TRANSNAV
http://www.transnav.eu
the International Journal on Marine Navigation and Safety of Sea Transportation
Volume 19
Number 3
September 2025

DOI: 10.12716/1001.19.03.32

Analysis of the Aerodynamic Drag of Selected Pneumatic Life Rafts

J. Jachowski & E. Książkiewicz
Gdynia Maritime University, Gdynia, Poland

ABSTRACT: The success of the Search and Rescue (SAR) operation is strongly influenced by the accurate determination of the search area for the drifting pneumatic life raft, with particular emphasis on leeway. The article refers to the issue of leeway of life raft. The leeway is directly dependent on the force of wind pressure acting on the above-water part of the life raft and the hydrodynamic drag acting on the underwater parts of the life raft. The paper presents a comparison of different types of pneumatic life rafts. The purpose of comparing the dimensions, shapes and windage areas of different life rafts is to demonstrate the relationship between the shape and the aerodynamic drag on the above-water part of the life rafts. Research has shown the dependence of aerodynamic drag on the shape and size of the above-water part of the life raft. The calculations presented in this study are based on the author's previous experimental and numerical research and results published in earlier publications.

1 INTRODUCTION

Environmental factors and leeway cause the life raft to drift. Because the raft tent is deformed by wind pressure, making it challenging to precisely identify the raft's reference position and search area, the leeway prediction of the pneumatic life raft represents a challenging task for search and rescue (SAR) [2]. Available computer programs, such as Sarcass (Search and Rescue Coordination and Support System), are used by search and rescue services to specify the search area. "Unfortunately, these applications do not take into account shape variation during drift, so they are not precise for deformable bodies" [10]. Using the Gdynia Maritime University's prior research, the authors developed a numerical simulation that considered the object's shape variability. The results of the drift simulation, taking into account the variable windage area of the raft tent, have been described in previous publications. This article presents an overview of pneumatic life rafts available on the market and models their geometric models in the Rhinoceros program. The article study different shapes of life rafts and the resulting aerodynamic drag acting on the above-water part of the raft. The authors believe that a detailed analysis of the factors determining leeway may explain this issue and consequently reduce the search area and increase the effectiveness of rescue operations.

2 LEEWAY OF PNEUMATIC LIFE RAFT

The leeway of a life raft is the movement of the raft on the water dependent on the wind pressure acting on the above-water part of the life raft (F_x) and the hydrodynamic resistance acting on the underwater part of the life raft (F_0) as shown in Fig.1.

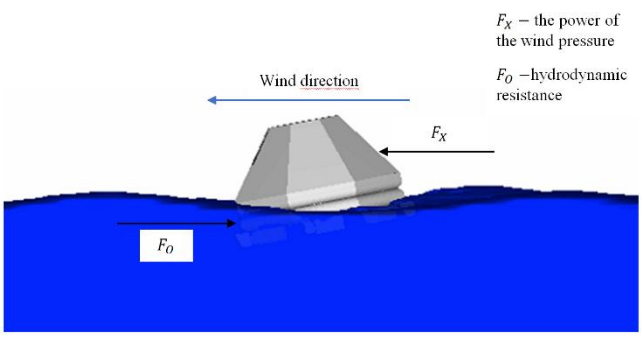


Figure 1. Forces causing leeway (source: current study, print screen of simulation)[9]

Both forces have a significant effect on the leeway of the pneumatic life raft and each forces must be taken into account. Previously performed numerical calculations allowed to determine: the force of wind pressure and the force of hydrodynamic drag (taking into account the variable shape of the flexible structure of the pneumatic life raft). The authors decided to use previous results of numerical simulations, the correctness of which had been verified and published. Current research and calculations are carried out for other types of life rafts available on the market.

