ISBN 1 904862 66 7

Specification No. 2

United Kingdom
Civil Aviation Authority

Issue: 2

Date: 1 November 1985

Inflatable Liferafts

1 Introduction

1.1 The Air Navigation Order requires that for certain categories of aircraft operation, the aircraft is to be equipped with liferaft(s) or their equivalent. In such cases the liferaft is required to be approved by the CAA.

1.2 This Specification does not apply to Sliderafts.

2 Applicability

2.1 This Specification prescribes the minimum standards of design and performance for liferafts submitted for approval in accordance with the provisions of the Air Navigation Order.

3 General

3.1 Approval of a liferaft in accordance with this Specification shall take into account the valise or container, the liferaft itself, and any attached or stowed equipment. The liferaft and its associated equipment shall be seaworthy and designed to maximise occupant survivability in all operating conditions.

3.2 With the exception of its floor diaphragm, full inflation of the liferaft shall be achieved by the operation of a single device with the liferaft initially in any attitude. The operation to initiate the automatic inflation of the liferaft shall be within the capability of one person, either in or out of the water.

3.3 Secondary inflatable compartments e.g. canopy supports, boarding ramps and floor, shall be so designed and arranged that damage to them will not significantly affect the primary buoyancy of the liferaft.

3.4 Provision shall be made to insulate those areas of the floor diaphragm which are in contact with the occupants of the liferaft. The insulation shall be at least equal to that given by a 25 mm (1 in) air cushion.

NOTE: Where the insulation is provided by inflation of the floor diaphragm this Specification takes no account of its buoyancy.

3.5 The attachment of all lines and equipment to the liferaft shall be such that failure or tearing off of the attachment will not damage any inflated compartment or the canopy.

The latest version of this document is available in electronic format at www.caa.co.uk, where you may also register for e-mail notification of amendments.

Printed copy is available from: TSO, PO Box 29, Norwich NR3 1GN www.tso.co.uk/bookshop
Telephone: 0870 600 5522 e-mail: book.orders@tso.co.uk Fax orders: 0870 600 5533

3.6 Retro-reflective Surfaces

3.6.1 The liferaft shall be provided with flexible retro-reflective external surfaces, of silver-white colour, of a minimum total area of 0.16m^2 (250 in^2), for increased conspicuity and to enhance the effectiveness of search lights, during search and rescue operation.

3.6.2 The arranged pattern of the retro-reflective material shall be generally as shown in Figure 1.

3.6.3 The retro-reflective material shall conform to the UK Ministry of Defence Specification RDAE 4/13, or equivalent.

3.7 The requirements of this Specification, insofar as they are applicable, shall be met for the normal and overload occupancy ratings of the liferaft.

4 Operation and Environment

4.1 The packed liferaft shall be suitable for fitment in an aircraft in accordance with the applicable aircraft installation requirements.

4.2 The method of packing the liferaft into its valise or container shall be such that the liferaft will successfully deploy in the correct attitude for boarding with a probability of not less than 0.90 under the conditions described in paragraph 16.

4.3 The packed liferaft shall be designed to inflate by means of its primary inflation system and be suitable for boarding in respect of buoyancy and stability within 30 seconds of the start of inflation, when soaked at all temperatures between -30°C and +70°C.

4.4 The liferaft, when packed in its valise or container shall be capable of withstanding temperatures of -30°C to +70°C without arty adverse effects for at least the period between inspections.

4.5 The liferaft in its container shall be capable of withstanding without significant deterioration such fluids and greases as it might come into contact with for at least the period between inspections. The liferaft when inflated shall withstand those fluids likely to be spread on the surface of the water in the event of an aircraft ditching. All materials used in construction of the liferaft and its equipment shall be suitably resistant to corrosion and fungus growth.

5 Buoyancy

5.1 The liferaft shall incorporate a minimum of two independent primary flotation chambers. With all chambers inflated to minimum design pressure the liferaft shall be capable of supporting its occupants up to the normal and overload rated occupancy in fresh water. The following minimum amount of freeboard shall be available:

a) 300mm (12 in) at normal rated occupancy.

b) 150mm (6 in) at normal rated occupancy with the most critical chamber deflated.

c) A positive freeboard at overload rated occupancy with the most critical chamber deflated.

