation

strand - an assembly of continuous filaments, without twist. A loosely bonded assemblage of fibers or filaments; the immediate product of the multifiber forming process. Also known as tow

strand count - the number of strands in a plied yam; the number of strands in a roving

strand integrity - degree of bond between the filaments in a strand

strand length differential - similar to catenary, a measure of the difference in length of the strands or yarns in a roving, the difference being caused by uneven tension, waywind, etc. (see also catenary)

strand tensile strength - tensile strength of a fiber strand, yam, or roving, when tested as a straight specimen

strength - maximum stress that a material can sustain. Like the stiffness of a composite material, strength is highly dependent on the direction and sign of the applied stress, such as axial tensile as opposed to transverse compression

strength ratio - useful measure related to margin of safety. Failure occurs when the ratio is unity. Safety margin is a factor of two, for example, if the strength ratio is two. The ratio is particularly easy to obtain if the quadratic failure criterion is used

stress - intensity of forces within a body

stress concentration - increased ratio of a local stress over the average stress

stress intensity - the equivalent intensity of combined stress, or in short, the stress intensity, is defined as twice the maximum shear stress. In other words, the stress intensity is the difference between the algebraically largest principal stress and the algebraically smallest. Tension stresses are considered positive and compression stresses are considered negative

stress-strain relationship - a linear relation is usually assumed for calculating stress from strain or strain from stress. For multidirectional laminates, it can be generalized to include in-plane stress-strain and flexural stress-strain relations. All anisotropic relations are simple extensions of the isotropic relation. Young's modulus is the quotient of stress divided by strain

surface mat - a very thin mat, usually 7 mils to 20 mils thick, or highly filamentized fiber

surface treatment - on fibers, the compounds which, when applied to filaments at forming, provide a loose bond between the filaments, and provide various desired handling and processing properties. For reinforcing plastics, the surface treatment will also contain a coupling agent. Also known as sizing

symmetric laminate - possessing midplane symmetry

tack - with special reference to prepreg materials, the degree of stickiness of the resin

thermal stress - a self-balancing stress produced by a non uniform distribution of temperature or by differing thermal coefficients of expansion. Thermal stress is developed in a solid body whenever a volume of material is prevented from assuming the size and shape that it normally would under a change in temperature. Two types of thermal stress are recognized, depending on the volume or area in which distortion takes place, as follows.

- General thermal stress, which is associated with distortion of the structure in which it occurs. Examples of general thermal stress are:
  - stress produced by an axial temperature distribution in a cylindrical shell;
  - stress produced by the temperature difference between a nozzle and the shell to which it is attached.
- Local thermal stress, which is associated with almost complete suppression of the differential expansion and thus produces no significant distortion. Examples of local thermal stress are:
  - stress in a small hot spot in a vessel wall;
  - thermal stress in layers of material which have different coefficients of expansion

thermoplastic - a plastic which is capable of being repeatedly softened by increase of temperature and hardened by decrease of temperature

thermoset - a plastic which, when cured by application of heat or chemical means, changes into a substantially infusible and insoluble material

thixotropic - the capacity of a liquid material to have high static shear strength (viscosity) and at the same time low dynamic shear strength. Such a material can be mixed (stirred), but will not flow under the force of gravity

tow - an untwisted group of continuous fibers (see roving)

transformation - variation of stiffness, strength, stress, strain, and other material properties due to the coordinate transformation or rotation of the reference coordinate axes. Transformation follows strict mathematical equations. The study of composite materials relies heavily on these transformation equations to correctly describe the directional dependency of the materials.

uniaxial load - a loading condition whereby a larninate is stressed in only one direction

unidirectional composite - having parallel fibers in a composite. Compare with unidirectional laminate

unidirectional laminate - a composite laminate in which aH the fibers are oriented in the same direction

vacuum bag molding - a process for molding composites in which a sheet of flexible transparent material is placed over the lay-up on the mold and sealed; a vacuum is applied between the sheet and the lay-up; the air is mechanically worked out of the layup and removed by the vacuum; the part is cured

veil - see surface mat

vinyl ester - a thermoset resin with epoxy backbone, but which cures by peroxide initiation like a polyester

voids - air pockets that have been trapped and cured into a laminate

volatiles - materials in a roving sizing or a resin formulation which are capable of being driven off as a vapor at room or slightly elevated temperature

wall stress - in a filament-wound part, usually a pressure vessel, the stress calculated using the load and the entire laminate cross-sectional area (see also fiber stress)

waywind - the number of wraps or turns that roving or yam make from one side of the wound package back to the same side

wet lay-up - a reinforced plastic which has liquid resin applied as the reinforcement is being laid up

wet-out - the condition of an impregnated roving or yam wherein substantially all voids between sized strands and filaments are filled with resin

wet-out rate - the time required for a plastic to fill the interstices of a reinforcement material and wet the surface of the reinforcement fibers, usually determined by optical or light transmission means

wet winding - filament-winding reinforced plastics when the fiber reinforcement is coated with liquid resin just prior to wrapping on the mandrel

winding pattern - total number of individual circuits required for a winding path to begin repeating by laying down immediately adjacent to the initial circuit; a regularly recurring pattern of the filament path after a certain number of mandrel revolutions, leading to the eventual complete coverage of the mandrel

winding tension - in filament winding, the amount of tension on the reinforcement as it makes contact with a mandrel'

yardage - see yield

yield - number of yards of yam, roving strand, etc., per pound of glass fibers; the reciprocal of weight per yard

Annex H

Requirements for Materials and Production

A. Definitions

1. Fibre-reinforced plastics (FRP)

Heterogeneous materials, consisting of a thermo setting resin as the matrix and an embedded reinforcing material.

2. Thermosetting resin

Two-component mixture consisting of resin and hardener as well as possible additives.

3. Reinforcing materials

Materials generally in the form of fibre products which are embedded in a matrix in order to improve certain properties. In doing so, fibres of different materials displaying isotropic or anisotropic properties are processed in the form of semi-finished textile products (mats, rovings, fabrics, non-wovens). For special requirements, mixtures of different fibre materials are also used (hybrids).

4. Prepreg

Reinforcing material which is pre-impregnated with a thermosetting resin which can be processed without any further addition of resin or hardener.

5. Laminate

A moulded part which is manufactured by placing layers of reinforcing material on top of each other together with the thermosetting resin.

6. Sandwich laminate

Two laminate layers connected together by means of an intermediate core of a lighter material.

B. Materials

1. Thermosetting resin

Depending on the purpose, and consequently the requirement, a distinction is made between laminating resin and coating resin. Compatibility shall be demonstrated for the combination of gelcoat and laminating resin if the basic formulation of the resins are not the same.

1.1 Gelcoat and Topcoat resin

Gelcoat and topcoat resins shall protect the surface of the laminate from mechanical damage and environmental influences. Therefore, in a cured stage, the resin is to have a high resistance to existing media (e.g. fuel, river and sea water), to maritime and industrial environments), and to abrasion, in addition to low water absorption capabilities. Thixotropic agents and colouring pigments are the only permitted additives for gelcoat resins. In topcoat resins, additives for low styrene evaporation are also permitted.

1.2 Laminating resin

Laminating resins shall have good impregnation characteristics when being processed. In a cured stage, they shall be resistant to fuels, river and sea water, and shall exhibit a high resistance to ageing. Furthermore, adequate resistance to hydrolysis shall be ensured when used with permissible additives and filling materials. When using unsaturated polyesters (UP) as the resin, the resistance to hydrolysis shall be significantly higher than that of standard UP resin (for example through the use of a resin with an isophtalic acid basis).

1.3 Additives

1.3.1 All additives (catalysts, accelerators, filling materials, colouring pigments etc.) shall be suitable for the thermosetting resin and shall be compatible with it as well as the other additives, such that a complete curing of the resin can be ensured. The additives shall be dispersed carefully throughout the resin, in accordance with the guidelines of the manufacturer.

1.3.2 Catalysts, which initiate the hardening process, and accelerators, which control the working time (pot life, gel-time) and the cure time, shall be used in accordance with the processing guidelines provided by the manufacturer. For cold-setting systems, catalysts shall be proportioned in such a way that complete curing is ensured between temperatures of 16 °C and 25 °C. Cold-setting systems that are to cure at temperatures outside of this range, as well as warm-curing systems, may be used after consultation with BKI Head Office.

1.3.3 Filling materials shall not significantly impair the properties of the cured resin. The type and quantity of the filling materials shall be approved by BKI-HO and shall not lead to non-compliance with the minimum properties of the resin (cf. Section 2). In general, the proportion of filling materials in the laminating resin compound shall not exceed 12 % by weight (including a maximum of 1.5 % by weight of the thixotropic agent). If a smaller value is specified by the manufacturer, this value shall apply. The proportion of thixotropic agent in the gelcoat resin compound shall not exceed 3 % by weight. Laminates used for fuel and water tanks shall not contain filling materials.

1.3.4 Colouring pigments shall be climate-proof and consist of inorganic or non-fading organic dyes. The maximum permissible proportion shall not exceed the value specified by the manufacturer; if no value is specified, then it shall not exceed 5 % by weight.

