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CF 188 life raft replacement study

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Technical Note

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17 Sep 01

CF 188 LIFE RAFT REPLACEMENT STUDY

Refs: A. 11680-12188-81 (DTA 3-6-3)
B. FSOD 1AMS-0006S, 23 Jun 00
C. MSC 70/23/ Add.1, 17 Dec 98
D. 1CAD Orders, Vol. 3, Book 2
E. NATO STANAG 2895
F. DCIEM Technical Report, TR 2001-125, Jul 01
G. CFTO C-22-305-000/MF-000
H. DTIC Technical Report, TR 831201, 15 Dec 83
I. Telecon DTA/AETE/DCIEM, 30 Jan 01

Introduction

Background

1. With the ever-increasing anthropometrics of today's aircrew and potential future aircrew, safe ejection from the CF188 is becoming more and more compromised. The CF188 escape system's current safe ejection limits correspond to an aircrew nude body weight range of 136 lbs to 225 lbs depending on the pilot's weight, clothing, and survival kit configuration. A project has been initiated to increase the allowable maximum nude body weight by various thrust-increasing and weight-reducing measures. As part of an attempt to reduce throw weight, DCIEM was tasked to identify and evaluate possible replacements for the current *CF One Man Life Raft*, or *LR-1*, that would be lighter but still meet the required specifications to ensure aircrew survivability (ref A).

2. Recent additions to the *Rigid Seat Survival Kit* (RSSK) inventory have caused numerous instances of inadvertent life raft inflation, and subsequent seat pack damage during repacking (ref B). DCIEM's tasking is hence two-fold in that a reduction of life raft weight would hopefully result in a smaller packed volume as well. As the life raft represents the bulk of the seat pack contents, any reduction in its packed size would then serve to alleviate any future repacking problems.

Aim

3. The aim of this task is to evaluate the acceptability of the *LR-1* and various alternatives for sea-environmental suitability and aircrew survivability in all theatres of CF188 operation.

Requirements/Criteria

4. The following criteria were considered when developing a solution set for the replacement of the *LR-1*:

a. according to the International Maritime Organization (IMO), as of July 1 1999, all life rafts intended for use shall meet the requirements of the International Life-Saving Appliances (LSA) Code. To ensure compliance of these requirements, a recommended list of tests is outlined in Annex 6, para 5 of ref C. For the purposes of this study, departmental approval in any form, as stated in its military specification, was taken into consideration;

b. the life raft should facilitate vacuum packing for placement in the CF188 RSSK. Its packed volume and weight should not exceed those of the *LR-1* (i.e., not more than 7600 cm^3 and 7.5 lbs respectively);

c. the life raft should be buoyant enough to accommodate the 95th percentile pilot aircrew in full winter flying dress with RSSK (total 311 lbs max). The minimum freeboard should not present risk of water ingress while in calm water;

d. the life raft should provide adequate survivability against the elements common to the various CF188 theatres of operation. The thermal resistance of the *LR-1* (approximately 0.60 Clo) will be used as a baseline for comparison; and

e. the life raft should provide adequate stability in sea conditions of the CF188 theatres of operation for both low and high weights of aircrew. According to Chapter 4, para 24 of ref D, unless specifically authorized by Unit COs, ejection seat aircraft will not conduct over-water flying operations beyond gliding distance of land when the maximum surface wind in the operating area is 35 knots or greater, and the wave height in the operating area exceeds 4 meters (sea state 6). Hence, each life raft would be required to withstand a *strong* wind (28-33 knots) and a wave height of 2.5 to 4 meters (sea state 5). These values also correlate with the probability maps depicted in ref E, where there exists a significant (10%) chance of *strong* conditions.

Method(s)

Industry Search

5. This search was conducted to identify potential replacement options for the *LR-1*. Other military organizations and civilian agencies were surveyed as to what single-seated life rafts they have used in the past and what they are using at the present. The

suppliers/manufacturers of these life rafts were then identified and asked to produce description sheets for their line of one-person life rafts. Various life raft companies were also identified from past SAFE conferences as well as from the Internet.