2.1 *Aerodynamic drag of the life raft*

The aerodynamic drag of the life raft is a force which is created by the interaction of air with the surface of the raft above water. Aerodynamic drag is the result of friction and pressure changes that occur as a result of air flowing around the object. Aerodynamic drag is one of the most important factors affecting the leeway of the life raft. Factors influencing the aerodynamic drag of a life raft which is include:

1. The shape of life raft is designed to provide the highest level of safety in various life- threatening situations at sea. The shape of the life raft determines the stability of the raft, capacity, aerodynamic and hydrodynamic resistance. There are several typical shapes of life rafts, each of which has its own characteristics and applications.
   – One of the most common shapes are round rafts. The advantages of this shape are: good stability on the water even in the event of strong waves, even distribution of forces from external conditions and passengers in the raft.
   – Rectangular shaped life rafts are often used on larger vessels because they have more space to accommodate more persons. The disadvantage of the shape is weaker stability, especially in difficult weather conditions.
   – Occasionally, there are rafts in the shape of a trapezium, and rafts with a rigid, inflatable bottom.
2. The windage area is the surface of the life raft above the water, which is directly proportional to the amount of aerodynamic drag. Additionally, the windage area depends on the dimensions and shape of the raft, and draft (which results from the weight of persons in the raft).
3. Wind speed and weather conditions. Wind directly increases aerodynamic drag, also generating wind currents and waves. Greater wind pressure means a greater angle of the raft and deformations of the tent, which changes the way air flow. Sea waves influence the wind profile directly at the water surface.

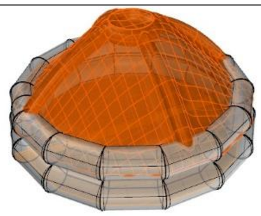
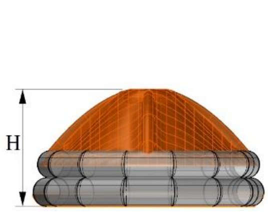
A detailed analysis of the aerodynamic drag is very important for further, correct calculations of leeway. The authors decided to analyse the types of life rafts available on the market, their dimensions and parameters.

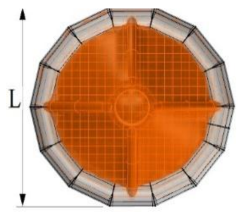
3 TYPES OF LIFE RAFT WITH DIMENSIONS

One of the basic life-saving equipment to protect survivors after abandoning a ship is the life raft. The authors collected information about the types of life rafts and prepared a short summary in the form of a Table 1.

Table 1. Types of life rafts (source: current study)

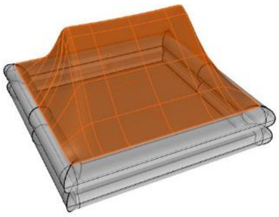
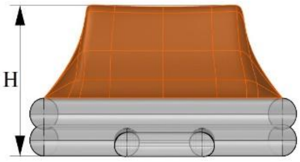
1. Pneumatic life raft (life raft were carried out in 2000 at the T-3 Low Velocity Tunnel at the Institute of Aviation in Warsaw)

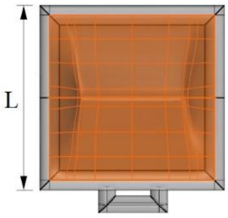






Size of raft [persons]	L [mm]	H [mm]	A_{min} [m²]	A_{max} [m²]	A_{mean} [m²]	Weight of life raft [kg]
6	2290	1190	1.92	2.01	1.96	90
10	2907	1225	2.50	2.62	2.56	110
20	3640	1760	4.50	4.71	4.61	180

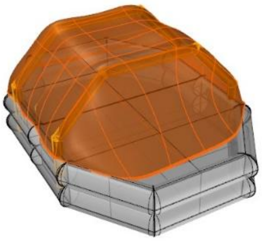
2. Life raft with square base – manufactured by company Iso raft.