2. Reinforcing materials

2.1 Various types of reinforcing materials with filaments of glass, carbon and aramide are available:

Roving:	A large number of parallel filaments placed together with or without twisting.
Mat:	Irregular layering of continuous filaments (fleeces), or chopped (minimum 50 mm long) which are joined together by means of a binder.
Fabric:	Rovings woven together by means of the weaving techniques used in the textile industry, such as binding cloth, satin, body, atlas etc. Different materials and/or filament thicknesses are possible for warp and weft.
Non-woven fabric:	Unidirectional layers of fibres which are laid on each other in an arbitrary manner. The layers are fixed by thin fibre strands, either together or on mats. Different materials and/or filament thicknesses are possible in the individual layers.

2.2 Fibre surface treatment with sizing, coupling agents or finish shall be matched to the thermosetting resin, in order to ensure adequate material properties, also under the influence of media.

2.3 Only low-alkaline aluminium boron silicate glass may be used for glass fibres (alkali oxide content ≤ 1 %), e.g. E-glass in accordance with VDE 0334/ Part 1, 9.72, Section 4.

3. Core materials for sandwich constructions

3.1 It shall be demonstrated that the core materials used are suitable for the intended purpose. They shall not impair the curing of the laminating resin.

3.2 The joining surfaces of local reinforcements made of metallic materials (e.g. inlets, connections) shall be cleaned in the same manner as for a gluing process, in order to ensure optimal bonding (cf. DIN 53281, Part 1).

3.3 Core materials other than those listed below may be used, provided that they are suitable for the intended purpose and that this is accepted by BKI-HO by beforehand.

3.4 Rigid foam materials

Rigid foam materials which are used as core material for sandwich laminates, or as shear webs, shall be of a closed-cell type and have high resistance against the laminating resin or the adhesive, as well as against ageing, fuels, river and sea water. A low water absorption capability is required, together with a minimum apparent density of 60 kg/m.

It shall be ensured that the allowable temperature of foam material is not exceeded during the curing reaction (exothermic reaction).

3.5 End-grained balsa wood

End-grained balsa wood used as core material for sandwich laminates shall fulfill the following requirements. It shall

- have immediately been treated after felling
- against attack by fungi and insects,
- be sterilized and homogenized,
- be kiln-dried within 10 days after felling, and
- have an average moisture content of maximum 12 %.

4. Prepregs

Fibre reinforcements pre-impregnated with laminating resin shall satisfy the requirements placed on their components. In addition, a minimum resin volume content of 35 % by volume shall be ensured, as well as adequate tack at the processing temperature.

5. Adhesives

5.1 When bonding fibre-reinforced plastics together, or with other materials, only solvent-free adhesives shall be used. Preference shall be given to two-component reaction adhesives, if possible with the same basis as the laminating resin.

5.2 Laminates shall only be bonded in the cured state. Hot-setting adhesives generally attain a higher strength; however, the maximum allowable temperature of the materials to be bonded shall not be exceeded. This applies especially when using single-component hot-melt adhesive.

5.3 The adhesives shall be used in accordance with the processing guidelines issued by the manufacturer. They shall not affect the materials to be bonded and shall exhibit a high resistance to humidity and ageing. The influence of the operating temperature on the adhesive strength shall be small.

5.4 Adhesives shall be usable within a minimum temperature range of –20° to +60°C.

C. Approval of Materials

1. All materials to be used during production of components from FRP shall first be assessed and approved by BKI. Approval by other organizations can be recognized following agreement by BKI, provided that the tests required for approval are in accordance with BKI requirements.

2. The manufacturer and/or supplier of the material shall apply to BKI-HO for approval.

3. Approval is granted if the material fulfils the requirements of BKI. For this purpose, specific tests are necessary, and they shall either be carried out under supervision of BKI or the results shall be documented in the report of a recognized testing institute. The respective test criteria are given in the Appendix.

4. Before production starts, the required material approvals shall be submitted to BKI-HO and/or the responsible BKI inspection office. If no approvals, or not all required approvals have been obtained, then as an exception and following agreement with BKI-HO, proof of the properties of the basic material can be demonstrated as part of material testing of the component laminate.

5. The packaging or wrapping material shall bear a reference to the approval.

D. Requirements for Manufacturers

1. General

1.1 All manufacturing facilities, store-rooms and their operational equipment shall fulfill the requirements of the responsible safety authorities and professional employers liability insurance associations. The manufacturer is exclusively responsible for compliance with these requirements.

1.2 The danger of contamination of laminating materials shall be minimized through separation of production facilities from store-rooms.

1.3 During laminating and bonding in the laminating shop, no dust-generating machinery shall be operated nor any painting or spraying operations carried out. As a matter of principle, such work shall take place in separate rooms.

2. Laminating workshops

2.1 Laminating workshops shall be closed spaces capable of being heated and having supply and exhaust ventilation. During laminating and curing, a room temperature of between 16 °C and 25 °C and a maximum relative humidity of 70 % shall be maintained, provided that the manufacturer of the laminating resin compound does not specify otherwise.

2.2 In order to control the climatic conditions, thermographs and hydrographs shall be provided. The equipment shall be set up following agreement with BKI, their number and arrangement depending on operational conditions. The equipment shall be calibrated in accordance with statutory regulations. The recordings shall be kept for at least 10 years and submitted to BKI on request.

2.3 Ventilation facilities shall be arranged in such a manner that no inadmissible amounts of solvents are removed from the laminate, and also that no inadmissible workplace concentrations (MAC values) occur.

2.4 The workplaces shall be illuminated adequately and suitably, but at the same time precautionary measures shall be taken to ensure that the controlled curing of the laminating resin compound is neither impaired through sunlight nor lighting equipment.

3. Storage-rooms

3.1 Laminating resins shall be stored in accordance with the manufacturer's instructions. If no such instructions are provided, then they shall be stored in dark, dry rooms at a temperature between 10 °C and 18°C. The temperature of the storage-rooms shall be recorded continuously by means of thermographs.

3.2 Prepregs shall be stored in special cold-storage rooms in accordance with the manufacturer's instructions. The temperature in general shall not exceed –22 °C.

3.3 Hardeners, catalysts and accelerators shall be stored separately in well-ventilated rooms in accordance with the manufacturer's instructions. If no instructions are provided, they shall be stored in dark, dry rooms at temperatures between 10 °C and 18 °C.

3.4 Reinforcing materials, fillers and additives shall be stored in closed containers, in dry and conditions.

3.5 Storage shall be arranged in such a way that the identification of the materials, their storage conditions and maximum period of storage (expiry date) as prescribed by the manufacturer are clearly visible. Materials whose duration of storage exceeds the expiry date shall be removed immediately from the stores.

3.6 Quantities of materials due to be processed shall be brought to the production shops as early as possible to ensure complete adjustment to the processing temperature $\Delta T \leq 2$ °C, with the containers remaining closed.

3.7 Materials taken from the stores and partially used shall only be replaced in the stores in special (e.g. hot-curing prepregs) and with the consent of BKI.

E. Regulations for Processing

1. General

1.1 As a matter of principle, only materials approved by BKI shall be used. In addition to the choice of suitable and approved materials, special care shall be taken when working with them because of the great influence on the properties of the product.

1.2 For the preparation and processing of the resin compounds and reinforcing material, these Rules, the instructions issued by the material manufacturers and the regulations of the local authorities shall also be observed.

1.3 Resin, hardener and resin additives shall be mixed in such a way as to ensure a uniform distribution and to minimize the amount of air introduced into the mixture as far as possible. A degassing of the resin compound may be necessary in individual cases.

1.4 During lamination, the processing time of the prepared resin compound specified by the manufacturer shall not be exceeded. If such a time is not specified, the pot-life shall be determined by means of a preliminary test and the processing time then established in consultation with BKI.

1.5 It is not possible to cover all types of moulds and processing methods in detail. Deviations are therefore possible for special cases with the consent of BKI.

2. Requirements for moulds

2.1 The moulds shall be made of a suitable material that, on the one hand, has adequate stiffness to prevent inadmissible deformations while laminating or curing, and on the other hand has no influence on the curing of the laminate. Moulds made of FRP may be used only after complete curing and subsequent tempering.

2.2 In the case of moulds for products which are made using vacuum bags, absolute air tightness of the mould shall additionally be ensured.

2.3 The surface of the moulds shall be as smooth as possible and shall have no sharp edges. The mould shall be designed in such a way as to permit flawless removal of the product from the mould.

2.4 Before commencing with the laminating, the surface of the components shall be treated with a sufficient quantity of a suitable release agent and brought up to the temperature required for lamination. The surfaces shall be dry and free of dust. It is not permissible to use release agents with a silicon base.

3. Building up the laminate

3.1 If the surface protection is to be achieved by providing a gelcoat, then the gelcoat resin compound shall be applied with a uniform thickness of between 0.4 and 0.6 mm, using a suitable process.

3.2 The first laminate layer shall be applied as soon as possible after application of the gelcoat. A fibre mat or fabric with low weight per unit area and a high resin content shall be used (e.g. for glass fibres: a maximum of 450 g/m^2 and a maximum of 30 % glass by weight).

3.3 The laminate shall be built up in accordance with the approved technical documentation, whereby BKI shall be consulted about the method. Air shall be adequately removed from the reinforcing layers and these layers shall be compacted in such a manner to ensure that the required proportion of resin is achieved. Resin enrichment shall be avoided.

