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## THE CHERNOMOR-2 UNDERWATER OCEANOLOGY LABORATORY

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In the Summer of 1969 the P.P. Shirshov Institute of Oceanology of the USSR Academy of Sciences carried out a series of oceanographic investigations using the underwater laboratory of the Institute, CHERNOMOR-2. In the course of the investigations, a crew of four aquanauts stayed underwater at a depth of 25 meters for 14 days [1]. Decompression which was conducted directly in the underwater laboratory upon completion of the crew's activity lasted for 39 hours. In the process of conducting underwater investigations, divers from the crew spent 2.5 to 3.5 hours each in the water, outside of the laboratory, every day attending bottom measuring equipment. /2\*

The CHERNOMOR-2 underwater laboratory of the Institute (fig.1) was developed on the basis of the CHERNOMOR underwater laboratory [2]. In the development of the project, consideration was given to the knowledge gathered as a result of operating the laboratory in the period from May to September 1968, and to the volume and peculiarity of research activities planned for 1969. The planned scientific program made provisions for conducting research from the underwater laboratory at depths down to 30 meters.

To make the operation of the laboratory feasible at depths to 30 meters the principal requirements imposed on it were the following: the laboratory should be self-sufficient throughout the entire period of deployment (2 weeks) with respect to gas (oxygen, nitrogen, air), fresh water, mixture-regenerating cartridges, and if possible, power supply.

The operating conditions of the laboratory in the 1968 period made it possible to determine the optimal number of crew members (4 to 5 men) and the most effective duration of an underwater stay for a single crew (12 to 15 days). Precisely all this had determined the basic direction of the theoretical and design work to be done in the development of the CHERNOMOR-2 underwater laboratory. /3

HULL. The principal structural element of the CHERNOMOR-2 underwater laboratory, the hull, is a special cylinder with a diameter of 2.9 meters and length of 8.1 meters, made of steel 6 to 12 mm in thickness, and strengthened with 11 ribs. The 25-mm thick flat end

\* Numbers in the right margin indicate original pagination.

plates of the hull also have stiffeners. Five portholes, two on the left side and three on the right side of the hull, are equipped with inner steel hermetic dogs.

The decompression of the crew upon termination of the experiment is conducted directly inside the laboratory. In this case, the CHERNOMOR-2, after surfacing with secured hatches, has an internal pressure identical to the pressure it had at the operating depth. Therefore, in order to check for strength and tightness, the hull was pressurized through internal hydraulic pressure.

Outside the hull of the laboratory (fig.1) a number of systems and devices are mounted: two groups of ballast tanks with a total water ballast capacity of 5.2 m<sup>3</sup> designed for providing bottoming and surfacing capability for the laboratory and for creating buoyancy on the surface; a four-section fresh water tank with a total capacity of 2.8 m<sup>3</sup>; and a hopper with solid ballast. Battery holders and gas containers with compressed air and nitrogen are mounted on the head end plate of the CHERNOMOR-2. /4

There was a substantial change in the method of bottoming the laboratory. In the 1968 experiment, the CHERNOMOR was "soft landed" by means of releasable ballast suspended on cables through a system of pulleys under the bottom of the laboratory. In view of a number of design shortcomings of this system, it eventually became necessary to discontinue it. The impact of the CHERNOMOR-2 laboratory against the sea bottom is softened by means of a chain fastened to the lower part of the hull. The hydraulic supports of the laboratory make it possible to increase the distance from the skirt of the diver access trunk to the bottom from 0.75 to 1.2 meters.

Mounted on top of the CHERNOMOR-2 hull is a deck fitted with the following: a mast; an inlet block for electric cables, pneumatic lines, and communication cables; and a deck lock. The distance from the water surface to the edge of the hatch of the deck lock at full buoyancy of the laboratory is 0.6 meter. To prevent water from entering the laboratory during high seas, the hatch of the deck lock is protected by a steel superstructure, a canopy.

