

ОРИГИНАЛЬНЫЕ СТАТЬИ / ORIGINAL ARTICLES

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HYPOBARIC CHAMBER: PAST, PRESENT, PROSPECTS

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OBJECTIVE. To conduct a comprehensive analysis of the evolution and current state of hypobaric chambers as a tool for psychophysiological training of aviation personnel of the naval aviation of the Russian Navy (Navy), and to determine the prospects for their use in the Armed Forces.

MATERIALS AND METHODS. The study was conducted using a retrospective analysis and descriptive analytical methods. It examined data on the development of pressure chamber technologies, modern methods for using low-pressure pressure chambers, the technical characteristics of the Edelweiss hypobaric pressure chamber module (HPM), and the results of its practical application.

RESULTS. It has been established that hyperbaric chamber technologies have evolved from the first experiments in the 17th century to the modern high-tech HPM Edelweiss complex. From 2015 to 2017, an innovative hyperbaric complex was created and installed at the Yeysk Naval Aviation Center. The complex includes the SVBK-30 hyperbaric chamber for high-altitude (up to 30,000 m) research and the TD-1 breathing simulator for interval hypoxic training. Over 700 tests have been completed, and paratrooper training programs have been implemented.

DISCUSSION. The obtained results confirm the effectiveness of using low-pressure chambers in the psychophysiological training of aviation personnel and for conducting medical flight examinations. The Edelweiss HPM complex has unique characteristics and technical potential for further improvement: the introduction of digital technologies, integration into the medical monitoring system, and expanded diagnostic capabilities. The HPM can be used to develop new psychophysiological training methods and non-drug treatments for certain chronic diseases.

CONCLUSION. Hypobaric chambers have come a long way, from observing the effects of high altitude on humans to the rapid development of high-altitude chambers with unprecedented physiological research. Modern high-altitude chambers are high-tech systems with automated control systems that have become a key tool for ensuring the professional longevity of flight crews. Future developments are linked to improved technical specifications and expanded medical monitoring capabilities, as well as the emergence of new possibilities for hypobaric treatments for certain diseases.

KEYWORDS: marine medicine, maritime medicine, hypobaric chamber, psychophysiological training, pressure drop chamber, altitude testing, altitude, medical monitoring, hypobarotherapy

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ГИПОБАРИЧЕСКИЕ БАРОКАМЕРЫ: ПРОШЛОЕ, НАСТОЯЩЕЕ, ПЕРСПЕКТИВЫ

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ЦЕЛЬ. Провести комплексный анализ эволюции и современного состояния гипобарических барокамер как инструмента психофизиологической подготовки авиационного персонала морской авиации Военно-Морского Флота Российской Федерации (ВМФ), определить перспективы их применения в Вооруженных Силах.

МАТЕРИАЛЫ И МЕТОДЫ. Исследование выполнено на основе ретроспективного анализа с применением описательно-аналитических методов. Проанализированы данные развития барокамерных технологий, современные методики применения барокамер пониженного давления, технические характеристики гипобарического барокамерного модуля (МГБ) «Эдельвейс» и результаты его практического применения.

РЕЗУЛЬТАТЫ. Установлено, что барокамерные технологии прошли эволюцию от первых опытов в XVII в. до современного высокотехнологичного комплекса МГБ «Эдельвейс». В 2015–2017 гг. создан инновационный барокомплекс, установленный в Ейском центре морской авиации ВМФ. Комплекс включает барокамеру «СВБК-30» для проведения высотных (до 30 000 м) исследований и дыхательный тренажер «ТД-1» для интервальных гипоксических тренировок. За период эксплуатации выполнено более 700 испытаний, реализованы программы подготовки десантников.

ОБСУЖДЕНИЕ. Полученные результаты подтверждают эффективность применения барокамер пониженного давления в системе психофизиологической подготовки авиационного персонала и в целях проведения врачебно-летной экспертизы. Комплекс МГБ «Эдельвейс» обладает уникальными характеристиками и имеет технический потенциал для дальнейшего совершенствования: внедрение цифровых технологий, интеграция в систему медицинского контроля, расширение диагностических возможностей. На МГБ возможно разрабатывать новые методики психофизиологической подготовки и немедикаментозные способы коррекции в системе лечения некоторых хронических заболеваний.

ЗАКЛЮЧЕНИЕ. Гипобарические барокамеры прошли долгий путь от наблюдения эффектов влияния высокогорья на человека через бурное развитие высотных барокамер с беспрецедентными физиологическими исследованиями. Современные высотные барокамеры представляют собой высокотехнологичные комплексы с автоматизированными системами управления, ставшие ключевым инструментом обеспечения профессионального долголетия летного состава. Перспективы развития связаны с совершенствованием технических характеристик и расширением возможностей медицинского контроля, а также появлением новых возможностей для гипобарических методов лечения некоторых заболеваний.