3.4 The maximum thickness of the material that can be cured at one time is determined by the maximum permissible heat development.

In the case of vacuum bagging, as a rule, the decisive factor is the maximum number of layers from which air can still be totally removed.

3.5 If a laminating process is interrupted for a period causing the base laminate resin to exceed the point of gelation, a test is to be performed to verify adhesion between the base laminate and the top laminate. For each resin system, under the given processing conditions, the permissible period of interruption of the laminating process is to be determined. In the event of this period being exceeded, the laminate shall be thoroughly ground in order to provide a surface exhibiting adequate adhesion properties after removal of the dust. For UP resins on an orthophthalic acid and standard glycol basis not containing any skin-forming agents a 48 h interruption on the laminating process may, without any further proof being furnished, be considered uncritical with respect to lamination.

3.6 Transitions between different thicknesses of laminate shall be made gradually. A minimum value (for glass fabric in the fibre direction) of 25 mm per 600 g/m^2 reinforcing material can be used. In the transition region from a sandwich construction to a solid laminate, the core material shall be tapered with a gradient of not more than 1:2.

3.7 If cutting of reinforcing layers is unavoidable in the case of complicated mouldings, then the cut edges shall overlap, or reinforcement strips shall be provided. In the butt or seam region of laminates, every reinforcing layer shall overlap by at least 25 mm per 600 g/m^2.

3.8 Different components may be laminated together only while they are not fully cured. Special attention shall be paid to crossings of laminates.

3.9 Parallel or insert linings shall be free of all moisture and pollution (dirt). Their bonding surfaces with the laminate shall be prepared in a suitable manner (roughening, coupling agent or similar).

4. Glass-fibre resin spraying

Glass-fibre resin spraying, a partly mechanical method of lamination by hand, requires fulfillment of the following specific requirements:

4.1 The equipment to be used shall be demonstrated before use and its suitability proven.

4.2 The qualification of the fibre-resin sprayer, and where appropriate his assistant, shall be demonstrated to BKI by means of procedure test.

4.3 The equipment shall be calibrated in accordance with the guidelines of the manufacturer. Calibration shall be checked regularly before fibre-resin spraying, but the very least at the beginning of every production day.

4.4 The length of a roving cut shall be between 25 mm and 50 mm.

4.5 A powder-bound textile glass mat of maximum 450 g/m^2 shall be used for the first laminate layer. The glass part of this layer (to be applied manually) shall be less than 30 % by weight.

4.6 The glass weight per unit area of the spray laminate layer of a combined laminate shall not exceed 1150 g/m^2.

4.7 After a maximum of 1150 g/m^2 of fibres have been sprayed, air shall be removed and the composite shall be compacted.

4.8 Tests shall be performed on a regular basis to check whether a uniform laying up of the reinforced layers as well as a uniform distribution of percentage glass weight has been achieved. BKI reserves the right to demand test pieces to check the resulting mechanical properties.

5. Curing and tempering

5.1 Completed components may only be taken from the moulds after adequate curing of the thermo-setting resin compounds. The required cure time generally depends on the manufacturer's instructions. Otherwise, a minimum cure time of 12 hours shall be observed for cold-setting systems.

5.2 Resin systems which cure under pressure, UV radiation and/or increased temperature shall be treated in accordance with the manufacturer's instructions.

5.3 Immediately after curing, the components should receive post-treatment at increased temperature (tempering). The tempering time depends on the resin in question and the temperature attained within the component during tempering, whereby this shall be below the temperature for dimensional stability under heat and shall be agreed on with BKI. Cold-setting systems which are not subsequently tempered shall be stored for 30 days at a temperature of 16 °C, and for correspondingly shorter periods at temperatures up to 25 °C. This period can be shortened with the consent of BKI, provided the relevant manufacturer's specifications regarding post-curing are available, or post-curing values exist which are supported by experimental results. If such values are not available, then in general the following tempering conditions can be used (polyester/epoxy resin):

at least 16 h at 40 °C / 50 °C or

at least 9 h at 50 °C / 60 °C

6. Bonding

6.1 General

6.1.1 Bonded joints for load-bearing parts shall in general be verified using a procedure test to be agreed on for each individual case. The scope of the required tests shall be determined in agreement with BKI.

6.1.2 For bonding of composite fibre materials, only adhesives approved by BKI shall be used. The adhesives shall not have any negative effects on the materials to be bonded.

6.1.3 The application limits for the adhesive, as specified by the manufacturer, shall be adhered to. A bonding-suitable design which as far as possible avoids peeling moments and forces shall be used, and thickness of the adhesive layer shall be kept as thin as possible. The joining surfaces shall be kept as large as possible, and forces shall be applied over a large area.

6.2 Surface pre-treatment

6.2.1 The different surface pre-treatments are listed in VDI (Association of German Engineers) guidelines 2229 and 3821.

6.2.2 The surfaces of the materials to be bonded shall be dry and free of grease, dust and solvents. Particularly when degreasing, attention shall be paid to compatibility of the solvent with the materials.

6.2.3 In the case of smooth surfaces, they shall be roughened e.g. mechanically by grinding or sand blasting, or chemically through pickling. This is absolutely necessary when there are coatings on the surfaces of the materials to be bonded which impair adhesion (e.g. skin-forming agents in polyester resins; see E.3.6).

6.2.4 In most cases, an increase of the adhesive strength is achieved by the application of specially primers, in particular, the use of primers recommended for bonding which is subsequently subjected to negative environmental influences.

6.3 Processing

6.3.1 The adhesive shall be used in accordance with the instructions issued by the manufacturer, whereby the proportion of filling materials shall not exceed the permissible value.

6.3.2 The adhesive shall be applied uniformly, free of voids and not too thickly onto the materials to be bonded.

6.3.3 If, for special reasons, gluing joints of 5 mm or more cannot be avoided, then the materials to be bonded shall be first provided with a thin coating of pure adhesive resin.

6.3.4 It is not permissible to apply loads to the bonding before complete curing of the adhesive.

6.3.5 In the case of cold-setting thermosetting resin adhesives, a subsequent tempering of the bonding is recommended.

6.3.6 The edges of the area treated with adhesives shall be protected by means of suitable measures against penetration of extraneous media (e.g. humidity).

7. Sealing

7.1 Laminate surfaces without surface protection shall be sealed after curing or tempering, using suitable agents. In particular, edges of cut-outs and bondings shall be protected carefully against the penetration of extraneous media (moisture).

7.2 The sealing materials used shall not impair the properties of the laminate or of the bonding. Furthermore, they shall be appropriate for the purpose of the component.

F. Manufacturing Surveillance

1. General

1.1 For components made of FRP, manufacturing surveillance consists of the quality control of the basic materials, production surveillance and the quality inspection of the finished components.

1.2 In the case of manufacturing surveillance, a distinction is made between internal and third-party (external) surveillance. In the sense of these Regulations, third-party surveillance means periodic and random checks by BKI of the internal surveillance as well as of the component quality.

1.3 BKI reserves the right to carry out inspections in the production facilities without giving prior notice. The manufacturer shall grant inspectors access to all areas used for production, storage and testing and shall present all documentation concerning records and tests carried out.

1.4 The scope of third-party surveillance can be reduced in the case of production facilities that have a certified quality management system.

2. Incoming inspection

2.1 Characteristic values and mechanical properties specified in the material approval shall be confirmed by the manufacturer, at least by a test report (DIN EN 10204-2.2). On arrival of the product, a check shall be carried out to ascertain whether it corresponds to the requirements. Material properties shall be checked by random sampling.

2.2 The products shall be listed in the inventory file and shall be stored in accordance with the requirements of these Regulations.

3. Production surveillance

3.1 Details of production shall be stipulated by means of check lists and routing cards which accompany each stage of the production and are signed by the employees in charge.

3.2 Production surveillance shall be carried out constantly by the internal quality department. The scope shall be stipulated in an inspection and test plan and signed by the employees in charge.

3.3 Employees involved in production shall be suitably trained and shall work under professionally qualified supervision.

3.4 The materials used in the production shall be documented in a clear and comprehensive manner. Parameters relevant for the quality (temperature, humidity etc.) shall also be recorded in the production documentation.

3.5 Details (including the direction) of reinforcing layers in the laminate shall be checked off immediately during the production process.

3.6 A sample shall be taken from each batch of thermosetting resin compound that is mixed, and this shall be labeled, cured and stored. These samples shall be subjected to random testing of the degree of their curing and the results shall be documented.

3.7 During production, laminate samples shall be prepared and shall be used for checking the characteristic values and the mechanical properties. The material strength values shall conform with the specified values. If no adequately-sized laminate samples can be obtained from cuttings or sections, then reference laminates produced in parallel with dimensions of approximately 50 x 50 cm^2 shall be prepared. Their quantity depends either on the number of the components, or the number of production days (the lower number can be chosen).

4. Structural tests

4.1 During production and on completion of production, the component shall be subjected to visual inspections. In particular, attention shall be paid to voids, delamination, warping, discoloration, damage etc. In addition, the general quality, e. g. surface finish, shall be assessed.

4.2 By means of suitable testing procedures, the quality of the components shall be determined, if possible during production, and at the latest on completion of production. Special attention shall be paid to the bonding and to the degree of curing of the component.