Literature Search

6. A literature search of the Mil-specification and/or manufacturer's test data for each selected life raft was conducted to efficiently and economically verify whether they were viable solutions for replacement. The characteristics of the baseline were used as the acceptable standard when comparing each option. For those life rafts having no associated mil-spec or appropriate manufacturer's test data, an in-house test and evaluation was conducted with the *LR-1* again as the baseline for comparison. Selected models not yet in DCIEM's inventory were acquired for this evaluation.

In-house Testing and Evaluation

7. The remaining options were further evaluated by DCIEM against the criteria including the *LR-1* baseline characteristics. The following properties were considered:

a. buoyancy;

b. stability;

c. survivability/thermal resistance;

d. packed weight; and

e. packed volume.

8. Buoyancy. The buoyancy of each life raft was determined by measuring the freeboard at each end (bow and stern) at three different payload categories; empty, minimum (179 lbs), and maximum (311 lbs). The following parameters were kept constant for all life rafts:

a. the air pressure of each raft was 2.0 psi;

b. the life raft floors were lined with a platform to prevent damage by the weights, the weight of which (approx 11.0 lbs) was included in the total payload;

c. the water ingress from the boarding tests was measured and its weight included with the total payload—21 to 25.2 lbs depending on the life raft;

d. the min/max nude weight was 116 and 287 lbs respectively;

e. included in the payload weight is the aviation life support equipment, including RSSK: and

f. all measurements were taken in a fresh water pool at 5°C.

9. Stability. Boarding test were conducted with each life raft, in random order, to confirm their initial stability on entry. Subject participants of varying size and weight were asked to climb into a life raft and report the ease of boarding using a scale from difficult to easy.

10. Due to a lack of suitable facilities at DCIEM, the tests required to satisfy the wind load and sea state criteria would have had to be conducted at the Institute for Marine Dynamics in St John's, Newfoundland. Given the considerable expense of such studies, and through an effort to minimize redundancy, it was deemed unnecessary to conduct these tests. The life rafts in question have been deemed accepted for operational use by the various departments as outlined in each respective military specification (see table 1 for Mil-Spec refs).

11. Survivability. The survivability of a downed aircrew in cold water is mainly a function of body heat loss or individual susceptibility to hypothermia. Since heat loss from aircrew will mainly occur through the floor of the life raft during exposure to the sea conditions, the thermal resistance of the floor is a critical factor of the aircrew's survivability. The Environmental and Applied Ergonomics section of DCIEM was tasked to evaluate the difference in thermal resistance of the floors of the various life rafts under consideration – the *LR-1* being the benchmark for comparison (ref F).

12. The life rafts that were assessed were the *LRU-23/P*, the *JPATS* and the *LR-1* life raft. To avoid redundancy, the *LRU-16/P* was omitted from the trial due to its similarity in floor design with the *JPATS*. Before each test, the life rafts were inflated to the recommended pressure according to the inflation test procedure of the Canadian Forces Technical Orders (ref G)– 2.0 psi for the buoyancy chamber and 0.33 psi for the inflatable floor. A leak check was performed at the beginning of every test day to ensure that the recommended pressure had been retained.

13. Eight subjects (four males and four females) were used to evaluate the thermal resistance of the raft floors as humans provide appropriate heat transfer and pressure on the floors of the life rafts. The anthropometrics of the participants can be seen in Table 1 of ref F; the mean weight was 73.3 kg, with a standard deviation of 19.7 kg. The life raft and subjects were rigged with thermal sensors and heat flow transducers. The subjects dressed in standard ALSE and boarded the life raft. The rafts were tested in random order. An amount of water appropriate to each raft was added to simulate ingress. The subjects remained still in the life raft for 60 minutes prior to collection of data. Pool water temperature was 5°C and ambient air temperature was 24°C. Data was collected using a Hewlett Packard Model 3457A data acquisition control unit and averaged over the last 10 minutes of a 1-hour immersion. The thermal resistance R of the floor system, including the water boundary layer, was calculated using the following equation:

$$R = ((Tsk - Tw)/Hsk)/0.155$$

Where;

- R is the thermal resistance, in units of Clo;
- Tsk is the average skin temperature for the 4 sites – buttocks and calves, in °C;
- Tw is the water temperature about 1 foot below the surface of the water, in °C; and
- Hsk is the average skin heat loss from the 4 sites, in W/m^2 .