КЛЮЧЕВЫЕ СЛОВА: морская медицина, гипобарическая барокамера, психофизиологическая подготовка, камера перепада, высотные испытания, высота, медицинский контроль, гипобаротерапия

Introduction. Aviation and space medicine is a specialized field of medical science focused on studying the functioning of the human body under the influence of flight and space factors. Priority objectives in this field include ensuring flight safety, improving the professional reliability of aviation personnel, maintaining occupational health and extending active flight longevity [1].

The development of modern aviation technology is accompanied by increasingly complex aircraft designs, a wider range of operating altitudes and speeds, and an increase in the intensity of flight operations. Under these conditions, a pilot's professional activities are characterized by high responsibility, significant psycho-emotional stress, and the need to make decisions under time pressure, including in emergency and non-standard situations.

Aviation personnel are significantly affected by a range of adverse flight factors, including low

barometric pressure, varying degrees of hypoxia, sudden pressure changes, G-forces, noise, vibration, and adverse microclimatic conditions. The combined effects of these factors create extreme professional conditions that require a high level of functional resilience and developed adaptive mechanisms [2, 3].

The flight medical support system focuses on professional selection, medical flight assessment, psychophysiological training, dynamic medical monitoring, recovery, and rehabilitation of flight personnel. Hypobaric chambers are among the most informative and versatile technical means for implementing these measures [4].

Hypobaric chambers allow to simulate factors of rarefied atmosphere, typical to high-altitude flights under controlled ground conditions. During chamber studies, various profiles of changes in barometric and partial oxygen pressure are reproduced, enabling detailed study of

cardiovascular, respiratory, and central nervous system responses [5].

Hyperbaric chamber studies are used to assess individual adaptive reserves, identify tolerance to hypoxia and pressure fluctuations, and predict the stability of professionally significant functions. The data obtained serve as the basis for medical and expert decision-making in flight medical examination.

An important application of hypobaric chambers is flight crews' psychophysiological training. Training develops skills for early recognition of oxygen deficiency, practices algorithms of actions for dealing with cabin leaks, and improves the resilience of professionally important functions in oxygen-deficient conditions.

Objective. To analyze the development and current state of hypobaric chambers as a key element of psychophysiological training of aviation personnel of the naval aviation of the Russian Navy (Navy) and to determine the prospects for their use in the Armed Forces.

Materials and methods. The study was descriptive, analytical, and retrospective in nature. The research material included historical data on the development of pressure chamber technologies, modern methods of using hyperbaric chambers of low-pressure, an assessment of the technical characteristics of the Edelweiss hypobaric pressure chamber module (HPM), and practical results of its use.

Results. The historical background for the development of pressure chamber technology dates back to the 17th century. In 1660–1662, the English physicist and chemist Robert Boyle first described the effect of air on living organisms in his book, “New Physical and Mechanical Experiments Concerning the Elasticity of Air, and Their Results.” At the same time, in 1662, the British priest and physician Nathaniel Henshaw first decided to use altered atmospheric pressure as a treatment: for this purpose, he used a system of siphons with one-way valves to change the atmospheric pressure in a sealed wooden chamber. This fact is the first documented evidence of the use of pressure chambers. In the 18th–19th centuries, the development of pressure chambers was primarily clinical in nature. French researchers made a significant contribution to the development of this field, developing stationary pressure chambers for the treatment of respiratory diseases and surgical interventions. In 1834,

the French physician Junod described the positive effects of high-pressure oxygen on humans and built a therapeutic pressure chamber based on the design of James Watt, the inventor of the steam engine. It consisted of a copper sphere 1.5 m in diameter, the air pressure in which could be increased to 4 atm. In 1837, Charles-Gabriel Pravaz built the largest pressure chamber in Lyon, France. It could accommodate 12 patients for the treatment of lung diseases, as well as other ailments. In 1877, the French surgeon Fontaine designed and built the first mobile pressure operating room, in which Jules-Emile Peanc successfully performed 27 hernia repairs. All pressure chambers created were used, as a rule, for therapeutic purposes [6].

A qualitatively new stage in the development of pressure chamber research was associated with the emergence of aeronautics and aviation. It was the emergence and rapid development of aeronautics that determined the need for high-altitude research into the physiology of the human body in conditions of virtually rarefied atmospheres. This research was undertaken by the outstanding scientist Paul Bert. In 1868, he constructed the first hypobaric pressure chamber (Fig. 1), in which he conducted experiments not only on animals but also on humans. His pressure chamber research was experimental in nature. For example, Bert thoroughly described the effects of reduced pressure on the body, as experienced by aeronauts during balloon flights. He devoted great persistence and energy to studying effects of reduced and increased barometric pressure on various animal species. He summarized the results of his work in his book “Barometric Pressure” (1878). P. Behr's fundamental work made it possible to study the effects of reduced atmospheric pressure on the human and animal body. His work laid the foundations of high-altitude physiology and had a significant influence on the development of aviation medicine. The impetus for the creation and construction of new hypobaric chambers was the growing interest in the physiology of high-altitude flights, associated with the development of aeronautics and the emergence of the first piston aircraft.