6 Occupancy Ratings

6.1 An average occupant weight of [1]91kg (200 lb) shall be assumed.

1. The value of 91kg (200 lb) per occupant has been used in lieu of the generally recognised value of 77kg (170 lb) to take account of the weight increase due to water saturation of the occupant's clothing.

6.2 The normal rated capacity of the liferaft shall be taken as the number of occupants that can be accommodated when each occupant is provided with a minimum width of back support of 460mm (18 ins) and a minimum of 0.33m^2 (3.6 ft^2) of floor area.

6.3 The minimum overload rating for the liferaft shall be the nearest whole number of occupants to the normal rated capacity times 1.50 with a minimum floor area of 0.22m^2 (2.4 ft^2).

7 Inflation Systems and Hand Pump

7.1 The primary inflation system shall meet all applicable equipment specifications and shall be capable of meeting all performance and environmental criteria contained in this Specification. The primary inflation system shall be fully automatic subsequent to initiation. Aspirators shall be protected and designed to preclude ingestion of objects which may prevent the seating of the gas seal. Any water ingested via the aspirator, if used, shall not prejudice the operation of the inflation system and the liferafts performance.

7.2 The inflation system shall be designed to prevent gas flow-back from a primary chamber or between primary chambers.

7.3 Protection shall be provided against chamber overpressure. Where this is by means of a relief valve the maximum hysteresis shall not exceed 20% of the valve's cracking pressure.

7.4 The means of activating the primary inflation system(s) shall be such that proper inflation of the liferaft can be achieved, even when the liferaft in its valise is submerged, by operating a single mechanism by the application of a force of 110 $\pm$ 20N (25 $\pm$ 5 lbf).

7.5 Each inflation chamber shall also be provided with a means to enable inflation using a hand operated pump.

NOTE: The Air Navigation Order requires liferafts to contain a means for maintaining buoyancy.

7.6 The function of every valve fitted in the surface of the liferaft shall be clearly marked in the vicinity of the valve. All such valves shall be located to enable their operation and observation to be carried out by occupants in the liferaft.

7.7 The method of operation and positioning of valves shall be such that they will not be operated inadvertently, and such as to minimise the risk of injury to occupants when boarding the liferaft.

7.8 Inflation valves to be used with hand operated pumps shall be of the non-metallic friction fit type with a minimum inside diameter of 16mm (5/8 in). They shall be fitted with a non-return valve, be located so as to facilitate inflation by hand pump, and shall not interfere with the comfort of the occupants.

7.9 Hand-operated inflation pumps shall be capable of easy connection to and disconnection from each inflation valve and of maintaining each inflated compartment at the minimum design pressure.

7.10 Hand pumps shall have a minimum displacement of air of 0.5 litres (32 in^3). for each complete cycle of operation, and shall have a means of being attached to the liferaft when stowed and during operation at each inflation point.

8 Strength

8.1 All materials, compartments, valves, attached equipment, and seams shall be of sufficient strength and durability to preclude premature failure during operation.

8.2 All inflated fabric compartments shall have minimum proof and ultimate strength factors of 2.0 and 3.0 respectively based on the maximum relief value of the pressure relief valves fitted to the primary buoyancy chambers. The design condition shall be assessed at a temperature of +45°C and in no case shall the proof pressure be less than 20.7kN/m^2 (3 lbf/in^2).

8.3 It shall be demonstrated that all fabricated material joints are of sufficient strength and integrity to achieve a declared absolute life. Guidance shall be given in the appropriate manuals regarding the inspection, maintenance and repair information necessary to maintain the serviceability of the liferaft between servicing.

9 Attached Equipment

9.1 **General** Any equipment attached to the liferaft (including that required by the ANO) shall be of such design and location that it will not interfere with the liferaft's operation and performance in any way. The attachment shall be such that the equipment will be retained if liferaft inflation occurs in the upright or inverted position.

9.2 Painter Line

9.2.1 A painter line which can be easily attached to the aircraft shall be provided. The line shall be of a length which is compatible with the operation and inflation of the liferaft, but shall be not less than 6m (20 ft) with the inflation initiation point at least 4.6m (15 ft) from the free end of the line. The painter line shall be distinctly coloured to indicate to the person inflating the liferaft the position of the inflation initiation point within 3m (10 ft).