4.3 Following agreement with BKI, individual or random tests shall be carried out on finished components under static and/or dynamic loads.

4.4 BKI shall be informed about repairs of any faults relevant to the strength of the component, and the procedure used to carry out the repair shall be in accordance with Annex J.

Annex I

Inspection and Testing of Fibre Composite Materials

A. Requirements

1. General

1.1 In accordance with the Rules and Regulations of BKI, the materials used for manufacturing components made of FRP under the supervision of BKI shall be approved by BKI. Approvals are granted for the following materials:

– Gelcoat and/or laminating resins

– Reinforcing materials

– Prepregs

– Core materials

– Adhesives

1.2 Applications for approval by BKI Head Office (BKI-HO) shall be made by the material manufacturer or an agent. Together with the application, the following shall be submitted to BKI-HO:

– Product description

– Safety data sheet

– Storage and processing instructions

– A declaration in writing by the applicant that the tested materials comply with those for which the approval is requested, and that the sample is manufactured in accordance with the Rules and Regulations of BKI.

– Copy of the test certificate of a recognized testing body, i.e. an accredited testing laboratory or a notified testing body.

1.3 The tests shall be carried out in accordance with the standards mentioned in this rule. However, comparable standards of other countries are also acceptable after agreement with BKI-HO in each individual case.

1.4 The minimum properties required by BKI for the tests shall be fulfilled by all specimens.

1.5 In the case of inadequate test results of individual specimens, attention shall be paid to the following (for a basic number of 6 tests):

– If one or two specimens yield inadequate results, the tests shall be repeated with twice as many specimens.

– If the test results are inadequate for three or more specimens, the test can be repeated on newly produced specimens, provided that BKI agrees to this.

– If even one sample yields inadequate results while repeat-testing, then approval is not possible.

1.6 If the material fulfils the BKI requirements, then a statement of material approval is issued by BKI-HO. This is generally valid for four years, whereby extensions are possible.

1.7 BKI-HO shall be notified immediately of all modifications or other changes, to the material. Decisions regarding the further validity of the material approval is made on an individual basis.

1.8 A constant material quality shall be provided by the manufacturer through suitable QM measures. If this is not ensured, BKI reserves the right to suspend, or withdraw, the approval.

1.9 BKI reserves the right to demand and/or carry out spot tests of the material properties during the period required for material approval. If, in doing so, there is no adequate comparison with the required values, the material approval can be suspended or withdrawn by BKI.

1.10 The approval refers only to the approved material. The applicability of this material in connection with other approved materials shall be demonstrated independently by the manufacturer, or the user, in a suitable manner. In cases of doubt, BKI reserves the right to require a check of the properties of the material combination.

2. Thermosetting resins

2.1 General

2.1.1 The basic requirements listed under item 1. apply for material approval.

2.1.2 A general description of the thermosetting resin, its processing conditions as well as the properties of resin in the processing state shall be submitted. The basic properties of the cured thermosetting resin shall be verified by the test certificate of a recognized testing body. These values shall fulfill specified minimum requirements.

2.1.3 Cold-setting unsaturated polyester (UP) resins and cold-setting epoxy (EP) resins are specifically described below. Other types of resins can also be approved after consultation with BKI-HO, whereby the required minimum properties are specified by BKI-HO on an individual basis. However, they shall at least comply with those of UP resins.

2.2 Description

2.2.1 A description of the thermosetting resin shall be submitted in order to allow an unequivocal identification:

– Resin type and state

– Purpose

– Manufacturer

– Trade name

2.2.2 In addition, the following shall be indicated:

– Storage conditions

– Environmental conditions for processing

– Type and proportion of allowed additives

– Curing conditions, tempering

2.3 Properties in the processing state and during curing

The properties shall be determined in accordance with the following standards:

– Density (DIN EN ISO 1675)

– Viscosity (DIN 53015 – ISO 2555)

– Reactivity:
UP resins: acid number
(DIN 53402 – ISO 2114)

EP resins: epoxy equivalent
(DIN 16945 – ISO DIS 3001)

– WP resins: Monomer proportion (ISO 3251)

– Gel time (temperature increase) (DIN 16945, Section 6.2, 6.3 – ISO 2535)

– Curing shrinkage (DIN 16945, Section 6.5)

2.4 Properties in the cured state

2.4.1 The following properties shall be submitted for all thermosetting resins in the cured state:

– Density

– Water absorption

– Strength, modulus of elasticity in tension, and tensile fracture strain

– Strength and modulus of elasticity in bending

– Dimensional stability under heat

2.4.2 For gelcoat and topcoat resins, the following additional information shall be submitted:

– Abrasion resistance (DIN 53754 – ISO 9352), 3 samples

– Resistance against seawater, fuels, hydraulic oil, weak acids and alkalis (DIN ISO 175)

2.4.3 With regard to the properties, the following shall be verified by the test certificate of a recognized testing body. For this purpose, specimens shall be used which are produced in accordance with the submitted processing guidelines. The specimens shall be cured and tempered for 16 h at 40 °C (polyester resins) or 16 h at 50 °C (epoxy resins). For gelcoat and topcoat resins, only the first four properties shall be identified-verified:

– Density (DIN 53479 – ISO 1183, method A), 3 specimens

– Water absorption (DIN ISO 175, Specimen 50 mm x 50 mm x 4 mm), 3 specimens

– Dimensional stability under heat (DIN 53461 – ISO 75, method A), 3 specimens

– Tensile strength, fracture strain, modulus of elasticity in tension (DIN EN ISO 527-2, test piece 1 B), 6 specimens

– Bending strength (DIN EN ISO 178), 3 specimens

– Modulus of elasticity in bending (DIN EN ISO 178), 3 specimens

2.4.4 The mechanical properties are normally determined at standard climate 23/50 (23 °C / 50 % relative humidity). If the intended operating temperature range of the resin is not between –20 °C and +50°C, further testing temperatures shall be agreed on with BKI-HO.

2.4.5 The testing speed in the case of tensile and bending tests shall be selected in such a way that a specimen or edge-fibre strain of about 1 %/min is ensured. This shall be documented in the test report. The modulus of elasticity shall be determined as a secant modulus between 0.05 % and 0.25 % strain.

The water absorption shall be specifically determined at 23 °C after 24 ± 1 h and 168 ± 2 h.

2.5 Minimum properties

2.5.1 For resin products consisting of UP resins, the following minimum properties are specified for use as laminating resins (values for gelcoat resins in brackets):

Tensile strength:	40 Mpa	(—)
Fracture strain:	2.0 %	(3.0 %)
Modulus of elasticity (tension):	2700 Mpa	(—)
Bending strength:	80 Mpa	(—)
Dimensional stability under heat	60° C	60° C
Water absorption 24 h / 168 h:	–/70 mg	(—/60 mg)

2.5.2 The following minimum properties apply to resin products consisting of EP resins:

Tensile strength:	55 Mpa	(—)
Fracture strain:	2.5 %	(3.5 %)
Modulus of elasticity (tension):	2700 Mpa	(—)
Bending strength:	100 Mpa	(—)
Dimensional stability under heat:	70 °C	(70 °C)
Water absorption 24 h/168 h:	– mg/50 mg	(– mg/50 mg)

2.5.3 The abrasion resistance properties and the resistance properties to extraneous media in the case of gelcoat resins may be determined by the applicant.

– The abrasion resistance determined in the test (sliding abrasion rate) shall be adequate.

– The properties stipulated in DIN 53476 under item 7.4 a - c should be determined after 24 h and 168 h at 23 °C. Taking these properties into account and following agreement between BKI-HO and the applicant, the following classification is made:

  – Resistant,
  – Conditionally resistant
  – Not resistant

3. Reinforcing materials

3.1 General

3.1.1 The basic requirements listed under item 1. apply for material approval.

3.1.2 A general description of the reinforcing material and of the filament shall be provided. Basic properties of laminate specimens taken from the reinforcing material shall be verified by the test certificate of a recognized testing body. These values shall fulfill specified minimum requirements.

3.1.3 The following applies to fibre reinforcements made of glass, carbon and aramide. Products with other reinforcing fibres can also be approved, following agreement with BKI-HO, whereby the minimum properties are then specified on an individual basis.

3.1.4 Due to the great number of the fibre reinforcing products on the market, only the most common ones can be listed. Products not covered (e.g. complexes, hybrids), can also be approved, following agreement with BKI-HO.

3.2 Description

3.2.1 A description is necessary which allows an unequivocal identification of the reinforcing material:

– Fibre material
– Reinforcement type (mat, fabric etc.)
– Manufacturer
– Trade name

3.2.2 In addition, the following is required:

– Form of supply
– Storage conditions
– Processing instructions

3.2.3 The filament and its treatment/sizing shall be submitted:

– Filament diameter (DIN 53811 – ISO R 137)
– Coupling agreed or sizing
– Resin compatibility

In the case of glass fibre products, the average filament diameter shall not exceed 19 µm.

3.2.4 In the case of reinforcing products consisting of a combination of different fibre materials and/or filaments, all fibre types shall be indicated.

3.2.5 If, in the case of textile glass reinforcing products, no E-glass or R-glass is used in accordance with DIN 1259-1, then an alkali oxide content (DIN ISO 719) of less than 1 % shall be verified by means of a test certificate from a recognized testing body.