The deck lock is in the form of a vertical cylinder 1.9 meters in height and 0.8 meter in diameter with a wall thickness of 10 mm. Both ends of the cylinder carry tightly secured circular hatches; the cylinder is pressurized through internal pressure. The deck lock is used only when the laboratory is afloat and is designed for entering the laboratory both when there is normal pressure within the laboratory and when the inside pressure is higher than the atmospheric pressure. /5

The inside of the deck lock has lights and a telephone linking the lock with the instrument panel of the laboratory and the apparatus installed in the deck superstructure.

The useful space inside the hull with a height of 2.05 m, length of 7.8 m, and width of 2.7 m (fig. 2) is divided into three compartments: a diver compartment, living quarters, and sanitary space, all separated by watertight bulkheads. The living quarters are nominally divided into the sleeping and laboratory areas.

The diver compartment contains the diver access trunk, deck lock, assembly hatch, control and monitor panel for the pneumatic systems of the lock, a telephone, and a rack for stowing diving gear.

The laboratory area has a bench for working and keeping scientific and recording equipment, a cabinet containing the regeneration system, and a control and monitor panel for the laboratory systems.

Four bunks in the sleeping area are arranged in tiers, one above the other, on the right and left sides of the laboratory. Lockers beneath the lower bunks and a cabinet mounted on the back end plate are intended for stowing various household articles and personal items of the aquanauts.

Maintaining and monitoring the given gas composition of the atmosphere. Since the CHERNOMOR-2 laboratory is designed to support the crew for an extended period under high pressure, it is natural that special attention was given to the problem of developing the parameters of the artificial environment, and particularly, of the gas composition of the atmosphere. The atmosphere of the CHERNOMOR-2 underwater laboratory during its operation in 1969 at a depth of 25 meters consisted of 88% nitrogen and 12% oxygen by volume compressed to a pressure corresponding to the hydrostatic pressure at the depth of deployment. The required mixture composition was prepared in two steps prior to submersion with the laboratory on the surface: first, air was pumped to a pressure ensuring the required amount of oxygen, and then, nitrogen was pumped to the design pressure.

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The CHERNOMOR-2 regeneration system designed for maintaining the composition of the breathing mixture within the given limits consists of two subsystems: one for regulating the supply of oxygen and the other for absorbing carbon dioxide and harmful impurities. The oxygen is supplied to the compartment from two separate outboard gas storage containers through a metering device, with the amount of oxygen flow monitored by panel instruments. Carbon dioxide and a number of harmful impurities are absorbed by a filter-ventilator unit which includes

a series-connected filter with activated charcoal and an absorption cartridge with a lime chemical absorbent. The absorbent, without cartridge replacement, has a life of 7 days. The onboard supply of absorption cartridges ensures a three-week endurance. The accumulated carbon monoxide and other impurities are removed by a hopcalite cartridge.

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The air regeneration system of the CHERNOMOR-2 underwater laboratory during its operation at a depth of 25 meters maintained the parameters of the breathing mixture within the following limits (at the working pressure of the mixture):

$O_2$  - 10 to 30%  $\pm$  0.5%;  
 $CO_2$  - 0 to 0.2%; and  
CO - 0.005 to 0.015 mg/l.

The gas in the laboratory was analyzed by means of chemical analyzers. The PAK-3 analyzer was used to determine the oxygen content in the breathing mixture, and the level of  $CO_2$  was determined using the Holden analyzer with both of its burets filled for determining the  $CO_2$  content. The level of carbon monoxide and other harmful impurities was determined by the GKh-4 high-speed analyzer. In addition to analyzing the mixture directly in the laboratory, the gas environment of the CHERNOMOR-2 was constantly checked in a chemical lab of the shore base, for which purpose the crew periodically sent to the surface samples of the atmosphere taken in the internal spaces of the laboratory.

System for maintaining microclimate parameters. When the ambient sea temperature is lower than the temperature inside the laboratory, constant leakage of heat through the hull walls to the outside takes place. This leads to a disruption of the heat balance in the laboratory and necessitates additional power to maintain a comfortable temperature. In order to reduce this heat exchange with the environment, most of the inner surface of the hull is covered with heat insulation consisting of alternate layers of foam plastic (50 mm in thickness), wood sheathing (20 mm), and decorative sheathing (2 mm).