NOTE: The painter line should be a minimum of 9.5mm (~ in) diameter under load to provide satisfactory graspability.

9.2.2 The painter line shall be manufactured from a material that will float, has resistance to rotting, and has a minimum breaking strength of 544 N (1200 lb). The attachment of the line to the liferaft shall be designed to release the liferaft without damage in the event of either the line being loaded to or beyond its ultimate strength value or the line being loaded to 0.75 times the load required to submerge the liferaft with the critical chamber deflated, whichever is the lower.

9.2.3 The location of the painter line attachment to the liferaft shall be such that it is readily accessible to the occupants of the liferaft and can be easily severed with the knife provided.

9.3 Sea Anchor

9.3.1 A sea anchor, which is permanently attached to the liferaft and is readily accessible to the occupants under all conditions, shall be provided.

9.3.2 Where the Sea Anchor is a trailing anchor device it must comply with the following:

a) The anchor shall have a minimum effective area equivalent to 0.8m^2 (1,200 in^2) when fitted to liferafts with a normal rating of more than 10 persons and 0.2m^2 (300 in^2) minimum for liferafts with a normal rating of 10 persons or less.

b) The anchor shall be attached to the liferaft by a line of IO.7m (35 ft) minimum length with a minimum breaking strength of 226 N (500 1b). Attachment of the sea anchor to the liferaft shall be so designed that the liferaft will be released without damage in the event of the line being loaded to or beyond its ultimate strength.

c) The anchor attachment line assembly shall include a swivel link with a strength at least equal to the strength of the anchor attachment line.

d) The anchor shall be arranged to minimise the risk of entanglement.

9.3.3 The location of the sea anchor attachment point on the liferaft shall be such that the deployed line does not interfere with boarding or with the operation and manipulation of the painter line.

9.4 **Rescue Line and 'Quoit'**

9.4.1 At least one rot—resistance rescue line, which will float and of not less than 23m (75 ft) in length, shall be provided to enable a survivor to be hauled to the boarding point. It shall be attached to the liferaft in the vicinity of, and accessible from, the primary boarding point. Attached to the free end of the line shall be a floatable device (quoit) of suitable size to be grasped by a survivor in the water.

9.4.2 The rescue line facility shall have a minimum breaking strength of 136 N (300 lb). The line attachment to the liferaft shall withstand 1.5 times the lines minimum breaking strength.

9.5 **Lights** The liferaft shall be fitted with an internal arid external light source.

9.5.1 **Internal Light** The internal light shall have an output sufficient to enable all printed instructions on the liferaft's internal surfaces or attached equipment to be read in the hours of darkness by a person with normal eyesight. The internal light source shall have an effective output of at least 1.0 lumen for a continuous period of not less than 12 hours.

9.5.2 **External Light**

a) The light shall be fitted to the canopy in such a way as to provide maximum practical conspicuity for search and rescue operations and shall have:

   i) a vertical light beam with a divergence of at least 5° about the vertical axis of the light fitting; and

   ii) a horizontal light beam that is radially continuous and have an emission angle of at least 5° above the horizontal plane of the light bulb element.

b) The light shall be switched on automatically as soon as the liferaft is inflated on water.

c) The light shall be capable of being switched on and of f by the occupants of the liferaft in all appropriate environmental conditions.

d) Output of the light shall be such that it is visible at night in clear atmospheric conditions at a distance of not less than 2 nautical miles, for a continuous period of not less than 12 hours.

e) If the light is a flashing beacon, the flash rate shall be between 50 and 70 flashes per minute, with an interval between flashes of 1.0 ± 0.15 second.

9.6 **Knife**

9.6.1 A knife which will float shall be provided and located in a position inside the liferaft to enable it to be readily used for cutting the painter line. The knife shall be suitably sheathed and attached to the liferaft by a line of sufficient length to facilitate its use without difficulty.

9.6.2 The shape of the knife shall be such, that it will not damage the liferaft's fabric if dropped inside the liferaft.

9.7 Survival Kit and Case

9.7.1 The liferaft shall be provided with a survival kit in accordance with, as a minimum, the requirements of the Air Navigation Order. The components of the kit shall be contained in a case which in turn can easily be attached to and detached from the liferaft. The contents of the survival kit shall be so packed that immersion in salt water will not cause them to be unfit for use.

