POLISH HYPERBARIC RESEARCH 3(92)2025
Journal of Polish Hyperbaric Medicine and Technology Society

OPTIMIZATION OF THE DESIGN OF A RESCUE DEVICE FOR AN ARGO FLOAT USING THE ZERO-UNITARIZATION METHOD

Adam Olejnik[1)], Waldemar Walczowski[2)]

[1)] Department of Underwater Works Technology, Polish Naval Academy in Gdynia, Poland
[2)] Observational Oceanography Laboratory, Institute of Oceanography, Polish Academy of Sciences in Sopot, Poland

ABSTRACT

This material is a continuation of previously published works related to the design of a rescue device for an ARGO profiling float. Earlier publications presented design variants of such a device and their SWOT/TOWS analysis. The present material describes the optimization of the design using the zero-unitarization method and a method for assessing the attractiveness of design variants. The work is carried out within the Argo-Poland consortium, which is part of the European research infrastructure EURO-ARGO-ERIC.
Keywords: technologia prac podwodnych, pływak ARGO.

ARTICLE INFO

PolHypRes 2025 Vol. 92 Issue 3 pp. 33 – 48
ISSN: 1734-7009 **eISSN:** 2084-0535
DOI: 10.2478/phr-2025-0017
Pages: 16, figures: 2, tables: 7
page www of the periodical: www.phr.net.pl

Publisher
Polish Hyperbaric Medicine and Technology Society

Original article

Submission date: 04.04.2025 r.
Acceptance for print: 13.05.2025 r.

INTRODUCTION

Argo is an international program that collects information from the ocean interior using a fleet of more than 4,000 profiling floats that drift with ocean currents (Fig. 1). The floats move autonomously through the water column by alternating between submerging and surfacing, measuring oceanic variables during each cycle. ARGO floats are being used with increasing effectiveness in enclosed seas [1]. In the Baltic Sea, floats have been deployed since 2012, with Finland being the first to do so. In 2016, Polish oceanographers joined the ARGO network and began deploying floats in the southern Baltic [2]. Germany joined the effort in 2021. Since 2022, activities in Poland have been continued within a consortium comprising the Institute of Oceanology of the Polish Academy of Sciences (PAS) in Sopot, the Institute of Geophysics of PAS in Warsaw, and the Polish Naval Academy in Gdynia, operating under the name ARGO-Poland. The consortium is a member of the European Research Infrastructure EURO-ARGO ERIC.

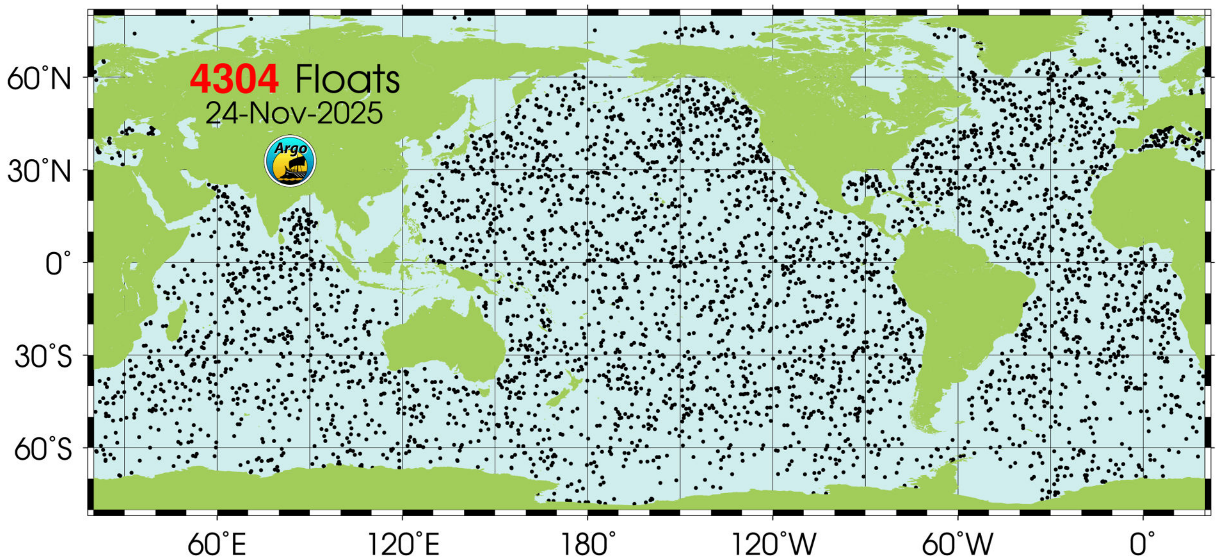

Fig. 1. Current status of the ARGO fleet based on [5].

