

TESTING OF THE ARGO RESCUE DEVICE IN SIMULATED MARINE ENVIRONMENT CONDITIONS

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ABSTRACT

This material is a continuation of previously published works related to the construction of a rescue device for the ARGO profiling float. Earlier publications presented design variants of such a device. Moreover, previous publications present a multi-criteria analysis of the developed designs, which resulted in the selection of a variant for construction. This material describes the course and results of preliminary laboratory tests of a technology demonstrator for such a device, which confirmed its design assumptions and form the basis for planning further experiments in conditions that more closely reflect real-life conditions. The work is being carried out as part of the Argo-Poland consortium, which is part of the European research infrastructure

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INTRODUCTION

Since 2022, the ARGO Polska consortium has been operating as part of the European Research Infrastructure ERIC (European Research Infrastructure Consortium), which is a member of the ARGO global ocean observation network (agreement with the Ministry of Education and Science No. 2022/WK/04) [1,2,9]. In addition to Poland, Euro-Argo includes research teams from 12 European countries. The team from the Department of Underwater Works Technology participating in this project is responsible for research and development work in the field of robotic profiling floats.

Argo is an international programme that collects data from the ocean using a fleet of over 4,000 robotic floats equipped with sensors to study the aquatic environment [5,6]. The key objective of the programme is to observe ocean data related to climate change. The environmental data collected by the floats is rendered available free of charge to a wide range of users around the world, who use it to assess the condition of the marine environment [5,6,7]. In Poland, this data is used, inter alia, by the Institute of Meteorology and Water Management (IMI GW) for analyses assessing the condition of the Southern Baltic Sea. The data collected by the network of robotic profiling floats is currently the most extensive source of data on temperature, salinity and pressure profiles in the world's oceans. This data helps scientists around the world understand how the physical state of ocean waters changes over time. It aids in research and understanding of the causes of ocean warming and water movement. It helps to monitor and manage ocean resources, the carbon cycle, ocean acidification and variability in ocean transparency. Global ocean measurements using robotic floats have provided insight into four key problem areas: ocean temperature and heat content, ocean salinity and freshwater content, sea level variability, and ocean circulation [5]. These issues are of fundamental importance for the protection of the marine environment and its monitoring over time.

The Argo-Poland project is an infrastructure project related to the maintenance of ocean research infrastructure and the provision of measurement data, which also encompasses research and development work. One of its manifestations is the development of a rescue device for the Argo float. Previously published articles have presented the concepts for such a device and the results of a multi-criteria analysis of the developed design variants. This article is a continuation of this topic. It will present the results of laboratory tests of a technology demonstrator for an Argo float rescue device carried out in simulated seabed conditions. The tests were carried out at the Department of Underwater Works Technology of the Polish Naval Academy in Gdynia in cooperation with the Laboratory of Observational Ocean Technology of the Institute of Oceanology of the Polish Academy of Sciences in Sopot as part of the Argo-Poland project.

METHOD

The tests were carried out using a demonstrator of the Argo float rescue device technology based on the principle of discarding lead ballast. The design details of the tested device are presented in publication [3]. In general, the principle of operation of this solution is to

equip Argo with an additional buoyancy element made of syntactic foam to counterbalance the lead ballast added to the float. When the on-board computer of the rescue device registers deviations from the planned mission profile, the float initiates the jettisoning of two ballast weights, which changes the buoyancy of the device and causes it to float to the surface. This solution was chosen on the basis of a multi-criteria analysis of design variants [4].

The aim of the research was to verify whether the adopted concept of the rescue device would work properly. During the current research, the degree of the float's immersion into the seabed was verified to determine how it would affect the operation of the designed device. The research was carried out in simulated seabed conditions organised in the test pool of the Department of Underwater Works Technology at the Naval Academy in Gdynia. Sand with a grain size of 1-2 mm was used as a simulated test bottom, placed on the bottom of the pool to form a layer approximately 30 cm thick (Fig. 1).



Fig. 1 Simulating sandy seabed conditions in a test pool during testing.

During the tests, four attempts were made to release the ballast of the rescue device with the float positioned differently in relation to the seabed:

- the float resting freely on the sandy seabed,
- the float buried in the sand to a depth of approx. 5 cm,
- float buried in the bottom to a depth of approx. 10 cm (2 tests).