In 19th-century Russia, balloon flights were a rarity, although as early as 1804, on assignment from the St. Petersburg Academy of Sciences, Academician Ya. D. Zakharov ascended in a hot air balloon to study effects of rarefied atmosphere on aeronauts. In 1878, in France, the scientist and

encyclopedia D. I. Mendeleev reached an altitude of 3,000 meters in a “Russkiy” hot air balloon. The history of Russian aviation is traditionally dated from the early 20th century, which also marked the beginning of research in high-altitude physiology. A profound study of the impact of environmental factors on humans was facilitated primarily by the enormous interest in aeronautics in the USSR in the 1930s, sparked by Auguste Piccard’s stratospheric balloon flights, as well as by the new generation of aircraft that replaced airplanes. However, class consciousness and good physical fitness were not enough to fly.

In 1936, research into the physiology of extreme conditions was conducted at the Leningrad Military Medical Academy under the direction of L. A. Orbeli. There, in the Physiology Department, L. A. Orbeli and M. P. Brestkin created a special pressure laboratory, which allowed for unique studies to be conducted on effects of a number of extreme factors on the body: high and low air pressure, hypoxia and hyperoxia, hypocapnia and hypercapnia, increased nitrogen pressure, high temperatures, and intense muscle activity. The results of the work conducted in the late 19th century The work of the luminaries of Russian

physiology I. M. Sechenov, D. I. Mendeleev, and I. P. Pavlov, as well as the subsequent research of L. A. Orbeli, M. P. Brestkin, P. I. Egorov, and A. A. Sergeev in the pressure laboratory, laid the physiological foundations for subsequent advances in aviation, high-speed flight, high-altitude flight, pilot and diver safety, and space physiology and medicine. This led to the development of scientific principles for medical support in aviation and, subsequently, space medicine [6, 7].

Meanwhile, constantly improving and complexifying aviation technology, expansion of its application scope in various, sometimes extreme, conditions, increasing complexity and responsibility of its management, in addition to early determination of suitability for mastering the profession of a pilot, required the assessment and prediction of pilot’s behavior stability under the influence of extreme flight factors. In addition to health itself, aviation medicine specialists were forced to pay attention to the study of the pilot’s ability to maintain sensory, motor and mental skills under any complication of the flight; the stability and ability to quickly switch attention; type of thinking, the pace of thought processes, the ability to quickly assess the surrounding sit-

