**STUDY OF REGULARITIES OF AIR CONSUMPTION BY DIVERS DURING UNDERWATER DEMINING**

Ihor Soloviov1,Yevhen Stetsiuk2, Viktor Strilets3

1Main Directorate of the State Emergency Service of UkraineinKhersonRegion,

2.3National University of Civil Defense of Ukraine, Kharkiv, Ukraine

1cross199110@gmail.com, 2stecyuke@gmail.com, 3vstrelec1956@ukr.net

If the experience of explosions on land, in this case in Ukraine [1], has accumulated vast experience, the issues of improving the efficiency of exploration and demining of the aquatic environment need further development, as the number of explosive substances that pollute peaceful waters, in that case of critical infrastructure (Fig. 1), does not decrease significantly [2].

An analysis of the literature has shown that since the First World War and during and after the Second World War, several world powers have dropped both chemical and conventional weapons into the oceans around the world. Thus, approximately 175,000 mines were laid in the Baltic Sea during the world wars. There are currently about 1985 minefields in the Baltic Sea and another 4,400 in the North Sea. The Baltic Ammunition Safety Council (BOSB) coordinates efforts and ensures common approaches [3]. However, the BOSB guidelines do not address the specifics of the use of existing demining facilities, and they have their own specifications in each country.

A similar situation occurs off the coast of North America. In [4] the existing approach to the management of emergencies related to underwater munitions facilities is considered, which includes the characteristics of the facility, risk assessment, survey results, as well as potential problems related to personal health. composition of pyrotechnics. At the same time, the preliminary ranking based on the risks of underwater ammunition does not take into account the time of operational work of personnel, and it is directly related to the time of protective action of personal respiratory protection. The tactical and technical characteristics of the latter are directly related to pulmonary ventilation or air flow of rescuers [5].

In [6] it is noted that even in the case when ammunition buried under water and it is unlikely that they will require withdrawal in the near future, there is a need for their underwater positioning, which without underwater reconnaissance is almost impossible. And the organization of its carrying out again demands knowledge of an estimation of time of work of pyrotechnicians under water. And even the use of autonomous submarines based on sensor technology, the use of chemical and biometric sensors, is based on underwater operational activities of personnel involved in the detection of underwater ammunition [7], which also requires consideration of the physiological characteristics of submarines. Thesameiscanceledin [8,9], itisshownthatflexibilityinplanningandexecutionofimprovisedworksonsubjectswhichdidnotexplodecreatesinvolvementofprofessionalsinthecarried-outimprovisedworksonapplicationofthecorrespondingmeansofindividualprotectionoflifeorgans, tacticalandtechnicalcharacteristicscorrespondtodivers.

ThemodernEuropeanperspective of preventing emergencies related to the underwater location of explosive objects is the application of the principles of "do not blow up" [11] and the transition to the realization of the capabilities of underwater robots [12]. But in the first and in the second case without the participation of specially trained divers [13] can not do, and the organization of their activities requires knowledge of estimates of the time of possible work of personnel, especially in the case of autonomous breathing apparatus [14,15].

Similar problems exist in Ukraine, where only in the Kherson region in the Black Sea were found two ships from the past wars, which in accordance with the Plan for the organization of reconnaissance and demining of the Kherson region are subject to priority demining. At the same time, the practice of demining with the destroyer Frunze near the Tenderovska spit of Holoprystansky district showed that the lack of documents in the AVM documents did not contribute to the planning of operational activities of the underwater demining department of the group of pyrotechnic works and special diving works. [17,18] estimates of thetimeofoperationalworkunderwater.

Thus, an important and unsolved part of the problem of underwater demining is to take into account the flow of air in compressed air vehicles in diver sappers during the most typical operations for personnel operations.

Based on this, it was analyzed how the type of operational activities and the conditions of its implementation affect the air flow of sapper divers during underwater demining.

To solve this problem, experimental studies were first conducted, in which subjects from the personnel of the submarine demining department of the group of pyrotechnic works and special diving emergency rescue team of the Main Directorate of the SES of Ukraine in Kherson region took part. During the spring and summer of 2020, they performed real search operations (Fig. 2) at a depth of 4 m, 6 m and 7 m and lifting (Fig. 3) from a depth of 6 m, in the event that there was no possibility of destruction on site , explosive devices intheBlackSea, whichrequiresdemining.

Ineachcase, the time (t, min.) Ofunderwateroperationalworkincompressedairdevices (AVM typedeviceswith a volumeVbof 12 and 15 lcylinders), initialpressure (Pinitial, bar) andpressure (Pterminal, bar) werecompleted. the operation under consideration. This allowed, using the Boyle-Marriott law, to proceed to the assessment of air flow [l / min]

, (1)

whereP atm ≈ 1 bar - atmosphericpressure.