So far, Argo-Poland has used 16 Argo floats. Seven of them were equipped with sensors measuring only the basic oceanographic parameters: pressure, temperature, and salinity (CTD). Another eight floats included additional sensors for measuring dissolved oxygen (DO), enabling more detailed monitoring of biogeochemical processes. In addition, one specialized BGC float was fitted with advanced sensors measuring chlorophyll-a concentration, suspended particulate matter, and irradiance—key parameters for assessing biological processes and the condition of the marine ecosystem. During this period, the Argo floats collected more than 8,000 CTD profiles. Among these, 4,100 profiles contained dissolved oxygen data, and nearly 600 were BGC profiles.

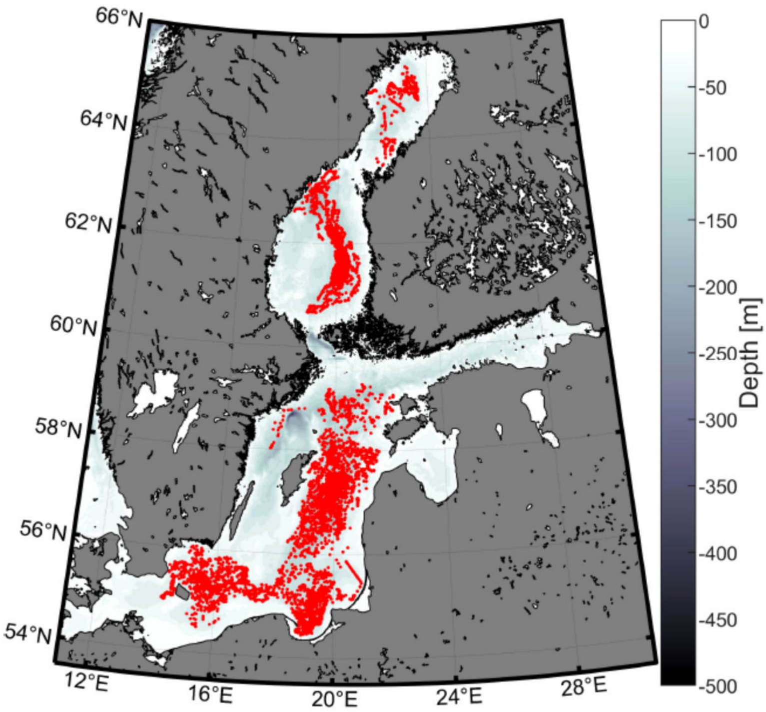

Fig. 2. All profiles collected by ARGO floats in the Baltic Sea [2].

Although the Argo-Poland project is an infrastructure undertaking focused on maintaining ocean-observation infrastructure and providing access to measurement data, it also includes research and development work. One manifestation of this work is the development of a rescue device for an Argo float. Earlier articles [3,4] presented the concepts of such a device as well as the results of a SWOT/TOWS analysis of the considered design variants. This article continues that line of research. It presents analyses related to optimizing the design of a rescue device for a profiling float using the zero-unitarization method.

Method

Comparing design variants with respect to different features (criteria) requires collecting appropriate information on the ratings of these variants for all the criteria considered. Because the criteria differ in nature, they are expressed using different types of assessments, both in terms of magnitude and units. This situation requires ordering, which is usually associated with normalizing the ratings of individual criteria. As a result, normalization enables a multi-criteria evaluation that takes all criteria into account and subsequently makes it possible to construct a ranking of the assessed decision variants.