3.3 Properties of the reinforcing products

3.3.1 Rovings

– Number of the filaments in the roving

– Roving fineness (DIN 53830-1 – ISO 4602)

When rovings are used as gun rovings (DIN 52316 – ISO DIS 3375), the stiffness shall be additionally verified by the certificate of a recognized testing body.

3.3.2 Mats (continuous and chopped-strand mats)

– Fibre length (for chopped-strand mats)

– Linear density of the fibre (DIN 53830-T1–ISO 1889)

– Weight per unit area (DIN 53854 – ISO 3374)

– Layer thickness (DIN 53855-T1– ISO DIS 3616)

– Binder (see 3.3.5)

3.3.3 Fabric

– Linear density of the fibres, warpwise and weftwise (DIN 53830-T3 – ISO 1889)

– Count, warpwise and weftwise (DIN 53853)

– Weight per unit area (DIN 53854 – ISO 4605)

– Fabric thickness (DIN 53855-T1 – ISO 4603)

– Weave (DIN 61101-T2)

3.3.4 Non-woven fabric

– Lay up

– Linear density of the fibres in all directions

– Weight per unit area of the individual layers and of the non-woven fabric (DIN 53854 – ISO 4605)

– Non-woven fabric thickness (DIN 53855-T1 – ISO 4603)

– Binder (see 3.3.5)

If a non-woven fabric contains mat or fabric layers, then the linear density and, where appropriate, the fibre length shall be indicated.

3.3.5 A difference shall be made between chemical and mechanical bond types. In the case of chemical bond types, the binder, the percentage weight (glass 1887, carbon DIN 29965) and its solubility (DIN 52332) shall be indicated. In the case of mechanical bond types, the type of weave shall be indicated.

3.3.6 In the case of reinforcing products with different fibre materials, the percentages of materials used in the respective reinforcing directions shall be indicated.

3.4 Laminate properties of the reinforcing products

3.4.1 For laminate production, it is strongly recommended that BKI-approved cold-setting UP resins are to be used. After curing, the specimens shall be tempered for 16 h at 40 °C. If, for special reasons, other (also warm-setting) thermosetting resins are to be used, then this shall be agreed in advance by BKI-HO.

3.4.2 For rovings, tensile test specimens shall be prepared for all fibre materials in accordance with DIN 29965, Section 4.1.3.5. The test certificate of a recognized testing body shall be submitted to verify the tensile strength, the fracture strain and the modulus of elasticity as the mean values from six tests carried out in accordance with DIN 65382. Furthermore, the tensile strength and the modulus of elasticity shall be determined in accordance with DIN 65469 on flat specimens prepared for testing under tension.

3.4.3 For all other reinforcing products, laminate test panels shall be prepared in accordance with DIN EN 2374, Section 5.3 (Method C). In doing so, the reinforcing products shall be arranged in identical alignment. Depending on number of the reinforcing directions, the laminates should have approximately the following thicknesses: unidirectional laminates 2 mm, bi-directional laminates 4 mm and directional laminates 5 mm.

3.4.4 Appropriate test panels shall be prepared by fibre resin spraying for the use of gun rovings. The length of the gun rovings in this case shall be 35 mm.

3.4.5 The gun prescribed number of specimens shall be cut out of the test panels for each test. In doing so, specimens shall be taken from each reinforcing direction of the laminate in order to test the mechanical properties. For products with randomly distributed reinforcing directions, specimens shall be taken from any two directions, but at right angles to each other.

3.4.6 The specimens shall be tested in accordance with DIN EN ISO 291 after at least 16 h under standard climate conditions.

If aramide fibres are used as a reinforcing material, an additional test shall be carried out on specimens which have previously been subjected to conditioning of 720 · 8 h at 23 °C in distilled water. The conditioning period can be reduced by 50 % for each temperature increase of 10 °C. While conditioning, the dimensional stability temperature of the thermosetting resin shall not be exceeded.

3.4.7 The following properties shall be verified by the test certificate of a recognized testing body:

– Fibre content (glass EN 60 – ISO 1887, carbon DIN EN 2564, aramide DIN 65356-2), 3 specimens

– Tensile strength, fracture strain, modulus of elasticity in tension (DIN EN ISO 527-4, test piece III), 6 specimens

– Bending strength, modulus of elasticity in bending (DIN EN ISO 14125, Method A), 6 specimens

In addition, for carbon and aramide fibres, the compressive strength and the modulus of elasticity in compression shall be demonstrated (carbon, Draft DIN EN 2850, test piece A1 with gauge length 8 mm, similarly for aramide).

3.4.8 The testing speeds shall be selected in such a way to ensure a strain rate of 1 %/min in the test piece or the edge fibre. The testing speed shall be indicated. The modulus of elasticity in tension shall be determined as a secant modulus between 10 % and 50 % of the fracture strain.

3.4.9 Testing shall be carried out in a standard climate 23/50 (23°C/50 % relative humidity). If the operating temperatures of the fibres are not between –20°C and +50 °C, then additional testing temperatures shall be agreed on with BKI-HO.

3.5 Minimum properties

3.5.1 For approval, fibre reinforced products shall fulfill specified minimum values for the mechanical properties. The influence of the fibre volume content on the properties has been taken into account when specifying the values. The values refer to the 0° direction in the case of a uniform lay up. If necessary, a correction to the actual lay up should be done.

3.5.2 The minimum values of all mechanical properties to be verified are determined by means of the following equation together with the values given in Table I.1:

$$X_{min} = \alpha[X_{ref} (\frac{\phi}{0.4})]$$

where:

X_{min} = minimum required value

X_{ref} = reference value for fibre volume content $\phi = 0.4$

α = factor for lay-up

ϕ = fibre volume content $0.2 \le \phi \le 0.6$

Deviations from the above specification are allowed for laminates with glass mats or gun rovings; in these cases, the minimum values for a percentage fibre weight content of $0.25 \le \phi \le 0.35$: are:

– Tensile strength:

$R_Z = 1278\ \phi^2 - 510\ \phi + 123$ [MPa]

– Young's Modulus (tension):

$E = [37\ \phi - 4.75]x\ 10^3$ [MPa]

– Bending strength:

$R_B = 502\ \phi^2 + 106.8$ [Mpa]

3.5.3 In the case of multidirectional lay up of the reinforcing products, the values shall be proved at least for one direction (preferably 0°).

3.5.4 For reinforcing products with different fibre materials in one direction, the values of the material with the lower minimum properties shall be fulfilled.

3.5.5 The minimum values for fabric are 95 % of the specified values for 0°/90° lay up.

3.5.6 The minimum values for the conditioned specimens made of aramide fibres are 90 % of the specified tensile values and of 80 % the specified compressive and bending values.

3.5.7 The stiffness of the gun rovings to be verified in accordance with DIN 52316 shall not be below 130 mm.

3.5.8 The linear relationship between the property and fibre volume content assumed when specifying minimum values does not apply for all properties, and shall therefore not be used to extrapolate measured values.

Table I.1 Coefficients for the determination of the minimum properties

Fibre	Property	Xref [Mpa]	α			
			0°	0°/90°	0°/ ± 45°	0°/90°/±45°
Glass	Tensile strength	500	1.00	0.55	0.50	0.45
	Young’s Modulus of elasticity	26000	1.00	0.71	0.57	0.55
	Bending Strength	650	1.00	0.55	0.45	0.40
Carbon	Tensile strength	800	1.00	0.55	0.50	0.45
	Modulus of elasticity	80000	1.00	0.55	0.45	0.42
	Bending Strength	725	1.00	0.55	0.45	0.40
	Compressive strength	600	1.00	0.55	0.50	0.45
	Modulus of elasticity compression	80000	1.00	0.55	0.50	0.45
Aramid	Tensile strength	650	1.00	0.55	-	-
	Modulus of elasticity	40000	1.00	0.55	-	-
	Bending Strength	400	1.00	0.55	-	-
	Compressive strength	170	1.00	0.50	-	-
	Modulus of elasticity compression	38000	1.00	0.50	-	-

4. Prepregs

4.1 General

4.1.1 The basic requirements listed under item 1. shall apply for material approval.

4.1.2 Since prepregs are based on resin systems which cure under heat, consultation with BKI-HO concerning the curing process of the resins is required.

4.1.3 The testing of cured prepreg laminates is identical with the laminate testing of fibre reinforced products. Taking into account the resin system, the minimum characteristic values shall be agreed on with BKI-HO.

4.1.4 Unidirectional non-woven prepregs and woven prepregs are considered within the framework of this Regulation. Other prepregs can also be approved, following agreement with BKI-HO.

4.2 Prepreg properties

4.2.1 A description is necessary which allows an unequivocal identification of the prepreg:

– Fibre material

– Resin system

– Reinforcement type

– Trade name

– Manufacturer

– Storage conditions, processing guidelines

4.2.2 The following properties shall be submitted for the non-cured prepreg material:

– Mass per unit area (DIN 53854)

– Resin percentage by weight (DIN 29971, Section 5.1.1.4)

– Layer thickness (DIN 53855-1)

– Resin flux percentage by weight (DIN 65090, Section 5.1.1)

4.2.3 The following are necessary for the reinforcing material:

– Filament diameter (DIN 53811 – ISO 137)

– Count (DIN 53853)

– bond type (only woven prepregs)

5. Core materials

5.1 General

5.1.1 The basic requirements listed under item 1 shall apply for material approval.

5.1.2 A general description of the core material shall be submitted. The basic properties shall be verified by the test certificate of a recognized testing body.