For a more detailed description of the experimental method and thermal resistance calculation, refer to ref F.

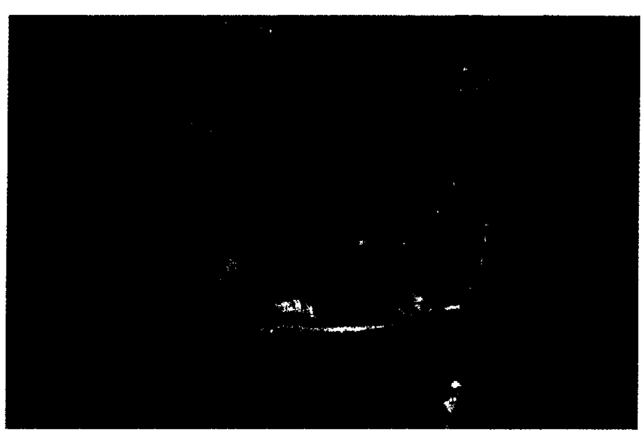
14. Packed Weight and Volume. A vacuum pump and *Audion Sealmaster* Model 580-RF press and pliers assembly were used to minimize the life raft's size for stowage in the RSSK. Pre-sealed plastic forms (open at one end) made by ATESS, Trenton were used. Once vacuum packed and sealed using Radio-Frequency (RF) welding, the life raft was then measured for weight (including empty CO_2 bottle) using a *Toledo Scale* Model 4181/8140. The approximate total volume was determined by multiplying the three dimensions (length, width, and depth) of the vacuumed package.

Results

Industry Search

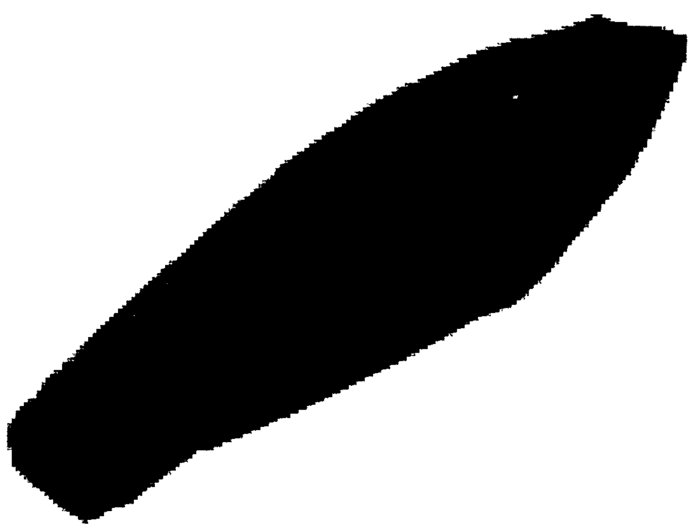
15. Many of the selected life rafts resulting from the search have been approved for use or are still being used by the air forces of various countries throughout the world. The following life rafts were selected as potential options:

a. Option 1 (Baseline): the *CF One Man Life Raft* or *LR-1*;



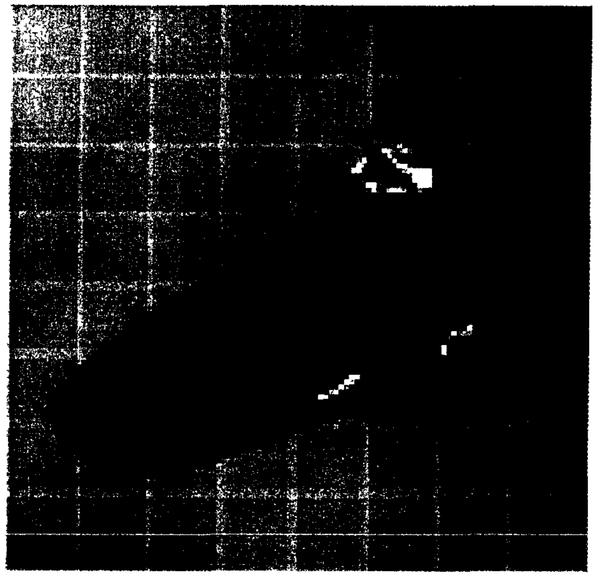
b. Option 2: the *LRU-16/P*;

c. Option 3a: the *LRU-18/C*;



d. Option 3b: the *LRU-18/U*: identical to the *LRU-18/C* with orange non-inflatable canopy (not shown);

e. Option 4a: the *LRU-23/P*; and



f. Option 4b: the *JPATS*—identical to the *LRU-23/P* but with non-inflatable canopy and non-inflatable floor (not shown).