10 Canopy

10.1 A canopy, covering the total occupiable area of the liferaft, and supported above the heads of seated occupants shall be provided. The canopy shall be automatically erected in sequence with the inflation of the liferaft. If the primary inflation system is used to deploy the canopy via a primary buoyancy chamber the canopy support system shall remain inflated in the event of damage to the buoyancy chamber. The canopy support system shall include a facility for inflation by means of the hand operated pump provided.

10.2 The canopy fitted to liferafts with a normal rated occupancy of more than 10 persons shall include a minimum of 2 entry points. Liferafts with a normal occupancy rating of 10 persons or less need only be provided with 1 entry point. The size and positioning of liferaft entry facilities shall be agreed with the CAA.

10.3 Each canopy entry point shall have a closing flap which can easily be closed or opened by the occupants. The flap shall be capable of being secured in a fully open or closed position or in intermediate positions. Where two entry facilities are provided they should be positioned 180° apart. The painter line attachment and location of knife shall be adjacent to one entry point.

10.4 The canopy, with the flaps open or closed, shall be capable of withstanding winds of 60km/h (40 mph) with gusts of 90km/h (60 mph). With the flaps closed the occupants shall be adequately protected from wind, rain, spray and breaking waves.

10.5 Facilities shall be provided for the collection and retention of rain water from the external surface of the canopy.

10.6 A facility shall be provided for the erection of a radio transmitting aerial.

10.7 The deployed canopy shall be able to withstand without damage or permanent collapse the impact of a jump by a person of weight 91 kg (200 lb) from a height of 3m (10 ft) above water level on to the top of the canopy.

11 Life Lines and Grab Lines

11.1 Life lines of a colour contrasting to that of the liferaft shall be provided around the external periphery of the buoyancy chambers. The lines shall be easily identified and readily available to support survivors in the water.

11.2 Grab lines of a colour contrasting to that of the liferaft shall be provided around the internal periphery of the buoyancy chambers. The lines shall facilitate use by the occupants to support themselves.

11.3 Life lines, grab lines and their attachments shall be capable of withstanding a minimum load of 226 N (500 lb).

12 Boarding Facilities

12.1 A boarding facility shall be provided at each entry point, which is self-erecting during the inflation of the liferaft and remains continuously available.

12.2 The design of the boarding aid(s) shall be such that a 91kg (200 lb) fully clothed person wearing a fully inflated lifejacket can board the liferaft without assistance. It shall also be possible for the liferaft occupants to retrieve unconscious survivors from the water with the aid of the boarding facility.

12.3 The strength of attachment of an inflated boarding facility to the liferaft's structure shall be such that excessive load on the facility will not prejudice the integrity of the primary buoyancy chamber.

12.4 Markings shall be provided on the external surfaces of the liferaft to indicate to survivors in the water the location of the boarding facility and if appropriate the best method of use.

13 Righting

13.1 A righting facility shall be provided for use if the liferaft inflates in the inverted position. The facility shall be such that the liferaft can be righted in all wind and sea conditions, up to the maximum conditions of 16.2, by one adult who has received instruction.

13.2 The method of righting an inverted liferaft shall be such that the maximum amount of water possible is drained from its interior during this operation.

14 Valise or Container

14.1 The liferaft shall be packed into a valise or container which in turn will be stowed and restrained on board the aircraft. The material used for the construction of the valise or container shall meet the requirements of the current issue of CAA Specification No. 8, Flame Resistance Testing for Aircraft Interior Materials, and shall be durable and chafe resistant. The liferaft packed and ready for stowage shall not support combustion, nor shall it be likely to be rendered unserviceable by inadvertent. contact. with .a lighted match or cigarette.

14.2 The packed liferaft shall be capable of being dropped from a height of 3 m (10 ft) on to a hard surface without adversely affecting the performance of the liferaft as prescribed by this Specification.

14.3 The valise or container shall include suitable lifting handles so the packed liferaft can be moved within the aircraft.

14.4 The packed liferaft shall have a positive buoyancy in fresh water at a temperature of +20°C. This shall be demonstrated and the buoyancy value established.