5.1.3 Rigid foam materials and cross-grained balsa are considered specifically as a core material within the framework of this Regulation. Cores made of other materials can also be approved, following agreement with BKI-HO.

5.2 Rigid foams

5.2.1 The following information is necessary for a general description:

– Basic material and additives

– Trade name

– Manufacturer

– Resin systems suitable for bonding/coating

– Storage conditions

5.2.2 The manufacturer shall provide details of the maximum permissible processing temperatures and the operating temperature limits. The long-term operating temperature shall at least cover the range - 20 °C to + 50 °C.

5.2.3 The test certificate of a recognized testing body verifying the following properties shall be submitted:

– Apparent density (DIN 53420 – ISO R 845); sample thickness ≥ 25 mm, 3 specimens

– Water absorption (DIN 53433 – ISO 2896), 3 specimens

– Compressive strength (DIN 53421 – ISO 844), 6 specimens, vertical to the plane of the test panel

– Modulus of elasticity (compression) (DIN 53457) 3 specimens, test piece III, vertical to the plate plane of the panel

– Shear strength (DIN 53294), 6 specimens

– Shear modulus (DIN 53294), 6 specimens

5.2.4 The specimens shall be tested without foam skin. The testing shall take place in a standard climate 23/50 (23°C/50% relative humidity). Testing procedures are given mainly for rigid foams, whereas in the case of tough foams BKI-HO shall be consulted if there is any doubt.

5.2.5 The following minimum properties are specified for an apparent density of 60 kg/m³ and 200 kg/m³:

Table I.2

	60 kg/m³	**200 kg/m³**
Compressive strength [MPa]	0.6	3.5
Modulus of elasticity (compression) [MPa]	40	200
Shear strength [MPa]	0.5	2.6
Shear modulus [MPa]	15	65
Water absorption [vol.-%] (after 28 Days)	2	2

5.2.6 In the case of other apparent densities, linear interpolation of the densities shall be used to determine strengths and moduli.

5.3 Cross-grained balsa wood

5.3.1 The requirements for cross-grained balsa wood are specified in Rules for Non Metallic Materials, Part-2, Wood – Requirements for Core Materials of Sandwich Laminates (Section 2).

6. Adhesives

6.1 General

6.1.1 The basic requirements listed under item 1 shall apply for material approval.

6.1.2 A general description of the adhesive shall be provided. Basic properties of the cured adhesive shall be verified by the test certificate of a recognized testing body.

6.1.3 The following specifically considers cold-setting and hot-setting thermosetting adhesives as well as hot-melt adhesives. Other adhesives, provided that they can be used for processing of FRP (e.g. expansion adhesives) can also be used, following agreement with BKI-HO.

6.2 Description

6.2.1 A description of the adhesive shall be submitted in order to allow an unequivocal identification of the adhesive:

– Type of adhesive

– Manufacturer

– Trade name

– Storage conditions

– Processing and curing guidelines

– Volume shrinkage after exceeding the gel point

– Glass transition temperature (ASTM E 1356-91)

6.2.2 In the case of adhesive films with backing, the backing material shall be specified.

6.3 Properties of the adhesive

6.3.1 In the processing state, the following information shall be provided:

– Density (DIN EN ISO 1675)

– Viscosity (DIN 53019)

6.3.2 In the case of two-component thermosetting resins which cure at room temperatures, the pot life (DIN 16945, Section 6.3) shall also be indicated.

6.4 Properties in the cured state

6.4.1 The following mechanical properties shall be verified by the certificate of a recognized testing body (on 6 specimens respectively):

– Tensile lap-shear strength (DIN EN 1465)

– Peeling resistance (DIN 53282)

In addition, a long-duration shear tension test (based on DIN 53283) shall be carried out. In doing so, the sample is subject to loads in a standard climate 23 °C/50 % relative humidity at 60 % of the mean tensile lap-shear strength for 192 ± 2 h.

6.4.2 The testing shall be carried out for three different conditioning states of the specimens:

– 24 ± 1 h after curing at 23 °C and storage at 50 % relative humidity

– 1000 ± 12 h storage at 60 °C and a maximum of 20 % relative humidity

– 1000 ± 12 h storage in distilled water at 23 °C

6.4.3 For each test and conditioning state, specimens with adhesive layer thicknesses of 0.5 mm and 3 mm shall be used.

6.4.4 All tests shall all be carried out in a standard climate 23 °C / 50 % relative humidity. In addition, the tensile lap-shear strength shall be verified at 60 °C on specimens with an adhesive layer thickness of 3 mm and subjected to a climate of 60 °C and a maximum of 20 % relative humidity for 1000 ± 12 hours before testing.

6.5 Minimum properties

6.5.1 The following properties shall be achieved for directly tested specimens as well as specimens tested after wet storage:

– Tensile lap-shear strength: 9 MPa

– Peeling resistance: 2 N/mm

6.5.2 For the specimens stored at elevated temperatures, the above minimum properties shall be reduced by 15 %.

6.5.3 Strain in creep shall be below 0.35 mm in the long-duration shear tension test.

Annex J

Repair of Components

A. General

1. Requirements for operation and personnel

1.1 Repairs shall only be performed by workshops which are approved by BKI for the repair of components made from fibre-reinforced thermosetting resins.

1.2 The shop approval for manufacturing components made of fibre-reinforced plastics using the hand lay-up method includes approval for repairing the parts within that production facility. For repairs out- side of the production facility (i.e. in the field), an extension of the shop approval is required.

1.3 The repairs shall only be carried out by persons with sufficient professional knowledge. This professional knowledge shall in general be verified by certificates of the corresponding training courses. If such certificates are not available, the minimum requirement shall consist of training completed for a technical profession, in conjunction with internal training and several months of experience.

1.4 The head of the repair team is responsible for proper execution of the repair and shall be named explicitly in the shop approval. His professional knowledge shall be verified by certificates of the corresponding training courses and professional experience of several years. In addition, a procedure test to be carried out at the shop under supervision of BKI is required.

1.5 The shop approval is granted by BKI Head Office (BKI-HO) on the basis of the information to be submitted with BKI Form and the report submitted by the BKI surveyor. The form deals with the following points:

– General information on the shop

– Personnel

– Internal quality management

– Incoming inspection

– Storage of the materials for repair in the shop and during field work

– Mechanical processing capabilities

– Production equipment.

2. Prerequisites

2.1 In the case of repairs which affect the structural integrity of the component, a repair plan shall be established and approved by BKI before the start at any repair work. If the same repair is to be carried out several times, a general repair plan can be established and submitted to BKI for approval.

2.2 Repairs to the gelcoat resin and (minor) repairs which do not fall under 2.1 shall be standardized and approved by BKI according to the standardized procedure.

2.3 For the approval of a repair according to 2.1, all design and repair drawings needed to assess the repair of the component shall be submitted to BKI. The repair plan will be examined by BKI-HO and approved if found suitable.

2.4 A report is required for each repair and has to be signed by the head of the repair team.

2.5 Only materials approved by BKI shall be used for the repair.

2.6 The thermosetting resins used for repair shall be at least equivalent to the original thermosetting resin used for production. To ensure low residual stresses in the area to be repaired, the use of fast-setting highly reactive thermosetting resins shall be avoided. The elongation at break of the thermosetting resins used for the repair shall be at least 2.5 %.

2.7 If the materials and laminates used for the repair are not identical to those employed when the component was manufactured, compatibility and equivalence of that particular combination of materials to the original ones shall be verified with respect to their properties.

B. Procedure

1. Preparation

1.1 Damaged material, or material which no longer exhibits complete bonding, shall be removed from the area to be repaired.

1.2 The region adjacent to the damaged area shall be chamfered. The chamfer ratio (chamfer length l_S to chamfer thickness t_S) depends on the tensile strength of the repair material, σ_{Mat}, in the chamfer direction, and the permissible shear stress τ. The minimum chamfer ratio shall be calculated by means of the following formula:

$$\frac{\sigma_{mat}}{T} = \frac{l_s}{t_s}$$

The permissible shear stress shall be 10 N/mm^2 for repairs in the shop and 7 N/mm^2 for repairs in the field.

1.3 The minimum overlap length for each layer shall not be less than 10 mm on all sides.

1.4 Because of the required draping ability needed (for curved surfaces and in the chamfered joint area; see Fig.1), the weight per unit area of the reinforcing materials used for repair work shall, as far as possible, not exceed 600 g/m^2 per layer (more layers with less weight per unit area are better than only a few layers with a high weight per unit area).

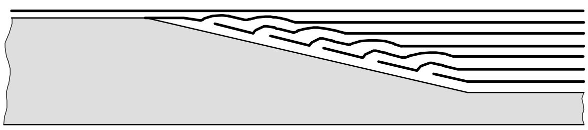

Fig. 1 Chamfered joint area for a repair (schematic)

1.5 In order that the stress magnification associated with a chamfered joint is as low as possible, at least three reinforcing layers should be used for each area to be repaired.