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The dehumidifying system of the CHERNOMOR-2 is based on the principle of cooling the breathing mixture until the excess moisture precipitates with the subsequent heating of the mixture to its original temperature. Calculations showed that in order to maintain a relative humidity of 75% to 85% in the compartment with the mixture temperature of 25 to 27°, the mixture has to be cooled to a temperature of 18 to 20° and then heated to a comfortable temperature. Since the water temperature

In the Black Sea at depths of 20 to 30 meters remains exactly within this range in the summer, it was decided to use sea water for cooling the mixture. Technically, the dehumidifying system operates as follows. The breathing mixture is drawn by an exhaust blower from the heat-insulated compartment into the space below the bilge ceiling. Since the hull in the space below the bilge ceiling does not have heat insulation over a rather large area, the mixture cools and the excess moisture condensates. The cooled mixture flows through the blower and heating unit and returns to the compartment. With a transmitting capacity of up to 300 m<sup>3</sup>/hour for the system, an average humidity of about 82% was maintained in the compartment.

The electric system of the CHERNOMOR-2 is designed for a total energy consumption of up to 5kw. It serves the following needs: lighting; electric motors for driving fans of the air regeneration and dehumidifying system; air heaters for the dehumidifying system; and water heaters for a fresh-water shower. All systems of the underwater laboratory requiring electrical energy are designed for 27 volts and may be operated with either d-c or a-c current.

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In addition, the laboratory carries 220-volt cables for operating the scientific equipment.

Under normal operating mode, the system obtains energy from the shore power line. Voltage of 220 volts supplied to the laboratory is stepped down to 27 volts by a transformer mounted on the upper deck and then applied to the control panel. The operator may supply at will either alternating current from the transformer or direct current from an on-board storage battery to the system.

The storage battery, which is placed on the outside of the laboratory and which consists of 5NKN-100 and TZhN-250 batteries with a total power capacity of about 75 kw-hr, is used as a d-c power supply. This energy reserve is sufficient for the normal operation of the laboratory system for a period of several days, which makes it possible, in case of the shore power line failure, to repair it without disrupting the normal working routine of the crew, for example.

The communication system consists of radio and wire equipment for telephone communication with the mother-ship and the shore support station. The control panel of the laboratory has a telephone, a switchboard for three parties, and a radio transmitter.

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The air and gas system is intended to support the underwater laboratory with oxygen, nitrogen and compressed air. The oxygen is supplied from twelve 40-liter cylinders (two containers with six cylinders each) to the compartment to maintain the given composition of

the breathing mixture. Nitrogen is kept in 500-liter cylinders and is meant not only for producing the breathing mixture, but also for the periodic purging of the outboard battery holders. Compressed air from four 400-liter cylinders is used for supplying air to divers, for purging the water ballast tanks, and for pressurizing fresh-water tanks. The on-board supply of air is sufficient to support the activities of two divers for 2.5 to 3 hours daily for a period of two weeks.

The sanitary and head facilities include the head, lavatory, and fresh-water shower. From a four-section tank located on the head and plate of the hull of the laboratory, fresh water is supplied with the aid of compressed air into a 500-liter service tank and a 120-liter hot-water tank. Two heaters with a total power of 2 kw heat the water in the tank to a temperature of 45° to 50°C. The tank is filled with fresh water through a filler neck on the upper deck prior to deploying the laboratory.

The successful completion of the 1969 scientific program with the use of the CHERNOMOR-2 underwater laboratory confirms the correctness of the chosen design of the underwater laboratory systems.