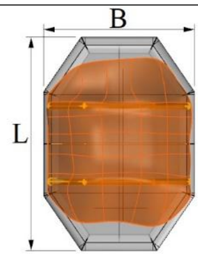






Size of raft [persons]	L [mm]	H [mm]	A_{min} [m^2]	A_{max} [m^2]	A_{mean} [m^2]	Weight of life raft [kg]
4	1634	1170	1.20	1.69	1.47	37,5
6	1956	1200	1.46	2.06	1.79	38,4
10	2458	1300	1.98	2.80	2.44	49

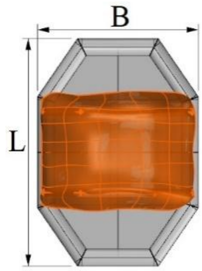
3. Life raft with an oval bottom – manufactured by Boaea.

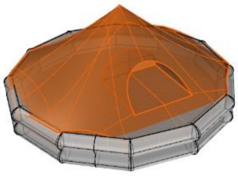
Size of raft [persons]	L [mm]	B [mm]	H [mm]	A_{min} [m^2]	A_{max} [m^2]	A_{mean} [m^2]	Weight of raft [kg]
6	2175	2175	1250	1.78	2.23	2.02	90
10	3245	2295	1300	2.45	3.05	2.82	110
15	4110	2700	1350	3.05	3.94	3.60	140

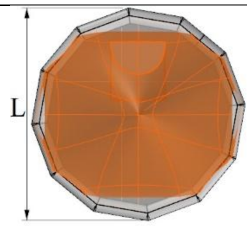
4. Life raft with an oval bottom – manufactured by Boaea.

Size of raft [persons]	L [mm]	B [mm]	H [mm]	A_{min} [m^2]	A_{max} [m^2]	A_{mean} [m^2]	Weight of raft [kg]
6	2175	2175	1250	1.77	2.29	2.07	90
10	3245	2295	1300	2.50	2.97	2.77	110
15	4110	2700	1350	3.06	3.79	3.49	140

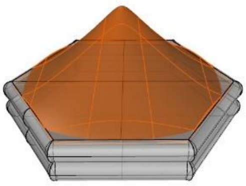
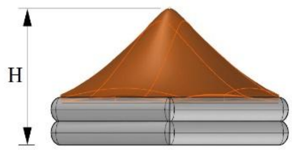
5. Life raft with polygon bottom – manufactured by Viking

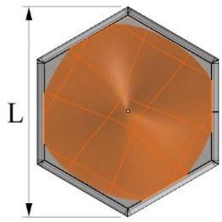



Size of raft [persons]	L [mm]	H [mm]	A_{min} [m^2]	A_{max} [m^2]	A_{mean} [m^2]	Weight of life raft [kg]
16	3342	1550	2.85	2.99	2.93	146
25	4076	2030	4.59	4.81	4.72	185