1.6 The area to be repaired shall be cleaned and grinded thoroughly, e.g. by using sandpaper with a grain of 80 or 120.

1.7 If the laminate has been in direct contact with water for a lengthy period, the laminate shall be dried properly before repair work is started.

1.8 As far as possible, the area to be repaired shall be relieved of the stress caused by its own weight. In the case of repairs performed in the field, special arrangements shall be taken if necessary to prevent the occurrence of external loads (e.g. caused by vibration).

1.9 For repairs in the field, the workplace shall be arranged in such a way that good accessibility to the area to be repaired and sufficient illumination are both ensured.

1.10 For repairs in the field, measures shall be taken against moisture as well as direct UV radiation.

1.11 The component temperature, at least within the repair area, shall be kept within the range permitted in 2.1.

1.12 The mixing ratio of resin to hardener shall be maintained as precisely as possible (in the case of epoxy resins, the relative deviation from the mixing ratio shall not exceed 3 %). The actual mixing ratio and the quantities used shall be recorded in a dosing report.

2. Execution

2.1 During the repair work and the curing period, a surrounding air and a component temperature between 16 and 25 °C as well as a maximum relative humidity of 70 % shall be maintained. If the resin or adhesive manufacturer has not specified other permissible values, these values shall apply.

2.2 Calibrated thermometers and hygrometers shall be used for monitoring in the vicinity of the repair or at a position agreed upon with BKI.

2.3 It shall be ensured that no changes in elongation occur in the laminate during the repair.

2.4 The lay-up at the prepared area to be repaired shall be performed by means of the hand lay-up method, as far as possible in the same sequence that was applied for the original laminate. The fibre orientation shall be identical.

2.5 Attention shall be paid to providing good impregnation of the reinforcing material. Voids shall be avoided.

2.6 A mat or fabric with a weight per unit area of approx. 225 g/m^2 (maximum 450 g/m^2 for boats) and a low percentage fibre weight content (approx. 30 %) shall be used as the final layer.

2.7 The laminate shall be given sufficient surface protection by means of a coating resin. If the repair areas are subjected to increased moisture levels, a high resistance to hydrolysis is required of the coating resin.

2.8 If unsaturated polyester or vinyl resins are used for the topcoat, inhibition problems shall be avoided by excluding atmospheric oxygen (e.g. by adding paraffin or using foil coverings).

3. Curing

3.1 During the curing process, it shall be ensured that no changes in elongation take place in the laminate.

3.2 Repaired components shall only be subjected to loads or put into further operation after the thermosetting resin has cured sufficiently.

3.3 If no explicit values are quoted for the curing process by the manufacturer of the thermosetting resin system, the following time periods shall apply for cold-setting resin systems:

– For a constant temperature of 16 °C:

  at least 72 h,

– For a constant temperature of 25 °C:

  at least 38 h.

3.4 If the repaired component was tempered during manufacture, the area to be repaired shall also be tempered after setting, if no proof is provided to show that this is not necessary.

C. Documentation

1. Repair report

1.1 The repair report shall at least contain the following points:

– Designation of the component and, if applicable, its identification number

– Date and location of the repair (address of the shop or location in the field)

– Start time of repair

– Position and type of damage

– Repair plan and approval No.

– Climatic conditions during repair and the curing period (and the wind speed, in case the work was not performed within a closed room)

– Materials used (with batch number)

– Mixing ratios for thermosetting resin systems; dosing report

– Lay up (number of layers and orientation)

– Any deviations from the repair plan

– Duration of the repair

– Curing time

– Signature of the head of the repair team

Note:

To assist in describing and explaining the repair, sketches or pictures may be added to the repair report.

D. Enclosures

1. The following examples of reports are enclosed:

– Example of a repair report

– Example of a survey report

Biro Klasifikasi Indonesia	**Laporan Survey Perbaikan Komponen - FRP** ***Survey Report for Repair of FRP-Components***

Komponen/ Pembuat :
Component/ (Manufacturer)
Lokasi (WEC) :
Site (WEC)
No. Identifikasi Lainnya :
Other Identification No.

No. Reg. *Reg. No*	Nama Kapal *Ship Name*	Lokasi Perbaikan *Site of Repair*	Tgl. Perbaikan *Date of Repair*	Tgl. Survey *Survey Date*

Pemilik :
Owner

Pemeriksaan kelayakan/ kesesuaian bengkel kerja
Examination of suitability of workshop

- Pengakuan bengkel oleh BKI ☐
  Shop approval by BKI
- Nama kepala tim perbaikan ☐
  Name of head of the repair team
- Kepala tim disebutkan namanya secara jelas dalam (sertipikat) pengakuan bengkel ☐
  Head of repair team named explicitly in the shop approval
- Tim Perbaikan mengetahui tentang Peraturan Perbaikan Komponen ☐
  Repair team familiar with Rules of Repair of Components

Pengawasan Perbaikan ☐
Repair Surveillance

- Rencana perbaikan telah disetujui oleh BKI ☐
  Repair plan approved by BKI
- Penyimpangan dari Peraturan BKI atau dari rencana perbaikan (misalnya: material, kondisi iklim, pengerjaan) ? ☐
  Deviation from BKI rules or from the repair plan (e.g. materials, climatic conditions, execution) ?

  Uraian :
  Description

  ……………………………………………………………………………………………………

  ……………………………………………………………………………………………………

  ……………………………………………………………………………………………………

- Laporan Perbaikan disertakan ☐
- *Repair report enclosed*

Tempat/ Tanggal
Place/ Date :

Tanda Tangan ……………………...…………
Signature *BKI - Surveyor*

1 : Yes 2 : No

Biro Klasifikasi Indonesia	**Laporan Perbaikan Komponen - FRP** ***Repair Report for FRP-Components***

Data Komponen
Component Data

Penandaan : ………….……………………………….. ………….... ………………………………………..
Designation

No. Register (untuk Kapal) :………………………… Lokasi (untuk WEC) :………………………………..
Register No. *Site (for WEC)*

No. Identifikasi lainnya : …………………………….
Other Identification No.

Pemilik : ……………………………………………..
Owner

Rincian Perbaikan :
Details of Repair

Lokasi yang diperbaiki :……...……………………… Tanggal :…………….………………….…………..
Site (of the repair) *Dated*

Kondisi cuaca pada saat perbaikan (setiap 3 jam)
Climatic conditions during repair (every 3 h)

Waktu *Time*	Temperatur *Temperature*	Kelembaban relatif *Relative Humadity*	Kecepatan Angin *Wind speed*
Mulai : *Begin*			
Selesai : *End*			

Material yang digunakan *Materials used*	No. Batch *Batch number*	Pengakuan BKI *BKI Approval*	
System resin *Resin system*	……………………………..	yes ☐	no ☐
Topcoat/ Lapisan atas *Topcoat*	……………………………..	yes ☐	no ☐
Adhesive *Adhesive*	……………………………..	yes ☐	no ☐
Material Penguat *Reinforcement material*	……………………………..	yes ☐	no ☐
	……………………………..	yes ☐	no ☐
	……………………………..	yes ☐	no ☐

Laporan Takaran/ Dosis
Dosing Report

No. Lot *Lot – No.*	Resin *Resin*	Agen Pengering *Curing Agent*	Akselerator *Accelerator*	Waktu *Time.*

2/2

Posisi dan tipe kerusakan (jika perlu sketsa atau gambar pada lembar/ halaman terpisah) *Position and type of damage (if necessary sketches or pictures on separate page(s))*
Uraian Penyimpangan dari rencana perbaikan (jika relevan) *Description of deviations from the repair plan (if relevant)*
Temperatur maksimum dan minimum antara mulainya perbaikan dan pemeriksaan komponen yang diperbaiki *Maximum and minimum temperature between start of the repair and commissioning of the repaired component* Maks :_______ [^{o}C] Min :_______ [^{o}C] *Max.* *Min.*
Komponen mulai diperbaiki *Comissioning of the repaired component* Tanggal : ________________________ Waktu : ___________________. *Date* *Time*
Tempat/ Tanggal *Place/Date* Cap Perusahaan *Stamp of Company* ______________________________. Tanda Tangan Kepala Tim Perbaikan *Signature of the head of the repair team*