During the tests, the standard float software was disabled, and the rescue device sensors were set to standby mode using the programmable ballast release function. Prior to each subsequent test, an emergency ascent was forced at a set time using the alarm programming procedure via Bluetooth communication. The behaviour of the rescue device during the underwater tests was recorded using video cameras operated by divers present in the pool during the tests.

TEST PROCEDURE

TEST No. 1

The float was placed freely on the bottom (Fig. 2). At the moment of emergency ballast release, their non-simultaneous release was recorded, which results from the uneven setting of the release latches in relation to the drive axis of the latches. The time interval between the release of the ballasts was 350 ms. The float detached from the bottom 420 ms after the release of the first ballast latch – which is referred to as the "ballast release start time (MRZB)". At $MRZB + 350$ ms, one ballast completely detached from the device, while the other was in an almost vertical position and was in the process of detaching – it continued to generate pressure and reduce buoyancy (Fig. 3). The buoy floated to the surface within 1 s of detaching from the bottom. The total operation time from MZRB to the buoy detaching from the bottom was 420 ms.



Fig. 2 Float with the rescue device resting on the test bottom in the pool.



Fig. 3 Release of ballast during Test No. 1.

TEST NO. 2

The float was sunk into the bottom to a depth of 5 cm (Fig. 4). Both ballasts were released from the latch catches at MRZB + 330 ms. The ballasts were completely released at MRZB + 630 ms (Fig. 5). The ascent began

before both ballasts were completely released at MRZB + 460 ms. After 1 s and 540 ms, the buoy detached from the bottom and at MRZB + 2 s 890 ms it floated to the surface. The total time of the operation from MZRB to the detachment of the buoy from the bottom was 2 s.



Fig. 4 Float with the rescue device embedded in the bottom to a depth of approx. 5 cm.



Fig. 5 Release of ballast during Test No. 2.

TEST NO. 3

The float was embedded in the bottom to a depth of 10 cm (Fig. 6). Both ballasts were released from the latch locks at MRZB + 290 ms. The ballasts were completely ejected at MRZB + 830 ms. The ballast release time was extended due to their sinking into the seabed and the resistance of the seabed material during their release. Once the ballasts were released, no visible sudden moment of float emergence was observed. The initial extraction of the Argo device from the seabed by 1 cm took 4 s and 330 ms. The float completely detached from the seabed at MZRB + 6 s and 580 ms, and then, after another 834 ms, the float ascended to the surface. The total

time of the operation from MZRB to the float detaching from the seabed was 6 s and 580 ms.



Fig. 6 Float with the rescue device embedded in the bottom to a depth of approx. 10 cm.



Fig. 7 Release of ballast during Test No. 3.

TEST NO. 4

Test No. 4 was performed under the same conditions as Test No. 3. The float was submerged into the bottom to a depth of 10 cm (Fig. 8). Both ballasts were released from the latch locks at MRZB + 240 ms. After release, the ballasts were not thrown away, but remained blocked by sand at an angle of $5 \div 10^\circ$ from the vertical position (Fig. 9). The float and ballast system remained virtually stationary. During 6 s 840 ms, the ballasts

deviated from the vertical by approx. 80° , and the float rose by 1 cm. After another 720 ms, the ballasts assumed a horizontal position and at that moment the float released itself from the ballasts (Fig. 10), where after 320 ms it detached from the bottom. The total time of the operation from MZRB to the float detaching from the bottom was 8 s and 200 ms.



Fig. 8 Float with the rescue device embedded in the bottom to a depth of approx. 10 cm – Test No. 4.



Fig. 9 Release of ballast during Test No. 4.



Fig. 10 Test No. 4 Float in a horizontal position before releasing the float.

TEST RESULTS

The tests carried out on the Argo rescue device for profiling floats were preliminary laboratory tests during which the function of the device was verified under simulated conditions. The tests allowed for the verification of the device's design assumptions and confirmed the assumptions regarding its operating principle. At this stage of the work, the number of tests carried out are not sufficient to analyze the data statistically or to reach clear conclusions. However, the release of the float upon activation of the rescue device was observed, indicating that a recess in the sandy bottom may affect the time it takes for the float to detach from the bottom. The float separation time observed during testing increases

significantly as the depth of the recess in the bottom increases; the preliminary estimated coefficient of determination for this data is close to unity. For this reason, it can be assumed that the depth of the recess will be decisive for the functionality of the designed device. The tests currently carried out allow for the development of a plan of experiments in conditions that closely reflect real-life conditions, which will be the subject of further work by the team.

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