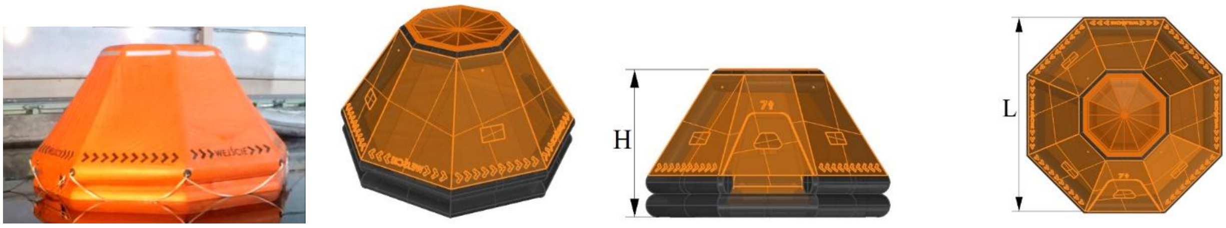
6. Life raft with a hexagonal bottom



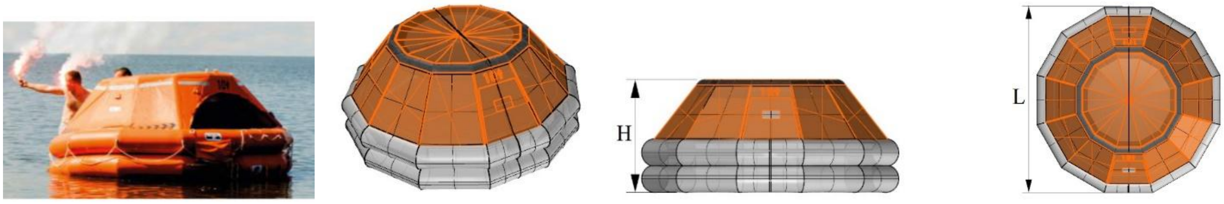
Size of raft [persons]	L [mm]	H [mm]	A_{min} [m^2]	A_{max} [m^2]	A_{mean} [m2]	Weight of life raft [kg]
10	3070	1540	2.56	2.77	2.62	98
12	3328	1550	2.77	3.00	2.84	109

7. Life raft with a stiff inflatable bottom and a stiffened tent- manufactured by Lubawa S.A. The life raft towing performance has been tested in the towing tank of Ship Design and Research Centre in Gdansk.



Size of raft [persons]	L [mm]	H [mm]	A_{min} [m²]	A_{max} [m²]	A_{mean} [m²]	Weight of life raft [kg]	Size of raft [persons]
6	2650	1600	3.30	3.58	3.44	80	6

8. Life raft with a grid, inflatable bottom and stiffened tent by Lubawa S. A.



Size of raft [persons]	L [mm]	H [mm]	A_{min} [m²]	A_{max} [m²]	A_{mean} [m²]	Weight of life raft [kg]	Size of raft [persons]
10	2830	1240	2.53	2.62	2.58	100	10

The table contains: the main dimensions of the life rafts and the modeled shapes of these rafts in three views. The parameters of the life rafts used in the Tab.1: L [mm] – life raft length; H [mm] –life raft height; A_{min} – minimum cross-sectional area of the raft [m²]; A_{max} – maximum cross-sectional area of the raft [m²]; A_{mean}- mean frontal cross- sectional area of the life raft [m²].

The geometric models of the life rafts were modelled in the 3D Rhinoceros program, which was then used to determine and calculate the cross-sectional areas of each life raft as shown in Fig.2 and Fig.3.

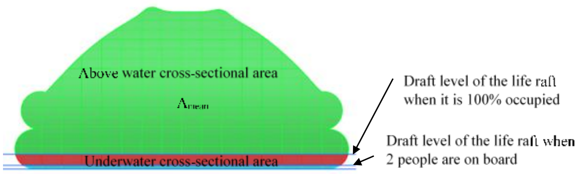


Figure 2. Cross-sectional of life raft (source: current study)

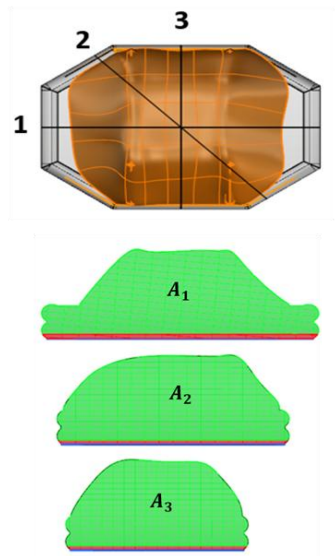


Figure 3. An example of a cross-sectional surface made for an oval 15 person life raft by Boaea (source: current study)

For the cross-sectional area: A_1, A_2, A_3, the mean cross-sectional area of the raft A_{mean} was calculated:

$$A_{mean} = \frac{A_1 + A_2 + A_3}{3} \quad [m^2]]$$

Geometric models of the life rafts are necessary to perform numerical calculations of the aerodynamic drag. Therefore, the authors created geometric models and their cross- sections for all life rafts listed in the Tab.1.