Literature Search

16. Table 1 shows a comparison of life raft characteristics indicated in available military specifications and manufacturer's product information sheets.

Table 1: Life Raft Characteristics

Item	Option 1 (Baseline) *LR-1*	Option 2 *LRU-16/P*	Option 3a *LRU-18/C*	Option 3b *LRU-18/U*	Option 4a *LRU-23/P*	Option 4b *JPATS*
References						
Manufacturer	TULMAR Safety Systems	Life Support International	PATTEN Co Inc.	PATTEN Co Inc	RFD Ltd	RFD Ltd
NSN	4220-21-846-5885	4220-01-003-6763	Not Specified	4220-01-395-2390	4220-99-352-4975	Not Available
Specification #	Mil-L-81542A	Mil-L-83491	Mil-L-85824	Mil-L-85824	RFD Spec 1008	RFD Spec 1008
Basic Shape						
Main Body	Asymmetric Raft	Symmetric Raft	Canoe	Canoe	Asymmetric Raft	Asymmetric Raft
Materials						
Main Buoyancy Tube	Polychloroprene Coated Nylon	Polyurethane Coated Nylon	Polyurethane Coated Nylon	Polyurethane Coated Nylon	Polyurethane Coated Nylon	Polyurethane Coated Nylon
Bottom	Polychloroprene Coated Nylon (Inflatable)	Neoprene Coated Nylon (Non-inflatable)			Polyurethane Coated Nylon (Inflatable)	Polyurethane Coated Nylon (Non-inflatable)
Canopy	Polychloroprene Coated Nylon (Non-inflatable	Neoprene Coated Nylon (Non-inflatable)	No canopy	Polyurethane Coated Nylon (Non-inflatable)	Polyurethane Coated Nylon (Inflatable)	Polyurethane Coated Nylon (Non-inflatable)

Table 1: Life Raft characteristics (cont'd)

Item	Option 1 (Baseline) *LR-1*	Option 2 *LRU-16/P*	Option 3a *LRU-18/C*	Option 3b *LRU-18/U*	Option 4a *LRU-23/P*	Option 4b *JPATS*
Construction						
Main Buoyancy Tube	Glued	Heat-sealed	Heat-sealed	Heat-sealed	R/F Welded	R/F Welded
Bottom	Glued	Glued			R/F Welded	R/F Welded
Canopy	Stitched/Glued	Stitched/Glued	N/A	Heat-sealed	R/F Welded	R/F Welded
Inflation						
Main Buoyancy Tube	100% automatic	100% automatic	25% automatic 75% manual	25% automatic 75% manual	100% automatic	100% automatic
Bottom	100% manual	Non-inflatable			100% manual	Non-inflatable
Canopy	Non-inflatable	Non-inflatable	N/A	Non-inflatable	100% manual	Non-inflatable
Inflation Time (automatic portion)	30 sec	30 sec	30 sec	30sec	Spec not avail	Spec not available
Leakage	0.4 psi drop (4-hr period)	0 5 psi drop (6-hr period)	0 25 psi drop (10 min period)	0 25 psi drop (10 min period)	0 5 psi drop (4-hour period)	0.5 psi drop (4-hour period)
Stability Devices						
Ballast Bags	1 large (rear)	2 small (sides)	None	None	2 large (sides)	2 large (sides)
Sea Anchor	yes	yes	yes	yes	yes	yes
Durability						
Burst Strength	150 lbs at bond	9 0 psi	40 lbs/seam	40 lbs/seam	7.5 psi	7 5 psi
Boarding Aids						
Righting Straps	Center Bottom	none	none	none	none	none
Hand Holds	4 outside 2 inside	4 outside 2 inside	none	none	4 outside	4 outside
Color						
Canopy	Orange	Orange (in) and Black (out)	N/A	Orange	Dark Blue or Orange	Dark Blue or Orange
Main	Black	Black	Yellow	Yellow	Dark Blue	Dark Blue
Bottom	Orange (upper) Black (lower)	Black			Dark Blue	Dark Blue
Miscellaneous						
Beacon pocket	no	Yes (inside)	no	no	yes	Yes
Strobe Light attachment pt	no	Yes	no	no	Yes	Yes
Sea Anchor stowage	no	yes	no	no	yes	Yes
Fasteners for Canopy	no	Yes	no	no	no	no
Bailing Assy	none	none	none	none	Integral Bailer	Integral Bailer
Markings	Std	Std	Std	Std	Std	Std
Miscellaneous Stowage	Large Inside Pocket	no	no	no	no	no
COST	$813 00 (CAD)	$787.50 (CAD)	$760.00 (USD)	$785.00 (USD)	£906 40 (GBP)	£856.50 (GBP)
Current CAD	$813 00	$787 50	$1192 53	$1231.76	$2080.31	$1965.79