14.5 The external dimensions of the packed valise/container shall be established.

14.6 Closing of the valise or container shall be by lacing with cord of a minimum breaking strength of 23~i (50 lb) or by equivalent means.

15 Materials and Processes

15.1 All materials used shall be to an acceptable specification which shows the material to be suitable for its intended application and compatible with other materials used in the liferaft's construction.

15.2 The choice of materials and protective treatments shall be such that, during the period between inspections, corrosion or deterioration will not render the liferaft unserviceable.

15.3 The liferaft when fully equipped and stowed in the aircraft shall not cause more than 1° deflection of an aircraft compass reading at a distance of 300mm (1 ft).

16 Seaworthiness

16.1 The liferaft and its equipment shall be capable of withstanding a marine environment in accordance with this Specification for a minimum period of 14 days when occupied to its prescribed maximum overload rating.

16.2 The liferaft shall be capable of withstanding without any malfunction of the liferaft or its equipment in sea and wind conditions of at least Sea State 6 and 60 km/h (40 mph) respectively.

16.3 The design of the liferaft shall be such that the possibility of the liferaft overturning in any sea or wind condition up to the maximum of 16.2 is minimised. Any stabilizing equipment e.g. stabilizing keels or equivalent shall be effective by the time the liferaft is ready for boarding, and shall remain automatically effective all the time the liferaft is floating.

16.4 Means shall be provided to enable the occupants (wearing cover-all immersion suits and inflated life-jackets) to propel the liferaft over short distances.

17 Tests

17.1 A liferaft of the type for which approval is sought shall be tested in both calm and disturbed water (e.g. in a swimming pool and in choppy sea or simulated choppy sea conditions). The Manufacturer's evaluation schedule for the liferaft to show compliance with this Specification shall be agreed with the CAP. and shall include the following tests or demonstrations.

17.1.1 Inflation Tests. With the valised liferaft floating in the water, operation of the primary inflation system shall be demonstrated as being in compliance with 7 by a person in the water wearing a lifejacket. A sufficient number of tests shall be carried out to show compliance with paragraph 4.2. Connection, disconnection and satisfactory operation of the hand operated pump shall also be demonstrated.

17.1.2 Freeboard Measurement (Buoyancy). The liferaft shall be demonstrated to comply with 5 and 6 for all prescribed conditions of occupancy and inflation appropriate to the intended application of the liferaft.

17.1.3 Boarding. Compliance with the requirements of 12 shall be demonstrated by male and female subjects for each boarding facility fitted to the liferaft.

17.1.4 Propulsion. With the liferaft fully inflated and overloaded to the prescribed rating the practicability of its propulsion over short distances, using the paddles or other equipment provided, shall be demonstrated.

17.1.5 Jump Test. Tests shall be made in accordance with the requirements of 10.7. This test can be simulated by using a weighted bag or equivalent weight.

17.1.6 Righting. Righting of the liferaft shall be demonstrated both fully inflated and with the most critical primary buoyancy chamber deflated in accordance with 5.1 b).

17.1.7 Strength Test (Refer to paragraph 8.2)

a) A proof pressure test shall be carried out on all inflated fabric components.

b) An ultimate pressure test shall be carried out on the most critical section of all primary buoyancy chambers.

17.1.8 Seaworthiness. Sufficient tests shall be completed to demonstrate that the liferaft can provide a survival capability when subjected to the most adverse combination of temperature, sea and wind states defined in this Specification.

18 Colour, Operational Markings and Packaging

18.1 The predominant colour of the liferaft shall be an approved International Rescue Colour, as specified in British Standards Institution Specification No. BS 38l.C[1] or acceptable equivalent.

18.2 The valise or container in which. the liferaft is. to be kept whilst on board the aircraft shall be approved as part of the liferaft's general assembly. The valise or container shall be clearly marked to the effect that a liferaft is contained therein. The method of operating and any precautionary information shall be clearly marked.

18.3 Instructions relating to boarding and operation of all equipment shall be provided with the liferaft, shall be bold and readable in low levels of illumination, and shall be kept to a minimum with the purpose of achieving speed of correct operation with minimum confusion.

19 Marking

19.1 Each detachable part of the liferaft shall where practicable be marked with:

a) The manufacturer's approved inspection stamp.

b) The part number.

c) Date of manufacture or batch record.