4 CALCULATIONS AND RESULTS

The results of the tunnel tests show that the value of forces is function of the shape and inflow wind [11]. Previous studies have provided information on the distribution of the wind profile affecting the part of the life raft above the water as show in Fig.4 [9]. The obtained wind profile was used for the current calculations. This knowledge was essential for modelling environmental conditions during numerical research.

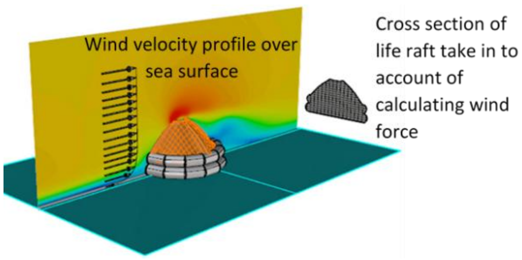


Figure 4. Aerodynamic wind force causing leeway (source: current study)

For all presented life raft models the following analysis was performed: cross- sectional area of the above- water and underwater surfaces as shown in Fig. 2.

Table 2. Life raft parameters (source: current study)

Life raft number from the TAB.1	Size of life raft [persons]	A_{mean} [m²] - cross-sectional area	A_{mean} / number of persons [m²/no of person]	Total weight [kg] = raft + 2 persons	Total weight [kg] = raft + max persons on board	T [m] – draft of the life raft (2 persons on board)	T [m] - draft of the life raft (max person son board)	Underwater cross-sectional area (2 persons on board) [m²]	Underwater cross- sectional area (max persons on board) [m²]	Percentage of underwater to above-water area (2 persons on board)	Percentage of underwater to above-water area (max persons board)
1	6	1.96	0.33	250	585	0.06	0.14	0.131	0.244	7%	14%
	10	2.56	0.26	270	935	0.04	0.14	0.134	0.363	6%	17%
	20	4.61	0.23	340	1830	0.03	0.18	0.129	0.556	3%	14%
2	4	1.47	0.37	197.5	367.5	0.07	0.14	0.109	0.220	8%	17%
	6	1.79	0.30	198.4	533.4	0.05	0.14	0.101	0.256	6%	16%
	10	2.44	0.24	209	874	0.03	0.14	0.072	0.320	3%	15%
3	6	2.02	0.34	250	585	0.05	0.12	0.081	0.179	4%	10%
	10	2.82	0.28	270	935	0.04	0.13	0.046	0.210	2%	8%
	15	3.60	0.24	300	1377.5	0.03	0.12	0.046	0.256	1%	8%
4	6	2.07	0.35	250	585	0.05	0.12	0.081	0.179	4%	9%
	10	2.77	0.28	270	935	0.04	0.13	0.046	0.210	2%	8%
	15	3.49	0.23	300	1377.5	0.03	0.12	0.046	0.256	1%	8%
5	16	2.93	0.18	306	1466	0.03	0.17	0.121	0.491	4%	20%
	25	4.72	0.19	345	2247.5	0.03	0.17	0.134	0.633	3%	16%
6	10	2.62	0.26	258	923	0.03	0.12	0.119	0.411	5%	19%
	12	2.84	0.24	269	1099	0.03	0.13	0.114	0.445	4%	19%
7	6	3.44	0.57	240	575	0.04	0.10	0.084	0.233	3%	7%
8	10	2.58	0.26	260	925	0.04	0.15	0.223	0.483	9%	22%

The analysis examined two loading scenarios, one with a fully occupied raft and the other with two survivors on board. The calculations assumed that each survivor weighed 82,5 kg on average. In addition, the calculations should take into account the variable windage area of the life raft. Then, three cross- sectional areas of each modelled raft were found. The mean cross- sectional area was used to make next calculations. The average ratio of the surface area above the water to the underwater area for a life raft with two persons was on average 4% and for maximum number of persons on board, this ratio increasing to an average of 14%. This percentage ratio tends to decrease with increasing raft size and the number of persons on board.