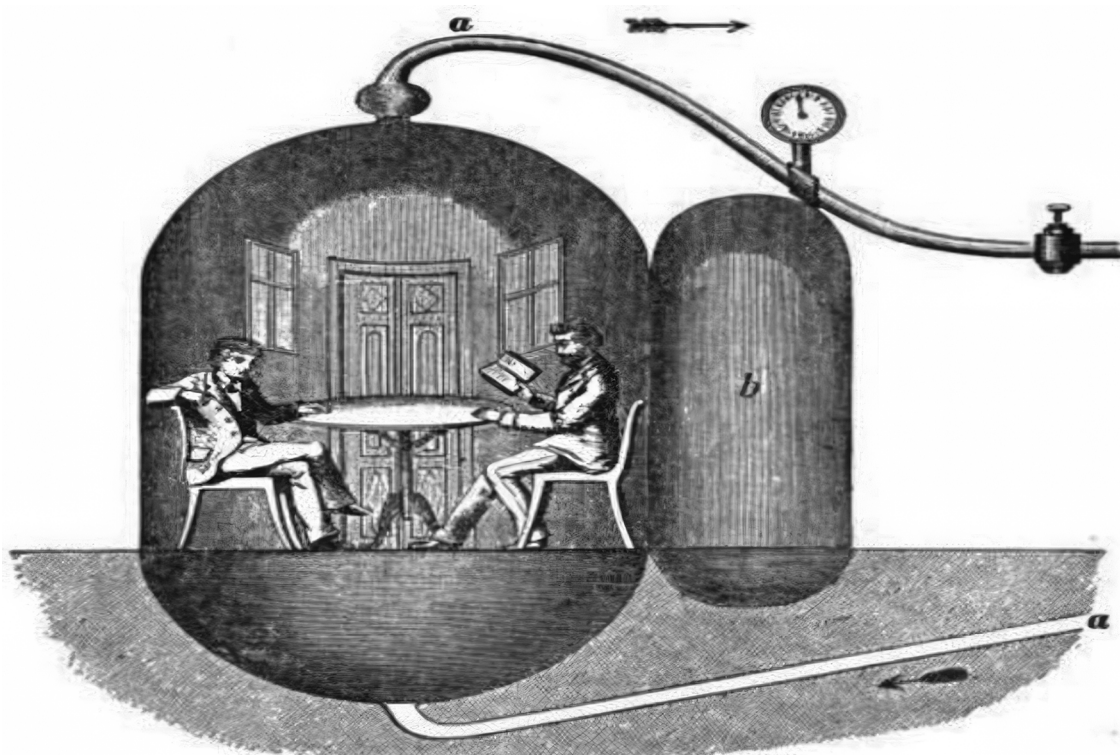


Fig. 1. Paul Bert pressure chamber
Рис. 1. Барокамера Поля Бера

uation and respond to it with correct and precise actions both in normal flight conditions and under the influence of extreme factors [8]. This necessitated the introduction of pressure chambers into the practice of aviation medicine.

Over time, the possibility and feasibility of using low-pressure chambers directly in flight units was substantiated both for conducting special training of flight personnel as part of psychophysiological preparation for high-altitude flights (developing resistance to changes in barometric pressure, low oxygen content, identifying a predisposition to high-altitude decompression illnesses), and for solving problems of ensuring the preservation, restoration and maintenance of physical and mental health, performance and prolongation of professional longevity of flight personnel.

The first domestic hypobaric chambers that were mass-produced were the SBK-48 chamber and its improved model, the SBK-48M (Fig. 2).

Both pressure chambers were stationary, rectangular in shape, and consisted of two compartments: the main compartment with a volume of 7 m³, which could accommodate four people, and an airlock with a volume of 3 m³. They had minor design differences, primarily related to the placement of pipelines and instrumentation. Despite their simple design, the pressure chambers were quite effective in conducting medical research and high-altitude training for flight crews, which explains their demand and mass production [6].

Along with the stationary version, mobile (transportable) versions of the SBK pressure chambers were also developed, designated PBK-50 and PBK-53. The pressure chambers and the necessary equipment were mounted on vehicle chassis (in bodies and trailers), and the equipment was powered by the vehicle's standard generator, driven by the gearbox.

A milestone in the development of domestic low-pressure chambers in the early 1980s was the development, creation, and commissioning of the PBK-70 chamber. This chamber made it possible to simulate ascents to an altitude of 30,000 m and, for the first time, the depressurization of an aircraft cabin (Fig. 3).

The pressure chamber was cylindrical and structurally comprised two sections: the main section with a volume of 7.5 m³, accommodating four people, and a "depressurization" chamber (pressure drop chamber) with a volume of 1.8 m³,

accommodating one test subject. The main section of the pressure chamber was used to test the flight crew's tolerance to low oxygen levels in the environment (hypoxia) and identify their predisposition to high-altitude decompression illnesses. The "depressurization chamber" was used to demonstrate and evaluate the protective properties of the oxygen supply and protective gear, and to test the flight crew's psychophysiological preparedness (training) for the effects of an explosive depressurization of the aircraft cabin.

Based on the results of the operation of the PBC-70, its improved, but slightly different in design, models of transportable pressure chambers TBK-73 and TBK-78 appeared.

If mobile models of low-pressure hyperbaric chambers were an analogue and subsequent improvement of the stationary pressure chamber SBK-48, then the stationary pressure chamber SBK-80, developed in 1980, which incorporated all the positive experience of operating mobile pressure chambers, became a kind of result of the development of Russian pressure chambers (Fig. 4).

Structurally, the SBK-80 was a stationary version of the PBK-70 pressure chamber, but was already equipped with a standard medical monitoring system, including operational monitoring. The pressure chamber made it possible to conduct a range of measures to determine professional suitability for flight, ensure pilots were trained to have stable performance under extreme con-



Fig. 2. Stationary pressure chamber SBK-48
Рис. 2. Стационарная барокамера СБК-48



Fig. 3. PBK-70 mobile pressure chamber based on a trailer

Рис. 3. Подвижная барокамера ПБК-70 на базе автоприцепа

ditions of high-altitude flights, maintain physical and mental health, professional performance, and extend the professional longevity of flight crews.

The rapid development of jet and supersonic aircraft required new psychophysiological criteria for pilot assessment and medical examination to determine suitability for operating modern high-speed aircraft; new assessments of flight crews' psychophysiological abilities to master high-speed flight and the body's ability to withstand G-forces. Meanwhile, technically and morally obsolete pressure chambers no longer fully met the newly established requirements of aviation medicine specialists for psychophysiological studies during high-altitude training.

Unfortunately, the reforms carried out in the country in the 1990s failed to spur the development of domestic low-pressure chambers. More-

over, a review of flight medical support principles and attempts to restructure it along Western lines led to the introduction of a simplified understanding of the medical support system, the formation of a view that testing pilots' resistance to moderate hypoxia in aviation units was sufficient, and the need to concentrate technical equipment simulating modern flight conditions exclusively in specialized medical and research institutions. As a result, the design and production of new low-pressure chambers was completely discontinued. To maintain the chambers' operability, a decision was made to exclusively perform maintenance beyond their established service life and partially replace medical monitoring equipment with more modern ones [9].