Having knowledge about *r* decision variants and *s* criteria for their evaluation, we can build a two-dimensional matrix $[x_{ij}]$, where *i* denotes the assessed decision variant and *j* denotes the criterion:

$$\begin{bmatrix} x_{11} & x_{12} & x_{1s} \\ \dots & \dots & \dots . \\ x_{r1} & x_{r2} & x_{rs} \end{bmatrix} \text{gdzie:} \begin{matrix} i \in (1 \div r) \\ j \in (1 \div s) \end{matrix} \qquad (1)$$

This matrix constitutes a set of variables which, after appropriate normalization, will allow for aggregation of the objective function enabling the selection of the optimal variant. This set can be divided into three disjoint subsets containing:

S – stimulants, i.e., diagnostic variables that increase as the evaluated criterion increases;
D – destimulants, i.e., diagnostic variables that decrease as the evaluated criterion increases;
N – nominants, i.e., diagnostic variables that have a predefined desirable value, called the nominal value (this may be a range of values or a single value).

In this study, the zero-unitarization method was used to normalize the variables; this method serves to evaluate a finite number of variants. The method is characterized by adopting a fixed reference point, defined as the range of a given normalized variable. One may say that this method makes it possible to select the variant that is least distant from a hypothetical target point, understood here as the optimal design solution. The range of each criterion *j*is calculated as:

$$R(X_j) = max(x_{ij}) - min(x_{ij}) \text{ for all } i \qquad 2)$$

Thanks to this, the range of the normalized features for each criterion is constant and equals 1. However, in order to perform the calculations, it is necessary to define the values of individual x_{ij}. This is done through an assessment by competent judges, i.e., within a group of experts. A nine-point scale for evaluating a criterion may be adopted:

Tab. 1

x_{ij}								
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Catastrophic situation	High-risk situation	Medium-risk situation	Low-risk situation	Acceptable situation	Satisfactory situation	Good situation	Very good situation	Excellent (outstanding) situation

The process of converting the values x_{ij}into values comparable across all criteria, i.e., their normalization, proceeds differently depending on whether the diagnostic variable is a stimulant, a destimulant, or a nominant. For a stimulant,normalization of the variable is carried out using the following relationship:

$$Z_{ij} = \frac{x_{ij} - min(x_{ij})}{R(X_j)} \quad (3)$$

Whereas for a destimulant, the following relationship is used:

$$Z_{ij} = \frac{max(x_{ij}) - x_{ij}}{R(X_j)} \quad (4)$$

In the case of a nominant, the optimal range of values $\langle c_{1j}, c_{2j} \rangle$ must first be defined, since it affects the method of normalization:

$$if\ x_{ij} < c_{1j} \qquad Z_{ij} = \frac{x_{ij} - min(x_{ij})}{c_{1j} - min(x_{ij})} \quad (5)$$

$$if\ c_{1j} \leq x_{ij} \leq c_{2j} \qquad Z_{ij} = 1 \quad (6)$$

$$if\ x_{ij} > c_{2j} \qquad Z_{ij} = \frac{x_{ij} - max(x_{ij})}{c_{2j} - max(x_{ij})} \quad (7)$$

Whereas if there is a single nominal value c_{0j}, then the following relationships are used:

$$if\ x_{ij} < c_{0j} \qquad Z_{ij} = \frac{x_{ij} - min(x_{ij})}{c_{0j} - min(x_{ij})} \quad (8)$$

$$if\ x_{ij} = c_{0j} \qquad Z_{ij} = 1 \quad (9)$$

$$if\ x_{ij} > c_{0j} \qquad Z_{ij} = \frac{x_{ij} - max(x_{ij})}{c_{0j} - max(x_{ij})} \quad (10)$$

The final form of the aggregated objective function, according to which the optimal variant is sought, is as follows:

$$Q_j = \sum_{j=1}^{s} (Z_{ij} \cdot w_j) \quad (11)$$

For each criterion $j$and each of the evaluated variants i, where $w_j$denotes the weight of a given criterion. If all criteria have the same priority, then $w_j = 1$each time. If, however, the weights differ, then in relation (11)/(3.23) a normalized weight is introduced as the criterion weight w_j:

$$\varpi_j = \frac{w_j}{\sum w_j} \quad (12)$$

Provided that the introduced normalized weights must satisfy the following condition:

$$\sum \varpi_j = 1 \quad (13)$$

Meeting condition (13) guarantees that the assumption that all criteria are taken into account is satisfied. The values of the individual weights $w_j$for the analyzed criteria are determined again using the competent judges method, assigning to each criterion a value from the table below:

Tab. 2

w_j				
1	**2**	**3**	**4**	**5**
insignificant criterion	significant criterion	important criterion	very important criterion	most important (key) criterion

Next, depending on the obtained value Q_j, the evaluated variants are ordered from the highest to the lowest Q_j value, thus building their ranking. This value can also be used to classify projects as best, average, and worst. For this purpose, the constant U is used:

$$U = \frac{maxQ_j - minQ_j}{i} \quad (14)$$

Then, the criterion for assigning (classifying) the decision variants is as follows:

$$\text{if } Q_j \in (maxQ_j - U; maxQ_j\rangle \quad \text{best decision variant}$$

$$\text{if } Q_j \in (maxQ_j - 2U; maxQ_j - U\rangle \quad \text{average decision variant} \quad (15)$$

$$\text{if } Q_j \in (minQ_j;\ maxQ_j - 2U\rangle \quad \text{worst decision variant}$$

Using the zero-unitarization method, normalized values in the range ⟨0, 1⟩ are obtained. This method enables optimization of a variant through the transformation of features with negative, positive, and zero values. After normalizing all diagnostic features, an overall multi-criteria evaluation of the analyzed variants is created. The calculations performed using relations (2) to (15) are compiled in the following table:

Tab. 3

	Criterion 1	Criterion 2	Criterion 3	....	Criterion j	
weight	w_1	w_2	w_3	....	w_j	$\sum w_j$
variant 1	x_{11}	x_{12}	x_{13}	....	x_{1j}	
variant 2	x_{21}	x_{22}	x_{23}	....	x_{2j}	
....	.....	....	....	....	....	
variant *i*	x_{i1}	x_{i2}	x_{i3}	....	x_{ij}	
min	$min(x_{i1})$	$min(x_{i2})$	$min(x_{i3})$	....	$min(x_{ij})$	
max	$max(x_{i1})$	$max(x_{i2})$	$max(x_{i3})$	....	$max(x_{ij})$	
R	R_{i1}	R_{i2}	R_{i3}	....	R_{i4}	
Normalized weight	ϖ_{i1}	ϖ_{i2}	ϖ_{i3}	....	ϖ_{ij}	$\sum \varpi_{ij} = 1$
variant 1	Z_{11}	Z_{12}	Z_{13}	....	Z_{1j}	
variant 2	Z_{21}	Z_{22}	Z_{23}	....	Z_{2j}	
....	....	....	....	....	....	
variant *i*	Z_{i1}	Z_{i2}	Z_{i3}	....	Z_{ij}	
						Q_j
variant 1	Q_{11}	Q_{12}	Q_{13}	....	Q_{1j}	$Q_{11} + \cdots + Q_{1j}$
variant 2	Q_{21}	Q_{22}	Q_{23}	....	Q_{2j}	$Q_{21} + \cdots + Q_{2j}$
....	....	....	....	....	....	....
variant *i*	Q_{i1}	Q_{i2}	Q_{i3}	....	Q_{ij}	$Q_{i1} + \cdots + Q_{ij}$

	U	$Q_j \in (maxQ_j - U; maxQ_j\rangle$	best decision variant
		$Q_j \in (maxQ_j - 2U; maxQ_j - U\rangle$	average decision variant
		$Q_j \in (minQ_j;\ maxQ_j - 2U\rangle$	worst decision variant

Using the zero-unitarization method and the previously presented SWOT/TOWS analysis of design variants [4], the design variants achieving the best results were selected and subjected to an attractiveness analysis.