Based on the developed dataset, the aerodynamic drag force F_d acting on the life rafts listed in Table 1 was determined. The calculations were conducted for calm water conditions, taking into account the wind profile above sea surface. According to previous experimental and numerical studies, the aerodynamic drag coefficient C_d ranges is from 0.5 to 0.7 [9]. For the purpose of this analysis, a representative value C_d=0,6 was adopted.

The aerodynamic drag force was computed using the standard drag equation:

$$F_d = \frac{1}{2} * C_d * \rho * A_{mean} * v^2$$

where:
F_d - the aerodynamic drag force [N],
C_d - the aerodynamic drag coefficient (assumed as 0.6),
ρ - the air density [kg/m³],
A_{mean} - the frontal cross- sectional area of the life raft [m²],
v - the wind velocity [m/s].

In this study, the frontal cross- sectional area A was treated as a variable parameter, dependent on the raft geometry. Wind speed ranging from 0 to 30 m/s were considered to evaluate the range of aerodynamic drag force. To illustrate the influence of raft shape on aerodynamic performance, the drag force was calculated as function of wind velocity for all 10-person raft types with varying geometrical configurations. The calculation results are presented in the form of a graph in the Figure 5 and Figure 6.

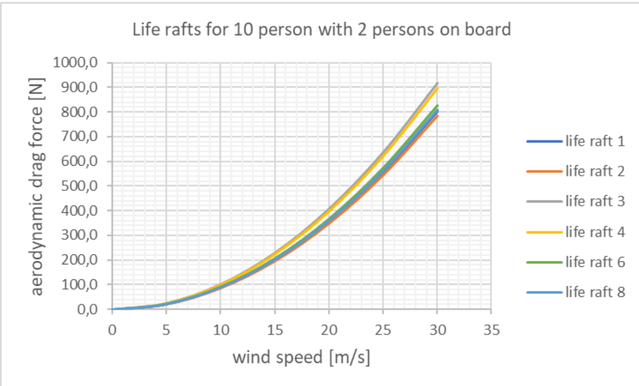


Figure 5. Aerodynamic drag force for all types of 10-persons life rafts with 2 persons on board (source: current study)

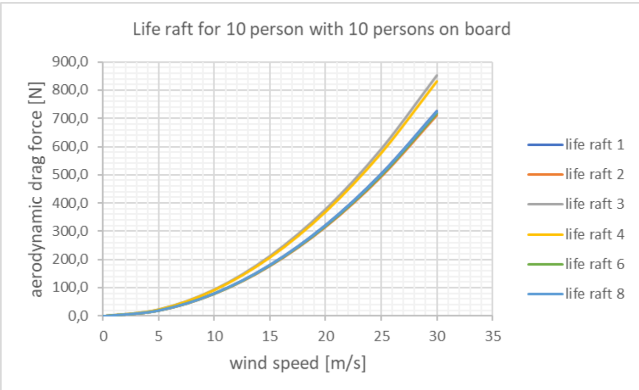


Figure 6. Aerodynamic drag force for all types of 10-persons life rafts with 10 persons on board (source: current study)

The purpose of the presented comparison is to prove the correctness of the statement that aerodynamic drag depends directly on the windage area of the above- water part of the life raft. Thus, the aerodynamic drag force, leeway, and drift of the life raft are all influenced by its shape. In order to implement a more precise and contemporary methodology for the leeway problem, the authors examine the extent of dependence between these parameters.