Preliminary Disqualifications—LRU-18 Life Raft

17. The US Army Materiel Test Center established many criteria for the *LRU-18/U* life raft in a tropical sea-environment (see ref H). This technical report indicated, and reports from the USN and RAAF verified, some unfavorable properties of the life raft. Consequently, it was poorly received and rejected by both the USN and RAAF for the following reasons:

a. it has no canopy and is therefore not recommended for situations involving prolonged exposure to the elements;

b. it is designed so that the CO_2 cartridge only inflates three of 12 chambers and the occupant, according to his/her weight, inflates the remainder orally. Hence, it is initially unstable and difficult to board. Ref H states that the *LRU-18/U* life raft allows for expeditious entry only when the three chambers are fully inflated. Slower entry times were reported when the three chambers did not fully inflate;

c. considerable oral inflation is required to achieve the minimum acceptable freeboard. Slow leakage can occur, hence periodic re-inflation is necessary to maintain desired rigidity;

d. the *LRU-18/C* is configured with two CO_2 cylinders perpendicular to each other. This prevents single-lanyard actuation, which is essential in ejection seat aircraft; and

e. the *LRU-18/C* life raft is not designed to be vacuum packed as the two CO_2 cylinders make for an overly large packed volume, and the oral inflation tubes are extremely susceptible to damage.

18. After careful consideration of the available information pertaining to the *LRU-18/C* and the *LRU-18/U* life rafts, a preliminary decision was made to discard these options as possible replacements to the current *LR-1* (ref I).

In-house Test and Evaluation

19. Buoyancy. All the life rafts under consideration provided acceptable buoyancy. Table 2 shows the freeboard of each life raft for the required range of payload. There were, however, some difficulties in establishing a consistent weight distribution within each life raft. Unlike the *LRU-16/P* (symmetric raft), the asymmetric rafts (*LRU-23/P*, *JPATS*, and *LR-1*) are designed to give a constant freeboard from bow to stern while the occupant is sitting upright, with his/her back against the stern. Simulating this scenario was difficult as the area at which the load should be applied (center of buoyancy) is near the stern and offers limited space to stack the weights. Hence, the freeboard is less at the stern than at the bow.

Table 2: Life Raft Freeboard Measurements

Option	Model	Payload (lbs)	Freeboard Bow (inches)	Freeboard Stern (inches)
Baseline	***LR-1***	0	12	8
		179 (min)	11	7
		309 (max)	10	4.5
2	***LRU-16/P***	0	8	6
		179 (min)	6.5	5
		311 (max)	5	3
4a	***LRU-23/P***	0	10	6
		178 (min)	7	5
		307 (max)	6	1
4b	***JPATS***	0	9	7
		179 (min)	7	4.5
		311 (max)	5	2

20. Stability. The calm-water boarding results (Table 3) indicate that all life rafts, except the *LRU-18/U* possess acceptable stability upon boarding. The *LRU-18/U* was included in the test to validate its disqualification and to act as a benchmark against which to compare the other life rafts.