The assessment of the attractiveness of the design variants is a comparative analysis, understood as the product of the assessment of the importance of a factor in individual categories and the assessment of the strategy:

$$A_i = \varepsilon_i \cdot \Lambda_i$$

where:

A_i	attractiveness of the strategy for the *i*-th factor
ε_i	assessment of the importance of the *i*-th factor, $\varepsilon_i \in \langle 1,4 \rangle$
Λ_i	assessment of the strategy for the *i*-th factor, $\Lambda_i \in \langle 0,4 \rangle$

For this purpose, all defined factors in the respective categories are again compiled in a table and evaluated (ε_i) on a scale from 1 to 4 with the following assignment:

1 – major weaknesses,
2 – minor weaknesses,
3 – minor strengths,
4 – major strengths,

and:

1 – major threats,
2 – minor threats,
3 – minor opportunities,
4 – major opportunities.

The assessment of the strategy for the *i*-th factor (Λ_i) is determined as follows: (16)

0 – the factor does not affect the choice of strategy,
1 – the strategy is acceptable,
2 – the strategy is feasible,
3 – the strategy is likely to be acceptable,
4 – the strategy is acceptable.

The data are compiled in tabular form as shown in Table 4.

On the basis of such a table, the strategy is selected, considering as appropriate the one that obtains the highest total attractiveness ($\sum A_{ij}$ or $\sum A'_{ij}$).

Tab. 4

Factor	Assessment of the factor	Aggressive strategy		Competitive strategy	
		rating	attractiveness	rating	attractiveness
S_1	ε_{S1}	Λ_{S1}	A_{S1}	Λ'_{S1}	A'_{S1}
……	…..	…..	…..	…..	
S_5	ε_{S5}	Λ_{S5}	A_{S5}	Λ'_{S5}	A'_{S5}
O_1	ε_{O1}	Λ_{O1}	A_{O1}	Λ'_{O1}	A'_{O1}
……	…..	…..	…..	…..	
O_5	ε_{O5}	Λ_{O5}	A_{O5}	Λ'_{O5}	A'_{O5}
W_1	ε_{W1}	Λ_{W1}	A_{W1}	Λ'_{W1}	A'_{W1}
……	…..	…..	…..	…..	
W_5	ε_{W5}	Λ_{W5}	A_{W5}	Λ'_{W5}	A'_{W5}
T_1	ε_{T1}	Λ_{T1}	A_{T1}	Λ'_{T1}	A'_{T1}
……	…..	…..	…..	…..	
T_5	ε_{T5}	Λ_{T5}	A_{T5}	Λ'_{T5}	A'_{T5}
			$\sum \boldsymbol{A_{ij}}$		$\sum \boldsymbol{A'_{ij}}$

Optimization of the design of a rescue device for an Argo float – design analysis using the zero-unitarization method and analysis of the attractiveness of variants

The designs of the rescue device for the Argo profiling float described in publication [3], i.e.:

- variant 1 (W1) – increasing volume by moving pistons,
- variant 2 (W2) – increasing volume by filling a buoyancy bag,
- variant 3 (W3) – increasing volume by transferring water,
- variant 4 (W4) – increasing volume by filling a flexible hose,
- variant 5 (W5) – changing mass by releasing a concrete ballast,
- variant 6 (W6) – changing mass by releasing a lead ballast,

were subjected to a multi-aspect analysis (PHR1(82)2023). The group of competent judges included three designers with many years of experience in designing submersible devices and two specialists with less experience or expertise in other fields, whose task was to generate hardly predictable or even surprising negative factors related to the operation of the designed device.

The above-mentioned design variants were analyzed using the zero-unitarization method, and four criteria (the same for each variant) were applied for their evaluation:

A1 – certainty of operation
Criterion description:
This criterion defines the probability of the rescue device operating effectively.

A2 – reliability of the design
Criterion description:
This criterion defines the degree of reliability of the analyzed design solution.

A3 – stability of performance effects
Criterion description:
This criterion defines the ability of the analyzed solution to maintain the required buoyant force.

A4 – simplicity of design
Criterion description
This criterion defines the degree of complexity of the designed device.