5 CONCLUSIONS

Geometric modeling and parametric analysis of pneumatic life rafts allow for improved estimation of leeway, thereby enhancing the accuracy of search area prediction in maritime Search and Rescue (SAR) operations. The leeway of a drifting raft is strongly dependent on aerodynamic drag acting on its above-water structure. In this study, eight commercially available life raft models were analyzed in terms of shape, dimensional parameters, and cross-sectional areas, which constitute key input variables in aerodynamic resistance calculations. A comparative assessment of aerodynamic drag was conducted for 6- and 10-person life rafts, selected as the most statistically representative group. The results indicate a direct correlation between raft occupancy and immersion depth, which leads to an increased underwater area and a higher underwater-to-above-water surface ratio (Aunder water /Aabove water), increasing from an average of ~4% at minimal occupancy (2 persons) to ~14% at full occupancy. The highest drag forces were recorded for rafts no. 3 and 4, characterized by oval geometries. Smaller rafts showed a larger wind area per person ratio, which means less influence of the wind. Conversely, increasing the number of occupants results in deeper immersion and greater hydrodynamic resistance.

Wind pressure depends on the size of the life raft and the number of occupants on board. Calculations showed a decrease in wind pressure as follows:

- For a 10-person life raft: a 10% reduction in wind pressure when comparing full occupancy to only 2 persons on board;
- For a 6-person life raft: a 6% reduction in wind pressure under the same conditions.

This corresponds to an approximate drag decrease of 1.3% per additional person on board.

The presented study aims to further improve algorithms for predicting wind drift and determining search areas used in SAR (Search and Rescue) planning tools.

ACKNOWLEDGEMENTS

This research was financed by Gdynia Maritime University Grant No. WN/2025/PZ/03.

REFERENCES

[1] Abramowicz-Gerigk T., Burciu Z., Jachowski J., Kornacka E., Wawrzusiszyn M., „Experimental and numerical investigation of towing resistance of the innovative pneumatic life raft", Polish Maritime Research, (94) 2017 Vol. 24, p. 40-47, doi: 10.1515/pomr-2017-0048

[2] Burciu Z., „Method of determining search areas in a rescue operation at sea" (in Polish), doctoral dissertation, Naval Academy, Gdynia 1997.

[3] Burciu Z., „Modeling of search areas in terms of the safety of human transport at sea" (in Polish), Printing House of Warsaw University of Technology, Warsaw, 2003.

[4] Burciu Z., „Reliability of SAR action in maritime transport"(in Polish), Printing House of Warsaw University of Technology, Warsaw 2012.

[5] Burciu Z. & Grabski Fr., "The experimental and theoretical study on the reliability of the life rafts", Reliability Engineering and System Safety, vol. 96, no. 11, 2011, doi: 10.1016/j.ress.2011.06.001.

[6] Breivik Ø., Allen A., Maisondieu Ch., Olagnon M., "Advances in search and rescue at sea", Ocean Dynamics, vol. 63, no. 1, 2013, p.83-88, doi: 10.1007/s10236-012-0581-1.

[7] Breivik Ø., Allen A. A., Maisondieu Ch., Roth J. Ch., "Wind-induced drift of objects at sea: the leeway field method", Appl Ocean Res 2011, p. 100-109, doi: 10.1016/j.apor.2011.01.005.

[8] IAMSAR, Manual, International Aeronautical and Maritime search and rescue manual, Volume III, Mobile Facilities, 2005 Edition.

[9] Jachowski J., Książkiewicz E., Szwoch I. „Determination of the aerodynamic drag of pneumatic life rafts as a factor for increasing the reliability of rescue operations", Polish Maritime Research 3, (111) 2021 Vol. 28, p. 128-136, doi: 10.2478/pomr-2021-0040

[10] Jachowski J., Książkiewicz E. „Numerical Prediction of Pneumatic Life Raft Performance", The International Journal on Marine Navigation and Safety of Sea Transportation, Volume 18, Number 1, March 2024, p. 229-232, doi: 10.12716/1001.18.01.24

[11] Research report, "Aerodynamic testing of pneumatic liferafts in the wind tunnel Ø 5m" (in Polish), Report nr 168/BA/2000/D Institute of Aviation, Warsaw 2000.

[12] Xinping Ch., Xiaodi W., Lin M., Kai X., Haiwen T., "Predicting drift characteristics of life rafts: Case study of filed experiments in South China Sea", Ocean Engineering, Volume 262, October 2022.