Table 3: Stability Upon Boarding

Option	Model	Boarding Test
Baseline	***LR-1***	Easy
2	***LRU-16/P***	Easy
3b	***LRU-18/U***	Difficult
4a	***LRU-23/P***	Moderate-Easy
4b	***JPATS***	Moderate-Easy

21. Thermal Resistance. Figure 1 shows the raft floor thermal resistance is considerably less for the un-insulated *JPATS* (0.06 ± 0.001 Clo) than for the insulated *LRU-23/P* (0.71 ± 0.25 Clo) and the *LR-1* (0.60 ± 0.16 Clo). The difference between the latter two is not statistically significant. If the LR-1 is used as the benchmark for survivability, then the results show that the *LRU-23/P* meets the requirement while the *JPATS*, and hence the *LRU-16/P*, do not.

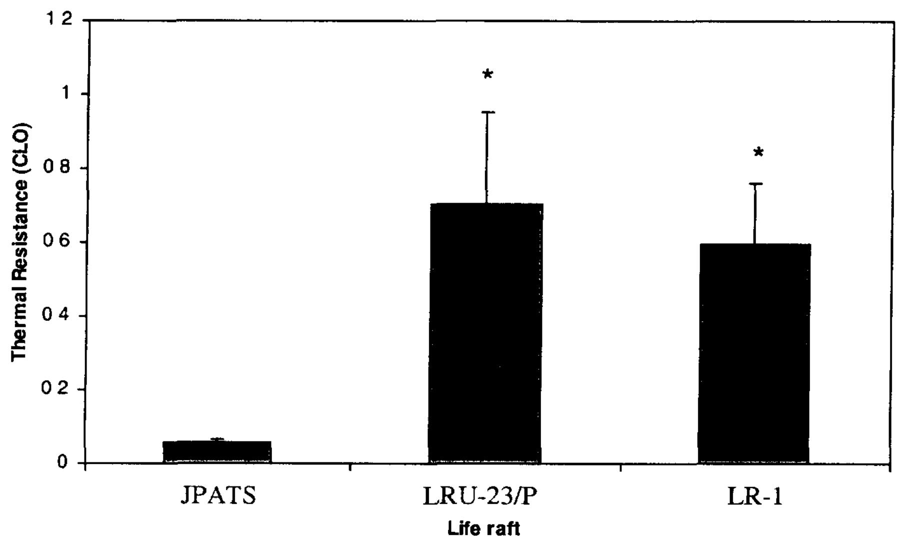


Figure 1: Thermal resistance of life raft floor. Shows mean value and standard deviation (error bar). (*) denotes statistical difference . (Data taken from ref H)

22. Packed Weight and Volume. In comparison with neoprene-coated or polychloroprene-coated materials used in the older life raft models, polyurethane-coated nylon with RF construction reduces the weight and bulk of the life raft while maintaining structural strength; this enhances its adaptability for use in seat survival kits. Furthermore, this method eliminates the use of glues, which are known to contain Toluene and MEK which are both are ozone-depleting substances. The *LRU-23/P* demonstrates this weight-saving property by being constructed of considerably more material (inflatable canopy) and having a packed weight that is notably less than the *LR-1* life raft (Table 4).

Table 4: Packed Weight and Volume Data

Option	Model	Packed Volume (cm^3)	Packed Weight (lbs)
Baseline	***LR-1***	7595	7.4
2	***LRU-16/P***	4575	5.8
4a	***LRU-23/P***	7600*	6.8
4b	***JPATS***	4575	5.8

* The value indicated is approximate as rigidity after packing was not retained.

Discussion

23. The literature search for this study proved to be the most difficult, especially when attempting to obtain test data from the manufacturer of life rafts having no associated military specifications (i.e., *LRU-23/P* and *JPATS*). The initial intent of this literature search was to acquire in as short a timeframe as possible the required test information to be used in the comparative study. With this information, the requirement for in-house test and evaluation would subsequently be reduced. The manufacturer of the *LRU-23/P* and the *JPATS* (RFD Ltd., Belfast, N. Ireland) provided the specification number along with some useful test results, however a complete compilation of specifications is still forthcoming.

24. The newer life rafts, with the exception of the LRU-18 series, are derivatives of the older *LR-1*. Table 1 shows a comparison which tends to favor the newer models over the *LR-1*; the newer material, RF construction methods, and integral bailer unit being the most prominent factors. The downfall being their cost is approximately 2.5 times greater.