The obsolescence of SBK-80, along with the reduced funding for design work on the creation of similar technical equipment, the cessation of their production by domestic industrial enterprises and a partial transition to the purchase of samples offered by foreign companies, have revealed the existing significant problems in the implementation of pressure chamber lifts.

Today, pressure chambers are among the few ground-based rigs that can accurately simulate many factors associated with high-altitude flight [10]. Faced with the particular urgency of pressure chamber studies of flight personnel (among many other issues related to flight medical support), in 2014 the Navy's General Command's medical service developed a concept for the development of a medical support system for naval aviation navy. This concept detailed the problematic aspects of medical support and proposed specific measures for their resolution. Recognizing that the service life of pressure chambers produced in the 1980s is limited, we decided to revive the development and serial production of domestic hypobaric pressure chambers that would correspond to the current level of development in aviation and medical technology, with room for further improvement. In order to implement the concept, in 2015, specialists from the medical service of the General Command and naval aviation of the Navy, together with scientists from the Research and Testing Center for Aerospace Medicine and Military Ergonomics of the Central Research Institute of the Air Force of the Ministry of Defense of the Russian Federation (RTC (AM and ME) Central Research Institute of the Air Force of the Ministry of Defense of the Russian

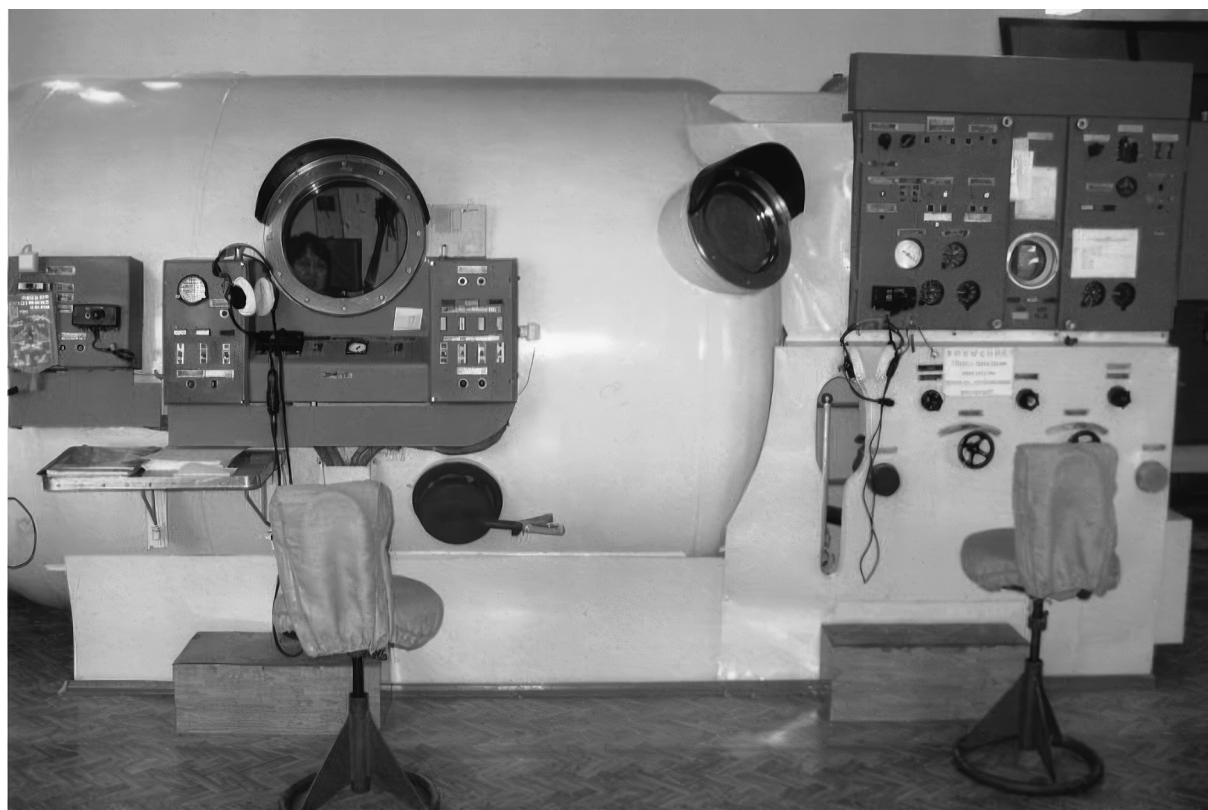


Fig. 4. Stationary pressure chamber SBK-80

Рис. 4. Стационарная барокамера СБК-80

Federation) developed the technical assignment “Additional equipping of aviation medicine laboratories of the aviation units of the naval aviation of the Navy with transportable hypobaric chamber modules in container design (MHB “Edelweiss”) with objective medical and technical control systems and their commissioning” [9].