Each criterion was assigned a weight reflecting its priority. The weighting scale ranges from 1 to 5, i.e. from an insignificant criterion (1) to the most important criterion (5). The following weights were assigned to the individual criteria:

A1 – certainty of operation
weight: 5 – most important criterion

A2 – reliability of the design
weight: 4 – very important criterion

A3 – stability of performance effects
weight: 4 – very important criterion

A4 – simplicity of design
weight: 2 – significant criterion

Next, each variant was evaluated with respect to each criterion; for every criterion, a rating on a scale from 1 to 9 was assigned, i.e. from a catastrophic situation to an excellent situation.

<u>*Evaluation of variant W1:*</u>
A1 – certainty of operation
rating: 3 – medium-risk situation
According to the SWOT/TOWS analysis, in this design variant the weaknesses reinforce the impact of threats.

A2 – reliability of the design
rating: 3 – medium-risk situation
According to the SWOT/TOWS analysis, in this design variant the weaknesses reinforce the impact of threats.

A3 – stability of performance effects
rating: 7 – good situation
After activation, the design should provide a constant buoyant force.

A4 – simplicity of design
rating: 6 – satisfactory situation
The design uses many pneumatic components and elements requiring precise machining.

<u>*Evaluation of variant W2:*</u>
A1 – certainty of operation
rating: 3 – medium-risk situation
According to the SWOT/TOWS analysis, in this design variant the weaknesses reinforce the impact of threats.

A2 – reliability of the design
rating: 3 – medium-risk situation
According to the SWOT/TOWS analysis, in this design variant the weaknesses reinforce the impact of threats.

A3 – stability of performance effects
rating: 7 – good situation
After activation, the design should provide a constant buoyant force.

A4 – simplicity of design
rating: 6 – satisfactory situation
The design uses many pneumatic components and elements requiring precise machining.

<u>*Evaluation of variant W3:*</u>

A1 – certainty of operation
rating: 3 – medium-risk situation
According to the SWOT/TOWS analysis, in this design variant the weaknesses reinforce the impact of threats.

A2 – reliability of the design
rating: 3 – medium-risk situation

According to the SWOT/TOWS analysis, in this design variant the weaknesses reinforce the impact of threats.

A3 – stability of performance effects
rating: 7 – good situation
After activation, the design should provide a constant buoyant force.

A4 – simplicity of design
rating: 6 – satisfactory situation
The design uses many pneumatic components and elements requiring precise machining.

Evaluation of variant W4:
A1 – certainty of operation
rating: 3 – medium-risk situation
According to the SWOT/TOWS analysis, in this design variant the weaknesses reinforce the impact of threats.

A2 – reliability of the design
rating: 3 – medium-risk situation
According to the SWOT/TOWS analysis, in this design variant the weaknesses reinforce the impact of threats.

A3 – stability of performance effects
rating: 7 – good situation
After activation, the design should provide a constant buoyant force.

A4 – simplicity of design
rating: 6 – satisfactory situation
The design uses many pneumatic components and elements requiring precise machining.

Evaluation of variant W5:
A1 – certainty of operation
rating: 9 – excellent situation
According to the SWOT/TOWS analysis, in this design variant the strengths of the design enhance the opportunities.

A2 – reliability of the design
rating: 9 – excellent situation
According to the SWOT/TOWS analysis, in this design variant the strengths of the design enhance the opportunities.

A3 – stability of performance effects
rating: 8 – very good situation
After activation, the design should provide a constant buoyant force.

A4 – simplicity of design
rating: 8 – very good situation
Compared with the other variants, the design is characterized by less complex technical solutions.

Evaluation of variant W6:

A1 – certainty of operation
rating: 9 – excellent situation
According to the SWOT/TOWS analysis, in this design variant the strengths of the design enhance the opportunities.

A2 – reliability of the design
rating: 9 – excellent situation
According to the SWOT/TOWS analysis, in this design variant the strengths of the design enhance the opportunities.
A3 – stability of performance effects
rating: 8 – very good situation
After activation, the design should provide a constant buoyant force.

A4 – simplicity of design
rating: 7 – good situation
Compared with the other variants, the design is characterized by less complex technical solutions, but a complex ballast shape is required for casting.

The calculation results are presented in the table below.