25. The tests completed by DCIEM were valuable in confirming the suitability of the life rafts for CF-188 operations. It was demonstrated during the buoyancy tests that all of the life rafts possessed acceptable freeboard in all weight categories. With maximum weight of just over 300 lbs, the least amount of freeboard occurred with the *LRU-23/P* (one inch at bow) followed by its derivative the *JPATS* (two inches at bow). Should the weight have been distributed to more realistically simulate an occupant in the seated position, the results would have shown an increased bow freeboard and decreased stern freeboard. This design property is admirable in that it allows for acceptable freeboard across the entire life raft while minimizing material. Nevertheless, the minimum values are still sufficient to prevent ingress of water in calm conditions. In rough conditions, it is advisable to close the life raft canopy.

26. It was seen from survivability study (ref F) that the thermal resistance of a life raft having an insulated floor (i.e., *LRU-23/P* at 0.71±0.25 Clo) is over ten times more protective than single-floor life raft (i.e., *JPATS* at .06 ±0.01 Clo)). This greatly reduces the downed aircrew's susceptibility to hypothermia, especially if not sufficiently clothed or immediate rescue is not possible.

27. During the vacuum packing trials, the life rafts made with polyurethane-coated nylon and RF-welded construction resulted in a lower packed weight while maintaining an acceptable packed volume for stowage in the RSSK. In comparison to the *LR-1*, the *LRU-23/P* has much more material but weighs slightly (0.6 lbs) less. If the *LR-1* life raft were made of new materials and with RF welds, its weight would be slightly reduced by an estimated 1.4 lbs. All life rafts were able to be vacuum packed except the *LRU-23/P*, which achieved acceptable packed dimensions but did not retain its packed rigidity. This is most likely due to unwanted air ingress after package sealing. It is suspected that the package had an incomplete seal or minute puncture, as the *JPATS* (identical to *LRU-23/P*

but with non-inflatable floor and non-inflatable canopy) had no difficulty in holding its packed shape.

Conclusion

28. This study demonstrates the beneficial aspects of newer life rafts that could replace the *CF One Man Life Raft* currently being used in the CF188 RSSK. The materials and construction methods used in manufacturing the newer life rafts result in a lighter, less bulky product that is also more environmentally friendly. This study also shows the substantially greater thermal and protection benefit for an inflatable floor than for a single-skin floor. It is concluded that the optimum replacement solution would be a life raft similar in design to the *LR-1* but using polyurethane-coated nylon with RF construction methods, such as the *LRU-23/P* with a non-inflatable canopy.

Recommendations

29. The replacement life raft should have an inflatable floor and single skin canopy. It should be made of polyurethane-coated nylon fabric constructed with RF-welded technology.

30. RFD Ltd. Belfast, N Ireland should be asked to develop a hybrid of the *LRU-23/P* with an inflatable floor and non-inflatable canopy.

31. Regardless of manufacturer's specifications, properties of the proposed design/configuration should be checked for compliance with the test and evaluation requirements laid out in Annex 6, article 5 of ref C. The stability (sea state) and wind loading tests should be amended to include the conditions described for the CF188 theatres of operation as illustrated in the prediction maps of ref H.

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14. ABSTRACT

(U) The purpose of this study was to evaluate the acceptability of the 'CF One Man Life Raft' and various alternatives for sea-environmental suitability and aircrew survivability in all theatres of CF 188 operation. Of the six life rafts studied, the LRU-23/P was the most suited for replacement. The life rafts were evaluated against the following criteria: buoyancy, stability, survivability (thermal resistance), vacuum packed volume, and vacuum packed weight. The study showed that the thermal resistance was at least ten times greater for life rafts with inflatable floors(0.60 Clo - 0.71 Clo) when compared to those with non-inflatable floors (0.06 Clo). This property greatly increases the chance for aircrew survival. It was also noted that life rafts made with polyurethane-coated fabric and RF-welded construction were lighter and less bulky than those made with older materials and glued construction. Hence, the LRU-23/P, possessing all the above characteristics, was recommended as a viable off-the-shelf replacement solution. To further reduce packed volume and weight, but still not jeopardizing aircrew survivability, a recommendation was made to consider a hybrid of the LRU-23/P - inflatable bottom with non-inflatable canopy.

15. KEYWORDS, DESCRIPTORS or IDENTIFIERS

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