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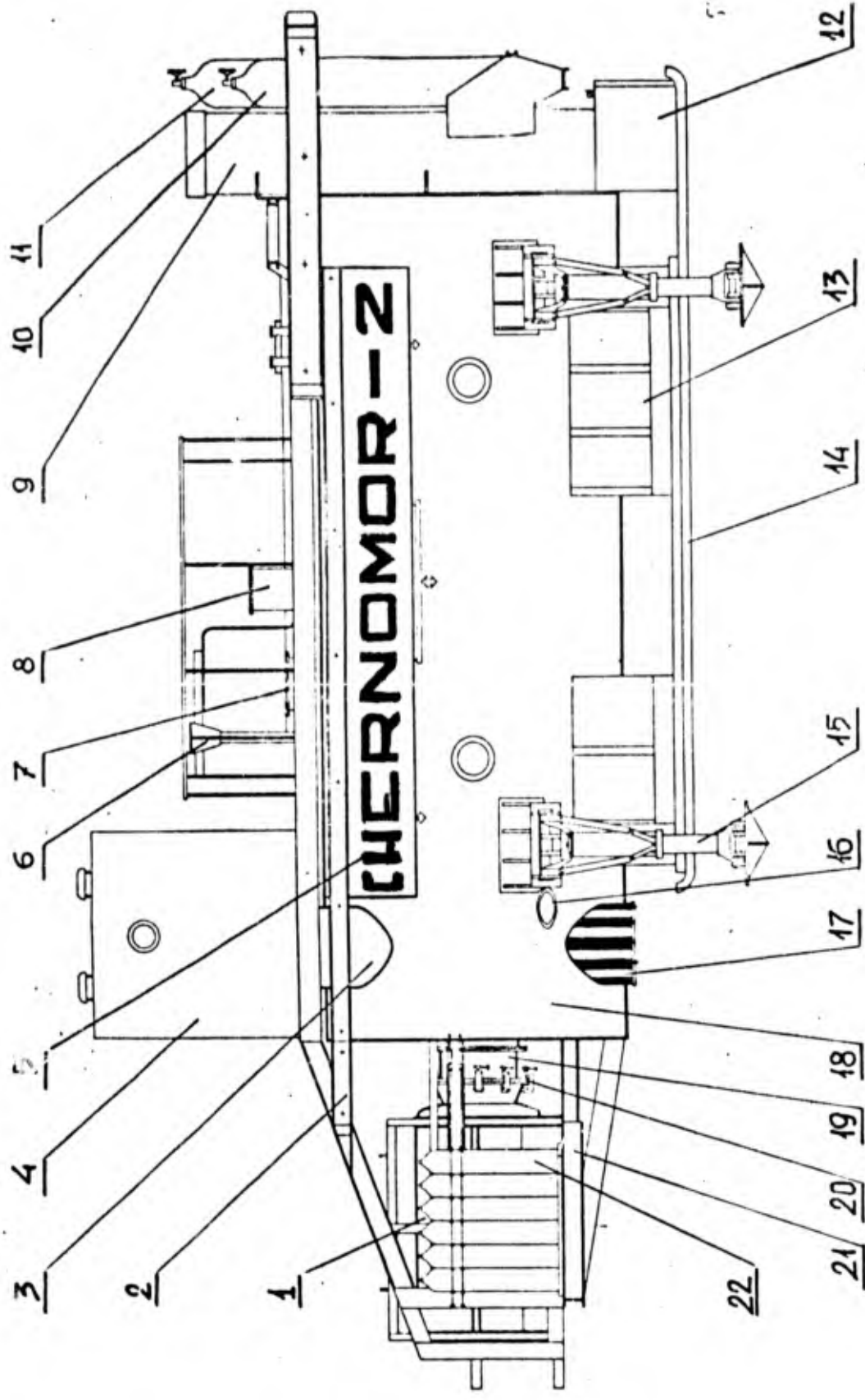