Tab. 5

	A1	A2	A3	A4	Sum of weight
Weight	5	4	4	2	15
W1	3	3	7	6	
W2	3	3	7	6	
W3	3	3	7	6	
W4	3	3	7	6	
W5	9	9	8	8	
W6	9	9	8	7	
Min	3	3	7	6	
Max	9	9	8	8	
R	6	6	1	2	check
Normalized weight	0,333333	0,266667	0,266667	0,133333	1
Z_{ij}					
W1	0	0	0	0	
W2	0	0	0	0	
W3	0	0	0	0	
W4	0	0	0	0	
W5	1	1	1	1	
W6	1	1	1	0,5	
Q_{ij}					**Qi**
W1	0	0	0	0	0,00
W2	0	0	0	0	0,00
W3	0	0	0	0	0,00
W4	0	0	0	0	0,00
W5	0,333333	0,266667	0,266667	0,133333	1,00
W6	0,333333	0,266667	0,266667	0,066667	0,93

From the table above it follows that, as a result of the analysis using the zero-unitarization method, the individual design variants received the following scores:

W1 - 0,00
W2 - 0,00
W3 - 0,00
W4 - 0,00
W5 - 1,00
W6 - 0,93

The constant U, calculated from relation (14), for the obtained values is 0.17 ($U = 0.17$). Then, the criteria for assigning the design variants to the intervals of best, average, and worst variants, calculated from relation (15), are as follows:

$$\begin{array}{ll} if\ Q_j \in \langle 0{,}83 \div 1{,}0\rangle & \text{best decision variant} \\ if\ Q_j \in \langle 0{,}67 \div 0{,}83\rangle & \text{average decision variant} \\ if\ Q_j \in \langle 0{,}00 \div 0{,}67\rangle & \text{worst decision variant} \end{array} \quad (15)$$

As shown by the calculation results presented in Table 5, all variants based on a change in volume (W1, W2, W3, W4) obtained a score of $Q = 0.00$, which means that they fall within the range corresponding to the worst variants. In contrast, the variants based on a change in mass (W5 and W6) obtained the following scores: W5 – 1.00 and W6 – 0.93, which places them in the range corresponding to the best variants.

The previously performed analysis of the design variants using the SWOT/TOWS method [4] indicated variants W5 and W6 as more optimal, and identical results were obtained when analyzing the designs using the zero-unitarization method (MUZ). For these reasons, these variants were selected for the attractiveness analysis.

The attractiveness analysis was carried out for the design variants operating on the basis of a change in mass, selected on the basis of the SWOT/TOWS analysis and the zero-unitarization method. The calculation results are presented in Table 6 (variant W5) and Table 7 (variant W6). Variant 5 (W5) obtained 137 points, whereas variant 6 (W6) obtained 142 points. For these reasons, variant 6 (W6), i.e. the design that uses a change in mass by releasing a lead ballast, was selected for further design work.

Tab. 6

W5 – Variant W5	Assessment of factor importance (1–4)	Assessment of strategy for factor (0–4)	Attractiveness (0–4)
Compact design	4	3	12
Generation of constant buoyant force	4	4	16
Simplicity of operation	4	4	16
Additional protection of the float when hitting the bottom	3	3	9
Low device weight	3	2	6
Absence of protrusions	3	3	9
Certainty of operation	4	4	16
Effectiveness of operation	3	4	12
No damage to the float	4	4	16
Reduced impact on the float's operating parameters	3	2	6
Concrete ballast	4	1	4
Large number of cables and electrical connections	2	1	2
Complex ballast release system	2	1	2
Susceptibility of external moving parts to fouling	1	1	1
Release module is flooded with water after activation	3	1	3
Environmental pollution by the concrete element	3	1	3
Failure risk – loss of tightness of components under voltage	1	2	2
Potential jamming of the release pin	1	1	1
Immobilization of the ballast	1	1	1
Single-use device	3	0	0
		TOTAL:	137