Fig.2. Search for explosive objects under water



Fig.3. Lifting explosive objects from under the water

To check the difference in air flow depending on both the depth of rescue operations under water and the nature of operational activities (search for explosive objects or their rise to the surface) were obtained statistical estimates of experimental results (mathematical expectations and standard deviations) for selected options operational activities under different initial conditions.

The results were obtained because samples with volumewereusedineachcase, weretestedforthe normality of the distribution by the Shapiro-Wilkie test [19]. It isdeterminedthatthelevelofsignificanceα= 0.05 theycanbeconsidered normal. In generalized form, they are presented in Figure 4, which shows estimates of the distribution of air flow by divers during the search (taking into account the depth of rescue operations) under water of an explosive object and its transportation to the surface.

****

Fig. 4. Distribution of air flow during underwater operational work in the AVM depending on the nature of the task performed by personnel

Thestrengthoftheresultsisthedefinitionofreliableindicators (with a significancelevelα = 0.05), whichcanbethebasisforjustifyingspecificproposalsfortheorganizationofworkonunderwaterdemining, thechoiceofpersonalprotectiveequipment, especiallyrespiratory, rescuers, tacticaljustification. technicalrequirementsforpersonalrespiratoryprotectionofdivers-sappersbothatthestageoftheircreationandatthestageofacquisition, aswellasduringtheorganizationoftheprocessoftrainingpyrotechnicians-submariners.Thestrengthofthe results obtained is the determination of reliable indicators (with the level of significance α= 0.05), which can be the basis for substantiation of specific proposals for the organization of work on underwater demining, the choice of personal protective equipment, especially respiratory, rescuers, justification of tactical and technical requirements for personal respiratory protection divers-sappers as on stage of their creation, and at the stage of acquisition, as well as during the organization of the process of training pyrotechnicians-submariners.

Representation with a level of significance α= 0.05 patterns of air flow during underwater work in the process of demining of water areas allows you to use them as input data for simulation models of emergency prevention associated with the underwater location of explosive objects.

Atthesametimeitshouldbenotedthattheapplicationofthechosenapproachinpracticeisaccompaniedbythecomplexityofexperimentalresearch, theresultsofwhicharethebasisforscientificallysounddecisionstoimprovetheeffectivenessofpersonnelofthedepartmentofunderwaterdeminingofpyrotechnicworksandspecialdivingworks, whereasthisprocessrequirestheinvolvementofhighlyqualifiedspecialistswhohavebothknowledgeandskillsinthepracticeofdeminingofwaterareasandintheorganizationofexperimentalresearchsoastoobtainstatisticallysignificantresults, whichwillformthebasisofappropriateproposals.Inaddition, a significantlimitationisthepossibilityofimplementingthedevelopedtechniqueonlyfordevicesincompressedair, whentheyareusedatshallowdepths.

Thus, tostudythe patterns of air flow by divers during underwater demining, a method of experimental research was developed, which allowed to obtain quantitative estimates of air flow by divers during submarine demining (mathematical expectations and standard deviations), which simultaneously characterize the nature operational work performed by a diver-sapper, and the conditions of his activity (the depth of the explosive object), and check by Student's criterion how significantly each of the selected factors affects the air flow during operation in the isolating apparatus. The results of statistical analysis of experimental results showed that at the level of significanceα= 0.05 results obtained during rescue operations for underwater demining under different conditions (depth of the explosive object) and the nature of the operation to be performed differ significantly, which confirms the need for increased attention to the training of personnel of the submarine demining group of pyrotechnic works and special diving works to carry out operational activities at depth.