NOTE: Where marking is not practicable alternative means may be agreed with the CAA.

19.2 The liferaft assembly shall be marked with:

a) The liferaft model designation;

b) The manufacturer's name and address;

c) Date of Manufacture;

d) Serial Number;

e) Date at which next service and overhaul are due.

19.3 The charged inflation cylinder shall be marked with its weight and the weight of charge.

19.4 All markings prescribed in 7.6, 12.4, 18.2, 18.3, 19.1, 19.2 and 19.3 shall be made such that they remain legible.

1. Obtainable from British Standards Institution, 2 Park Street, London W1Y 4AA

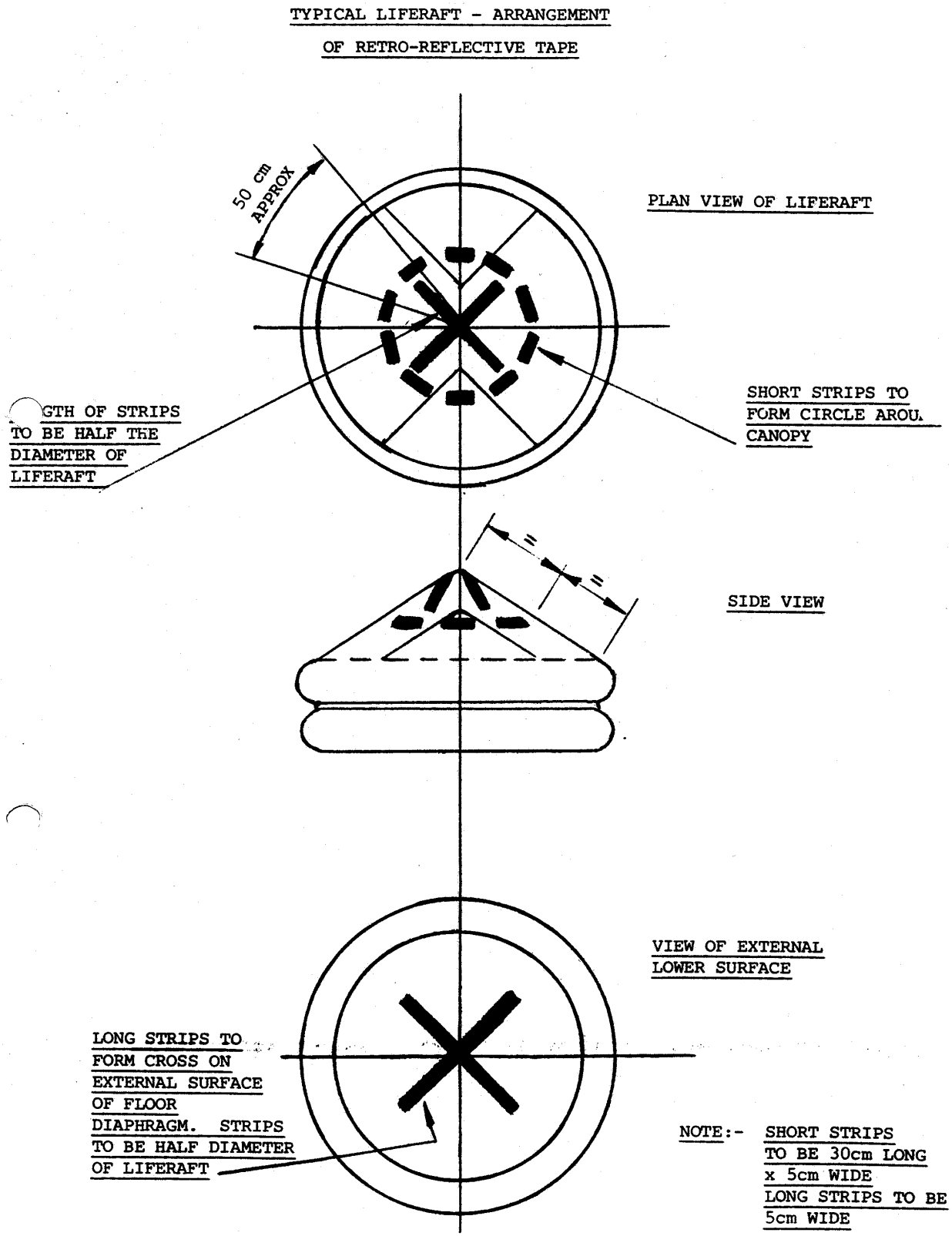
TYPICAL LIFERAFT - ARRANGEMENT
OF RETRO-REFLECTIVE TAPE
50 cm APPROX
PLAN VIEW OF LIFERAFT
GTH OF STRIPS TO BE HALF THE DIAMETER OF LIFERAFT
SHORT STRIPS TO FORM CIRCLE AROU. CANOPY
SIDE VIEW
VIEW OF EXTERNAL LOWER SURFACE
LONG STRIPS TO FORM CROSS ON EXTERNAL SURFACE OF FLOOR DIAPHRAGM. STRIPS TO BE HALF DIAMETER OF LIFERAFT
NOTE:- SHORT STRIPS TO BE 30cm LONG x 5cm WIDE
LONG STRIPS TO BE 5cm WIDE