Annex K

Recognised Standards for Testing of Fibre Composite Materials

Standard	Part	Title	Dated
DIN EN 60		Glass reinforced plastics; determination of the loss on ignition *Bestimmung des Glühverlustes*	Mar 77
DIN EN ISO 75	–3	Plastics, determination of temperature of deflection under load *Kunststoffe – Bestimmung der Wärmeformbeständigkeitstemperatur*	Mar 96
ISO R 137		Wool, Determination of fibre diameter, Projection microscope method	Feb 75
DIN ISO 175		Plastics; Determination of the effects of liquid chemicals, including water *Kunststoffe – Bestimmung des Verhaltens gegen Flüssigkeiten einschließlich Wasser*	Apr 89
DIN EN ISO 178		Plastics; determination of flexural properties *Kunststoffe, Bestimmung der Biegeeigenschaften*	Feb 97
DIN EN ISO 291		Plastic, normal climate for conditioning & testing *Kunststoffe, Normalklima für Konditionierung und Prüfung*	Nov 97
VDE 334	–1	Determination for glass sheet production for electrotechnic Part 1, fabric of glass cloth Section 4 *Bestimmungen für Textilglaserzeugnisse der Elektrotechnik: Teil 1 Textilglasgewebe, Abschnitt 4*	Sep 72
DIN EN ISO 527	–2	Determination of tensile properties, Test conditions for moulding and extrusion plastics *Bestimmung der Zugeigenschaften, Prüfbedingungen für Norm- und Extrusionsmassen*	Jul 96
DIN EN ISO 527	–4	Determination of tensile properties, Test conditions for isotropic and orthotropic fibre-reinforced plastic composites *Bestimmung der Zugeigenschaften, Prüfbedingungen für isotrop und anisotrop faserverstärkte Kunststoffverbundwerkstoffe*	Jul 97
DIN ISO 719		Glass, water resistance from glass forming at 98^{o} C, Testing system and Group division *Glas, Wasserbeständigkeit von Glasgrieß bei 98 °C, Prüfverfahren und Klasseneinteilung*	Dec 89
ISO 719		Glass, Hydrolytic resistance of glass grains at 98 degrees C; Method of test and classification	Oct 85
ISO 844		Cellular plastics - Compression test for rigid materials - Specification	Jun 98
ISO 845		Cellular plastics and rubbers; determination of apparent (bulk) density	Dec 88
ISO 1183		Plastics; Methods for determining the density and relative density of non-cellular plastics	Jul 87
DIN 1259	–1	Glass, Definition for glass forming & glass group *Glas, Begriffe für Glasarten und Glasgruppen*	Sep 86
DIN EN 1465		Determination for overlapping joint of high tensile strength *Bestimmung der Zugscherfestigkeit hochfester Oberlappungsklebungen*	Jan 95
DIN EN ISO pr 1657		Plastics - liquid resins - Determination of density by pyknometer method *Kunststoffe - Flüssige Harze - Bestimmung der Dichte nach dem Pyknometer-Verfahren (ISO 1675:1985)*	Dec 84

Standard	Part	Title	Dated
DIN ISO 1887		Textile glass; Determination of combustible-matter content *Textilglas; Bestimmung des Glühverlustes*	Dec 84
ISO 1889		Reinforcement yams - Determination of linear density	May 97
DIN EN 2374		Glass fabric reinforcement, forming substance & core bond *Glasfaserverstärkte Formstoffe und Kernverbunde*	Oct 91
ISO 2535		Plastics; Unsutured polyester resins – Measurement of gel time at 250C	Mar 97
IS0 2555		Plastics, resins in the liquid state or as emulsions or dispersions; determination of apparent viscosity by the Brookfield method	Feb 89
pr EN 2850		Carbon fibre thermosetting resin unidirectional laminates, Compression test parallel to fibre direction *Unidirektionale Laminate aus Kohlenstofffasern und Reaktionsharz, Druckversuch parallel zur Faserrichtung*	Apr 98
ISO 2896		Cellular plastics, rigid – Determination of water absorption	Dec 87
ISO DIS 3001		Plastics – Epoxy compounds – Determination of epoxy equivalent	Nov 97
IS0 3251		Paints and vanishes; Determination of non-vol	
ISO 3374		Textile glass mats; Determination of mass per unit area	Nov 90
ISO 3375		Textile glass; Determination of stiffness of rovings	Dec 75
IS0 3616		Textile glass, Mats; Determination of average thickness, thickness under load and recovery after compression	Dec 77
VDI 3821		Adhesive bonding of plastics *Kunststoffkleben;*	Sep 78
ISO 4602		Reinforcements – Woven fabrics – Determination of number of yarns per unit length of warp and weft	Dec 97
ISO 4603		Textile glass; woven fabrics; determination of thickness	Nov 93
ISO 4605		Textile glass; Woven fabrics; Determination of mass per unit area	Nov 78
IS0 9352		Plastics – Determination of resistance to wear by abrasive wheels	Nov 95
DIN EN 10204	2.2	System for certification test condition, fabric reinforcement plastic, determination for bonding propeties *Arten von Prüfbescheinigungen Faserverstärkte Kunststoffe; Bestimmung der Biegeeigenschaften*	Aug 95
DIN EN ISO 14125		Fibre reinforced plastic composites – Determination of flexural properties	Jun 98
DIN 16945		Resin reaction, reaction matrix and mass of resin reaction, testing procedures *Reaktionsharze, Reaktionsmittel und Reakfionsharzmassen, Prüfverfahren*	Mar 89
DIN 53282		Testing for metal substance and metal bonding, angle ultrasonic testing. *Prüfung von Metallwerkstoffen und Metallklebungen - Winkelschälversuch*	Sep 79
DIN 53283		Determination for bonding strength of part from overlapping bonded joint (tensile test) *Bestimmung der Klebfestigkeit von Einschnittig überlappten Klebungen (Zugscherversuch)*	Sep 79

Standard	Part	Title	Dated
DIN 53294		Testing for core bond, shear testing *Prüfung von Kemverbunden, Schubversuch*	Feb 82
DIN 53420		Testing for foam material, determination for tightness *Prüfung von Schaumstoffen, Bestimmung der Rohdichte*	Dec 78
DIN 53421		Testing for foam material, compression test *Prüfung von Schaumstoffen, Druckversuch*	Jun 84
DIN 53433		Testing for hard foam material, determination water content in submersion *Prüfung von harten Schaumstoffen, Bestimmung der Wasseraufnahme im Untertauchversuch*	Jul 83
DIN 53452		Bending test *Biegeversuch*	Apr 77
DIN 53457		Testing for plastic, determination for modulus elasticity in tensile, compression & bending test *Prüfung von Kunststoffen, Bestimmung des Elastizitätsmoduls im Zug-, Druck- und Biegeversuch*	Oct 87
DIN 53479		Testing for plastic and determination for tightness *Prüfung von Kunststoffen und Elastomeren, Bestimmung der Dichte*	Jul 76
DIN 53754		Testing for plastic, determination of rough surface according to rough wheel system *Prüfung von Kunststoffen - Bestimmung des Abriebs nach dem Reibradverfahren*	Jun 77
DIN 53811		Testing for textile, measurement of fibre diameter in micro projection of longitudinal view *Prüfung von Textilien - Faserdurchmesser-Messung in Mikroprojektion der Längsansicht*	Jul 70
DIN 65090		Textile glass, filament impregnated E-glass (prepeg), technical delivery condition *Textilglas, Vorimprägnierte Filamentgewebe aus E-Glas (Prepreg), Technische Lieferbedingungen*	Jul 79
DIN 65356		Air, airspace, aeronautic, polyamid, aramid fixed thread & technical delivery condition *Luft- und Raumfahrt; Aromatisches Polyamid (Aramid); Hochfeste Aramidfilamentgarne; Technische Lieferbedingungen*	Nov 88
DIN 65382		Air, air space, strengthening limitation for plastic, tensile test of thread impregnated material *Luft- und Raumfahrt; Verstärkungsfasem für Kunststoffe; Zugversuch an imprägnierten Garnprüfkörpem*	Dec 88
DIN 65469		Fibre reinforced plastics; tensile test of monolayer flat tension specimen *Faserverstärkte Kunststoffe, Zugversuch an einlagigen Zugflach- prüfkörpern*	Aug 92

Annex L

List of Symbols used in Section 12

Symbol	**Explanation**
A^+	Ultimate tensile strain
A^-	Ultimate compression strain
E	Young's modulus
E_x	Young's modulus in global x-direction
E_y	Young's modulus in global y-direction
E_z	Young's modulus in global z-direction
$E_{//}$	Young's modulus in longitudinal direction of fibre
$E_{\perp}$	Young's modulus in transversal direction of fibre
G	Shear modulus
G_{xy}	Shear modulus in global coordinates
$G_{\perp //}$	Shear modulus in fibre coordinates
R_{m^+}	Ultimate tensile strength
R_{m^-}	Ultimate compression strength
$R_{m//^+}$	Ultimate tensile strength in longitudinal direction of fibre
$R_{m\perp^+}$	Ultimate tensile strength in transversal direction of fibre
$R_{m//}$	Ultimate compression strength in longitudinal direction of fibre
$R_{m\perp}$	Ultimate compression strength in transversal direction of fibre
R_s	Ultimate shear strength
$R_{//\perp IL}$	Interlaminar shear strength
α	Coefficient of thermal expansion
α_x	Coefficient of thermal expansion in global x-direction
α_y	Coefficient of thermal expansion in global y-direction
α_z	Coefficient of thermal expansion in global z-direction
$\alpha_{//}$	Coefficient of thermal expansion in longitudinal direction of fibre
$\alpha_{\perp}$	Coefficient of thermal expansion in transversal direction of fibre
ν	Poisson's ratio
ν_{xy}	Poisson's ratio in global coordinates (elongation in x-direction as a result from loading in y- direction)
ν_{yz}	Poisson's ratio in global coordinates (elongation in y-direction as a result from loading in z- direction)
ν_{zx}	Poisson's ratio in global coordinates (elongation in z-direction as a result from loading in x- direction)
$\nu_{\perp //}$	Major Poisson's ratio (elongation in transverse direction as a result from loading in longitudinal direction)
$\nu_{//\perp}$	Minor Poisson's ratio (elongation in longitudinal direction as a result from loading in transverse direction)
ρ	Density