The Special Design Bureau of Experimental Equipment at the Institute of Medical Problems of the Russian Academy of Sciences, in collaboration with the Navy Medical Service, designed and manufactured the Edelweiss low-pressure chamber, which has no analogues in the world. The complex was produced with the participation of more than 20 domestic enterprises, including large corporations: SPE Cryogenmash (Balashikha), SPE Prima (Nizhny Novgorod), UIDB (Ulyanovsk), Medical Systems LLC (Rostov-on-Don), SPE Respirator JSC (Orekhovo-Zuyevo), and SP Avtomatika (Dolgoprudny). In manufacturing MHB, practical experience in operating previously manufactured low-pressure chambers was taken into account, ready-made (certified) solutions were used, and the issue of import substitution was completely resolved (Fig. 5).

The complex is designed for ground-based training of flight personnel for flight operations and medical monitoring of flight personnel as one of the factors in ensuring the safety of naval aviation flights of the Navy, including:

- training and testing of flight personnel at altitudes up to 30,000 m for the purpose of medical flight examination and psychophysiological preparation for flights on aircraft in order to increase resistance to high-altitude flight factors and the ability to safely operate an aircraft, use weapons in case of emergency, and coordinate actions in the event of operational damage both at operating and at maximum flight altitudes;
- identifying individual tolerance to various degrees of oxygen starvation, latent forms of diseases accompanied by a decrease in the body's resistance to high-altitude flight factors;
- training and testing of flight personnel skills in using oxygen equipment;
- determining the tolerance of high degrees of atmospheric rarefaction in flight personnel after injuries, illnesses that can reduce the body's resistance to hypoxia, and long breaks in flights; the tolerance of changes in barometric pressure

in flight personnel after illnesses that can impair the barofunction of the ear and paranasal sinuses.

MHB pressure chamber (Fig. 6) is designed for:

- conducting group expert high-altitude studies at altitudes of up to 12,000 m and individual psychophysiological training for stratospheric flights up to an altitude of 13,500 m in the “main” compartment with the placement of up to 4 people;
- studies of the tolerance of high degrees of atmospheric rarefaction using high-altitude equipment at altitudes from 12,000 to 30,000 m in a “drop compartment” with the placement of one person.

In addition to the pressure chamber, MHB includes the TD-1 breathing simulator (Fig. 7), which is a hardware and software complex designed for comparative analysis and monitoring of the functional state of the body, conducting interval breathing training to develop adaptive abilities, as well as for inhalation of artificial heated mixtures of oxygen and inert gases for the purpose of accelerated recovery after exposure to physical and psycho-emotional stress [11].

TD-1 allows to:

- conduct interval breathing training aimed at developing the adaptive capabilities of the human body as a factor in active adaptation to various types of hypoxia, contributing to increased resistance to extreme hypoxic, physical and psycho-emotional influences;

- assess the functional state of the body in order to warn about the presence of potentially dangerous health conditions, as well as to identify trends in changes in functional indicators for the correction of methods and programs of breathing and physical training, pressure chamber tests;

- increase the body's general non-specific resistance to the effects of extreme physical and psycho-emotional stress, including pressure chamber tests, and effective forced recovery after their effects.

The fundamental basis of the breathing simulator operation is the technology of non-drug effects of artificial breathing gas mixtures of oxygen with inert gases: oxygen-helium (OH), oxygen-argon-helium (OArH).

The uniqueness of the new pressure chamber complex, both as a whole and its main components, is worth noting. Firstly, most of the high-altitude pressure chambers currently in use were manufactured over 40 years ago. The creation of MHB can be considered a significant event, as it has restored the design and production technology for technically complex hypobaric pressure chambers. Secondly, a production base has been created and sustainable cooperation has been established between manufacturers for the production of the unique components and assemblies that comprise the pressure chamber complex.