Figure 1

Appendix

30th September 1988

Helicopter Liferafts

1 Introduction

This appendix contains variations to the requirements of Specification No.2 which will be acceptable to the Authority as satisfying the provisions of the Air Navigation Order in respect of liferafts to be carried in helicopters. These variations are only applicable to liferafts used for operations within helicopter SAR coverage and where all aircraft occupants wear survival suits.

2 Variations

2.1 **Floor Insulation** (See Spec. 2, paragraph 3.4)

Paragraph 3.4 may be disregarded where the liferaft floor is not normally in contact with the water.

2.2 **Damage Tolerance** (See Spec.2, paragraph 5.1)

The liferaft shall incorporate a minimum of four independent primary buoyancy chambers or alternatively two primary buoyancy tubes supplemented by a minimum of two independent fendering buoyancy tubes.

2.3 **Buoyancy** (See Spec. 2, paragraph 5.1 c))

Paragraph 5.1 c) may be replaced by the following:

Freedom from flooding at overload rated occupancy with the most critical chamber deflated. In this case credit can be taken for any benefit that may be derived from features such as a properly erected canopy to provide effective freeboard and protection from green water ingress.

2.4 **Canopy** (See Spec. 2, paragraph 10)

a) The requirement within paragraph 10.1 regarding automatic erection of the canopy may be disregarded.

b) Facilities for the collection of rain water required by paragraph 10.5 may be disregarded.

c) The following requirement is also applicable:- The canopy shall remain usable in the event of deflation of the most critical buoyancy chamber.

2.5 **Righting** (See Spec.2, paragraph 13)

Paragraph 13 shall be replaced by the following:

The liferaft shall be fully reversible unless it can be demonstrated that it cannot remain inverted in the fully inflated condition.

2.6 **Valise or Container Weight and Size** (See Spec. 2, paragraph 14)

The following requirement .is also applicable:-

Where automatic launching of liferafts is not possible, the weight and dimensions of the packed valise or container shall be such that it can be easily moved to, and launched from, any prescribed ditching emergency exit by one person (male or female).

NOTE: It is recommended that the maximum weight should not exceed 36.30 kg (80 lb).

2.7 **Seaworthiness** (See Spec. 2, paragraph 16.1)

The following note to paragraph 16.1 is applicable:-

NOTE: For helicopter operations satisfying the conditions of paragraph 1 of this Appendix, some shorter time may be agreed between the operator and the Authority.

Corrigendum No. 1 To Specification No. 2

Issue 2

30th September 1988

Inflatable Liferafts

In paragraphs 9.2.2, 9.3.2 b), 9.4.2, 11.3 and 14.6 the SI conversion are in error. These should be amended as follows:

Paragraph	9.2.2	delete	544N	(1200 lb)	replace with	5340N	(1200 lbf)
Paragraph	9.3.2 b)	delete	226N	(500 lb)	replace with	2225N	(500 lbf)
Paragraph	9.4.2	delete	136N	(300 lb)	replace with	1335N	(300 lbf)
Paragraph	11.3	delete	226N	(500 lb)	replace with	2225N	(500 lbf)
Paragraph	14.6	delete	23N	(50 lb)	replace with	225N	(50 lbf)