###### List of sources used

1. Order of the SES of Ukraine dated August 08, 2018 № 461 "On approval of the Standard Operating Procedure 09.10-12 (1) / SES" Procedure for bodies and units of civil protection to clean (demine) areas contaminated with explosives. Operational response "".
2. Order of the SES of Ukraine of January 21, 2020 № 68 "On the implementation of major mine action measures in 2020 and special blasting."
3. Möller, Gunnar. From a DC-3 to BOSB: TheRoadto a BreakthroughinMilitarySafetyMeasuresAgainsttheRisksofHistoric, ExplosiveOrdnance. MarineTechnologySocietyJournal, Volume 45, Number 6, November / December 2011, pp. 26-34 (9). DOI:<https://doi.org/10.4031/MTSJ.45.6.1>
4. Sayle, Stephen; Windeyer, Tom; Charles, Michael; Conrod, Scott; Stephenson, Malcolm. Site Assessment and Risk Management Framework for Underwater Munitions. Marine Technology Society Journal, Volume 43, Number 4, Fall 2009, pp. 41-51 (11). DOI:<https://doi.org/10.4031/MTSJ.43.4.10>
5. Fundamentalsofcreationandoperationofdevicesincompressedair / [R.A.Kovaliov, V.M. Sagittarius, O.V. Elizarov, O.E. Bezuglov]. - H.: ACZU, 2005. - 359 p.
6. Schwartz, Andrew; Brandenburg, Erika. An Overview of Underwater Technologies for Operations Involving Underwater Munitions. Marine Technology Society Journal, Volume 43, Number 4, Fall 2009, pp. 62-75 (14). DOI:<https://doi.org/10.4031/MTSJ.43.4.12>
7. Camilli, Richard; Bingham, Brian S .; Jakuba, Michael V .; Duryea, Anthony N .; LeBouvier, Rand; Dock, Matthew. AUV Sensors for Real-Time Detection, Localization, Characterization, and Monitoring of Underwater Munitions. Marine Technology Society Journal, Volume 43, Number 4, Fall 2009, pp. 76-84 (9). DOI:<https://doi.org/10.4031/MTSJ.43.4.6>
8. Rancich, Tom. Search and Recovery of Munitions by Divers. Marine Technology Society Journal, Volume 45, Number 6, November / December 2011, pp. 75-79 (5). DOI:<https://doi.org/10.4031/MTSJ.45.6.9>
9. Herbert, John. Risk Mitigation of Chemical Munitions in a Deep-Water Geohazard Assessment. Marine Technology Society Journal, Volume 44, Number 1, January / February 2010, pp. 86-96 (11). DOI:<https://doi.org/10.4031/MTSJ.44.1.4>
10. Maser, E., Strehse, JS “Don’t Blast”: blast-in-place (BiP) operations of dumped World War munitions in the oceans significantly increase hazards to the environment and the human seafood consumer. Arch Toxicol 94, 1941–1953 (2020).<https://doi.org/10.1007/s00204-020-02743-0>
11. Huet, C., Mastroddi, F. Autonomy for underwater robots — a European perspective. Auton Robot 40, 1113–1118 (2016).Availableat:<https://doi.org/10.1007/s10514-016-9605-x>
12. NickCooper, SimonCooke, KevinBurgess. RiskyBusiness: DealingwithUnexplodedOrdnance (UXO) intheMarineEnvironment. Coasts, MarineStructuresandBreakwaters 2017. PublishedOnline: August 21, 2018. Availableat:<https://doi.org/10.1680/cmsb.63174.0157>
13. Mijajlovic, Veselin (2013) "TheRegionalCenterforDiversTrainingandUnderwaterDemining," TheJournalof ERW andMineAction: Vol. 17: Iss. 2, Article 13. Availableat:<https://commons.lib.jmu.edu/cisr-journal/vol17/iss2/13>
14. deWaard L., Dekeling R. AnOverviewoftheDisposalofAmmunitionintheDutchSectionoftheNorthSea: PresentPracticeandDevelopmentofSafetyMeasures. - 2013. Availableat:<https://schleswig-holstein.nabu.de/natur-und-landschaft/aktionen-und-projekte/munition-im-meer/miremar/13199.html>
15. RiskyBusiness: DealingwithUnexplodedOrdnance (UXO) intheMarineEnvironment. CooperNickandCookeSimon. Coasts, MarineStructuresandBreakwaters 2017. January 2018, 157-167. Availableat:<https://doi.org/10.1680/cmsb.63174.0157>
16. Soloviov I.I., Strilets V.M. Problematic issues of underwater demining. Energy saving and industrial safety: challenges and prospects. Third International Scientific and Practical Conference. Kyiv: KPI, NNDI PBtaOP. 2020. P.225-231
17. DSTU-P IMAS 09.60: 2014 (IMAS 09.60: 2014, IDT) Underwater exploration and clearance ofexplosives (GNP) Availableat: <https://www.mineactionstandards.org/fileadmin/MAS/documents/standards/translations/IMAS_09.60_ukr.pdf>
18. Standard Operating Procedures for Humanitarian Underwater Demining in South Eastern Europe. Available at:<https://old.mineactionstandards.org/fileadmin/MAS/documents/references-publications/Humanitarian-Underwater-Demining-in-South-Eastern-Europe.pdf>
19. Statistical methods. Check of deviation of distribution of probabilities from normal distribution: GOST R ISO 5479-2002. - [Effective from 2002-07-01]. Moscow: GosstandartofRussia, 2002. - 31 p.
20. Mitropolsky A.K. Technique of statistical calculations - Main edition fiz.-mat. Literature of the publishing house "Science", 1971. - 576 p.
21. Khalafyan A.A. STATISTICS 6 Statistical data analysis / А.А. Halafyan. - М .: 000 «Binomial-press», 2007. – 512p.