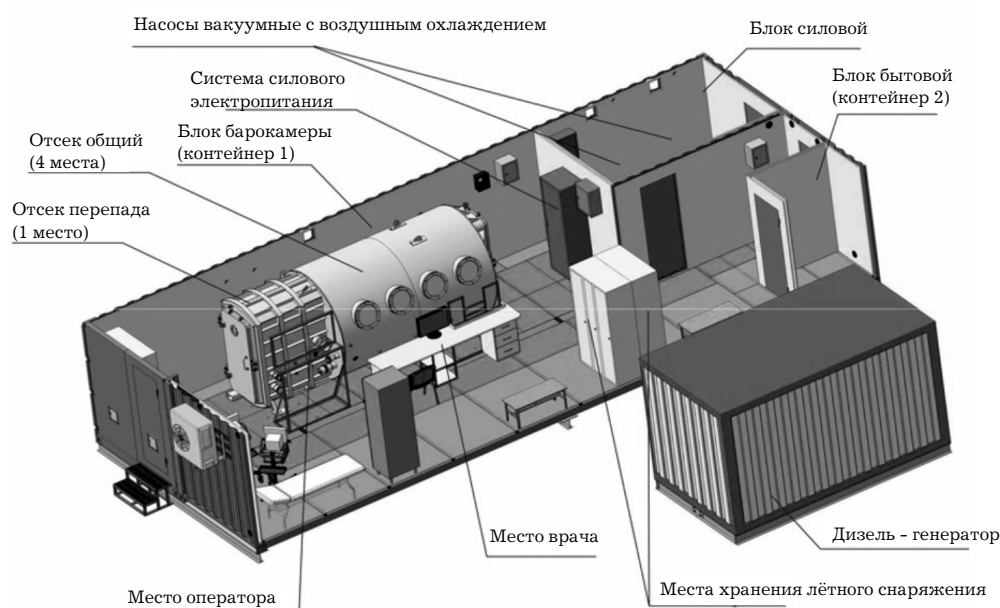


Fig. 5. The scheme of MHB «Edelweiss»

Рис. 5. Схема МГБ «Эдельвейс»



Fig. 6. Pressure chamber SVBK-30

Рис. 6. Барокамера СВБК-30



Fig. 7. Breathing simulator TD-1

Рис. 7. Дыхательный тренажер ТД-1

SVBK-30 hyperbaric chamber, part of MHB, is unparalleled in its technical solutions and equipment: high-performance vacuum pumps with low noise and vibration levels, updated ergonomics for test subjects' workstations, the ability to use standard pilot oxygen and protective gear for different types of aircraft, automation and redundancy of the chamber's control and monitoring systems, and objective technical and medical monitoring systems with the ability to store and

subsequently analyze the necessary data. For the first time in the naval aviation medical service, the TD-1 breathing simulator has been included in MHB.

The first module was put into operation in November 2017 at the Center for Combat Employment and Retraining of Naval Aviation Flight Personnel in Yeysk.

Following the commissioning of the module, the main advantages of the new barocomplex were highlighted:

- conducting interval breathing training aimed at developing the adaptive capabilities of the human body;
- simultaneous monitoring and recording in real time for each subject of heart rate, ECG, oxygen saturation, blood pressure, respiratory rate, body temperature;
- modular design based on standard sea containers, providing a certain mobility and freedom of placement, regardless of the terrain and the availability of special premises;
- recording necessary indicators of the body's condition in real time and the possibility of their subsequent processing;
- new prospects for scientific activity.

Since the Edelweiss MHB's commissioning, more than 700 tests have been conducted on the complex to test its tolerance to moderate hypoxia and barometric pressure fluctuations. The researchers used standard methods for altitudes up to 5,000 and 6,000 meters. In addition to flight

personnel, other military specialists also underwent psychophysiological training at the new decompression complex (Fig. 8).

In April 2020, for the first time in world history, there was a group airdrop of personnel using special-purpose parachute systems in Arctic conditions from an altitude of 10,000 meters, using oxygen equipment, followed by combat training missions. This had never been done before. Without prior specialized training, such jumps would have been impossible. It was at the Yeysk hyperbaric complex that the paratroopers underwent psychophysiological training, including altitude chamber ascents to test their tolerance to high-altitude hypoxia (up to 6,000 meters) and severe atmospheric rarefaction (up to 10,000 meters). It is worth noting that of 185 paratroopers scheduled for training, six specialists demonstrated reduced tolerance to moderate hypoxia, and 15 were not cleared for testing for medical reasons. A total of 154 personnel completed training in full. Thus, the measures taken to prepare military specialists for psychophysiology made it possible to carry out parachuting from high altitudes without harm to health and to maintain their combat readiness.

Regarding the chosen containerized design of the decompression system (Fig. 9), several details need to be clarified. At first glance, it might seem that the containerized design of the system is intended to ensure its mobility. This is only partially true. While the decompression system can indeed be moved from one site to another if necessary, this is often impractical. The main advantage of the containerized design of the decompression system in terms of mobility is its significant simplification of delivery from the manufacturer to the customer, as well as rapid installation and setup of the equipment at the destination.

The decision to use a container-based design was made considering the availability and condition of the barracks. The condition of the existing permanent buildings does not allow the full deployment of the barracks complex without major renovations or reconstruction. Furthermore, the construction of new buildings requires additional funding and the resolution of other related issues. The ability to locate the complex in an open area in any climate zone eliminates the need for additional new construction or major renovations of existing buildings.