Tab. 7

W6 – Variant W6	Assessment of factor importance (1–4)	Assessment of strategy for factor (0–4)	Attractiveness (0–4)
Compact design of the device	4	3	12
Generation of constant buoyant force	4	4	16
Protection of the float's bottom components	3	3	9
Low device mass	4	4	16
Simplicity of operation	4	4	16
Absence of protrusions	3	3	9
Certainty of operation	4	4	16
Undisturbed operation of the float's measuring elements	4	4	16
Reduced impact on the float's operating parameters	3	2	6
Absence of damage	4	4	16
Lead ballast	1	1	1
Complex release system	1	1	1
Susceptibility of external components to fouling	1	1	1
High energy demand	1	1	1
Complex ballast shape for casting	1	1	1
Environmental pollution	1	1	1
Susceptibility to failure	1	1	1
Immobilization of the ballast	1	1	1
Limited operating time	1	1	1
Lack of effective operation	1	1	1
		TOTAL	142

CONCLUSIONS

The designs of the rescue device for the Argo profiling float described in publication [3], i.e.:

- variant 1 (W1) – increasing volume by moving pistons,
- variant 2 (W2) – increasing volume by filling a buoyancy bag,
- variant 3 (W3) – increasing volume by transferring water,
- variant 4 (W4) – increasing volume by filling a flexible hose,
- variant 5 (W5) – changing mass by releasing a concrete ballast,
- variant 6 (W6) – changing mass by releasing a lead ballast,

were subjected to a multi-aspect analysis. The group of competent judges included three designers with many years of experience in designing submersible devices and two specialists with less experience or expertise in other areas, whose task was to generate hardly predictable or even surprising negative factors related to the operation of the designed device. In the course of the SWOT/TOWS analysis, the competent judges identified the strengths and weaknesses of the analysed designs, as well as their opportunities and potential threats, and assigned appropriate weights to them. The results of these activities were published in Polish Hyperbaric Research in 2023 [4]. These results show that, among the six preliminary design concepts of the rescue device for ARGO that were analysed, those based on a change in volume may not guarantee proper operation of the designed device.

In the next research step, optimization of the proposed design was carried out by means of the zero-unitarization method and analysis of the attractiveness of the solutions. On the basis of the analyses presented in this paper, a decision was made to continue further design work using variant W6, i.e. a design that changes the mass of the float by releasing a lead ballast. The course of the subsequent design work and verification of the selected variant will be the subject of a further publication.

This publication was prepared within the framework of a project funded by the Minister of Education and Science under contract No. 2022/WK/04.

REFERENCES

1. Merchel M.; Walczowski W.; Rak D.; Wieczorek P.: The use of ARGO floats as virtual moorings for monitoring the South Baltic Sea; Oceanologia 66 (2024) ISSN 0078-3234; eISSN 2300-7370; pp. 99-110; https://doi.org/10.1016/j.oceano.2024.01.002
2. Merchel M.; Walczowski W.; Wieczorek P.: Anchored ARGO profiling float experiments in the southern Baltic Sea: Puck Bay and Hel Peninsula; Frontiers in Marine Science Volume 12 2025; e-ISSN 2296-7745; DOI: https://doi.org/10.3389/fmars.2025.1569261;
3. Olejnik A.; Walczowski W.; Dawidziuk M.; Jakus B.; WieczoreK P.: Rescue device concept for the ARGO profiling float; Polish Hyperbaric Research 2(80) 2022; ISSN 1734-7009; eISSN 2084-0535; pp. 23 – 38; DOI: 10.2478/phr-2022-0014;
4. Olejnik A.; Walczowski W.; Dawidziuk M.; Jakus B.; Wieczorek P.: Design optimisation of the device for the ARGO profiling float SWOT/TOWS analysis of design variations; Polsih Hyperbaric Research 1(82) 2023; ISSN 1734-7009; eISSN 2084-0535; pp. 33-66; DOI: 10.2478/phr-2023 -0002
5. Praca zbiorowa: https://euroargodev.github.io/argoonlineschool/intro.html - dostęp 24.11.2025

Adam Olejnik

Akademia Marynarki Wojennej im. Bohaterów Westerplatte 81 – 103 Gdynia 3,
Katedra Technologii Prac Podwodnych Akademia Marynarki Wojennej w Gdyni
e-mail: aolej@wp.pl