Work is currently underway to commission the

Complex and launch it into serial production. In accordance with the 2024 updated concept for the development of medical support for naval aviation and the exclusion of aviation medicine laboratories from the fleets in favor of the “300 LAM,” we have decided to equip naval clinical hospitals (NCHs) with new decompression systems. By the end of 2026, the new system will be delivered to the Pacific Fleet, and subsequently, as production progresses, the remaining fleets will be equipped. This will address the problematic issue of psychophysiological preparation (pressure chamber studies and training) for high-altitude flights and medical examinations of flight personnel for the purpose of medical flight examination in the Navy, as well as implement certain provisions of the concept for the development of medical support for naval aviation units.

In addition to equipping NCHs with new hyperbaric systems, we also see prospects for developing hypobaric therapy for various diseases. The hospital’s multidisciplinary clinical facilities and the addition of a modern medical monitoring system to the hyperbaric chamber will enable the implementation of hypobaric therapy methods not only to preserve the professional health of flight personnel but also for the treatment process.

Hypobarotherapy is a physiotherapy treatment method that exposes patients to reduced atmospheric pressure. Unlike the more common hyperbaric oxygen therapy, this method simulates high-altitude conditions. As early as the 18th and 19th centuries, doctors noted that high-altitude residents suffered less frequently from certain ailments, and that spending time in the mountains helped with consumption (pulmonary tuberculosis). The main effects of this treatment method are well known: it increases red blood cell and hemoglobin levels, activates blood flow in tissues and organs, normalizes metabolism and hormonal balance, and reduces swelling and inflammation. Hypobarotherapy is often used for rehabilitation and disease prevention, as well as in training of athletes and certain specialists.

Hypobaric therapy methods have not gained widespread acceptance in aviation medicine for several reasons. The draft “Guidelines for Medical Support of State Aviation Flights (RMOP-200)” proposed, among numerous appendices, hypobaric and normobaric interval hypoxic therapy techniques. However, these techniques were not included in the final document “Federal Aviation Rules

for Medical Support of State Aviation Flights,” enacted by Order No. 265 of the Minister of Defense of the Russian Federation dated April 2009.

Meanwhile, the development of hypobaric therapy in aviation medicine has not stopped. Specialists at the Kirov Military Medical Academy have done extensive work studying the impact of hypobaric treatment methods on maintaining the professional health of flight personnel with various chronic diseases, and have developed and tested various hypobaric treatment

regimens and methods.

Clearly, there are new prospects for using low-pressure chambers in the Navy. Equipping the Naval Medical Group with Edelweiss-type hyperbaric systems will open up the possibility of their therapeutic and prophylactic use, not only to preserve the longevity of aviation specialists, but also to treat certain chronic illnesses in other categories of Navy personnel.

Discussion. The obtained results confirm the efficacy of using low-pressure chambers in the psy-



Fig. 8. Psychophysiological preparation before high-altitude landing in the Arctic
Рис. 8. Психофизиологическая подготовка перед высотным десантированием в Арктике



Fig. 9. Container version of the MHB «Edelweiss»
Рис. 9. Вариант контейнерного исполнения МГБ «Эдельвейс»

chophysiological training of aviation personnel and for conducting medical flight examinations. In today's environment, high-pressure chamber testing and research will continue to be a key element of aviation and space medicine. Without them, it will be impossible to fully address the diagnostic, training, rehabilitation, and scientific support needs of aviation personnel. The Edelweiss MHB complex possesses unique characteristics and has the technical potential for further improvement: the introduction of digital technologies, integration into the medical monitoring system, and expansion of diagnostic capabilities. MHB can be used to develop new psychophysiological training methods using the TD-1 breathing simulator and non-drug correction methods for treating certain chronic diseases at naval clinical hospitals.

Conclusion. As an analysis of historical and scientific documents shows, the use of low-pressure chambers has come a long way: from long-term observations of the effects of high-altitude conditions on humans in the 18th and 19th centuries, through the rapid development of high-altitude chambers and unprecedented physiological research in the interests of aviation medicine, to the cessation of the development of new low-pressure chambers, with only the previously

achieved level of this field being maintained. The creation of a modern hyperbaric complex like the MHB "Edelweiss" with the SVBK-30 hyperbaric chamber and the TD-1 breathing simulator opens a new chapter in the history of hypobaric hypoxic training and research for the psychophysiological preparation of aviation specialists.

Today, a hypobaric chamber is a high-tech medical complex equipped with automated control systems, objective medical monitoring, and real-time recording of physiological parameters. Their use allows not only to train and examine flight personnel, but also to conduct comprehensive scientific research.

Prospects for further development of hypobaric chambers are associated with the introduction of digital technologies, expansion of diagnostic capabilities, development of non-drug methods for correcting functional status and integration of pressure chamber complexes into a unified system of medical monitoring of aviation and space activities.

Thus, hypobaric chambers are one of the key elements of the aviation and space medicine system, providing solutions to the problems of diagnostics, training, rehabilitation and scientific support of the professional activities of aviation personnel.

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