FIG. 1

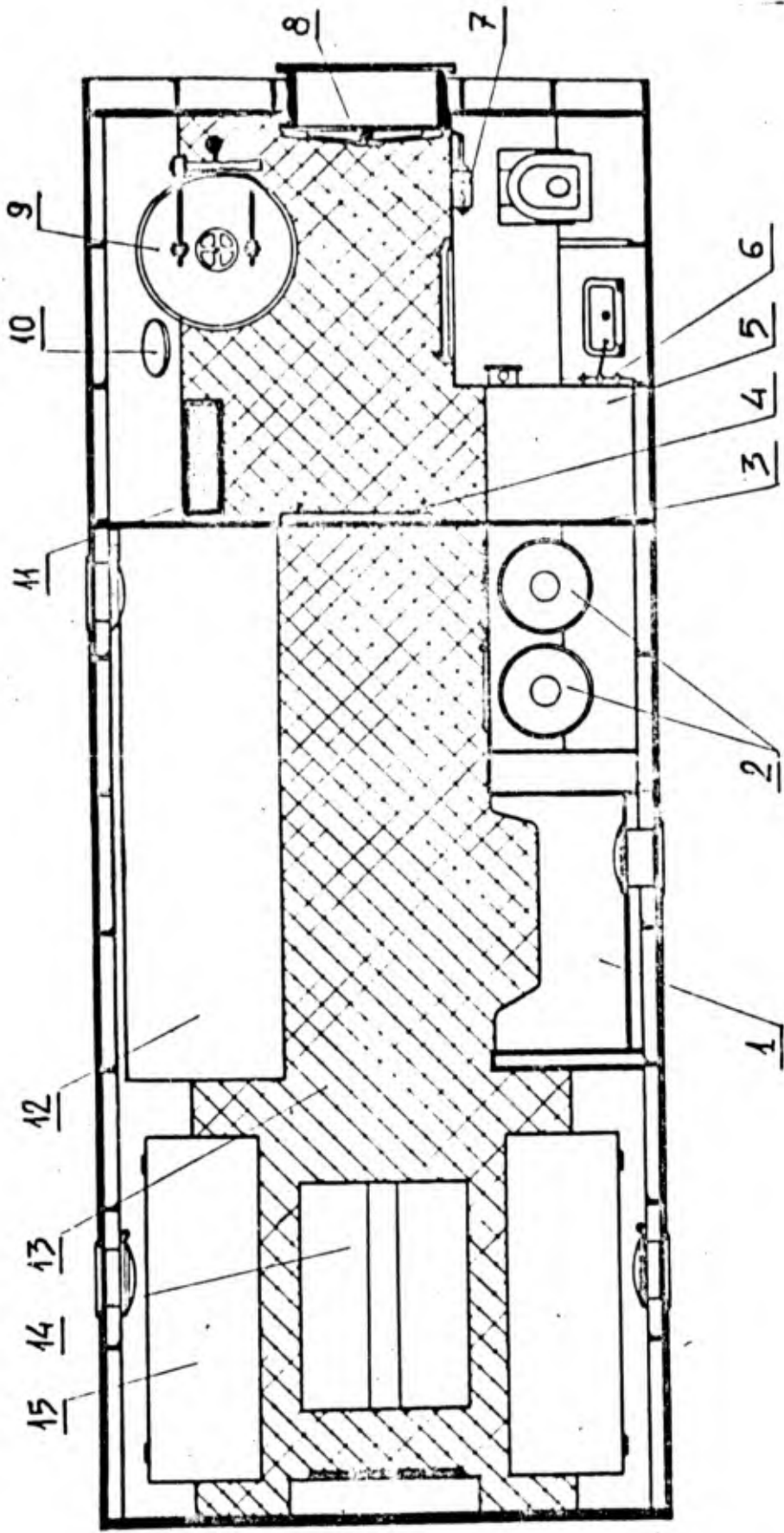


FIG. 2

Fig. 1. External view of the CHERNOMOR-2 underwater laboratory

- |                                 |   |
|---------------------------------|---|
| 1 - evacuation compartment;     | 12 - fresh-water tank;                          |
| 2 - guard rail;                 | 13 - hopper with solid ballast;                 |
| 3 - deck access trunk and lock; | 14 - "skis";                                    |
| 4 - cape;                       | 15 - hydraulic supports;                        |
| 5 - water ballast tanks;        | 16 - diver compartment porthole;                |
| 6 - mast;                       | 17 - diver access trunk;                        |
| 7 - inlet block;                | 18 - hull shell;                                |
| 8 - transformer;                | 19 - transfer lock;                             |
| 9 - battery holders;            | 20 - rapid-release connection between the       |
| 10 - air tanks;                 | evacuation compartment and transfer lock;       |
| 11 - nitrogen tanks;            | 21 - frame seat for the evacuation compartment; |
|                                 | 22 - oxygen tanks.                              |

Fig. 2. Interior of the CHERNOMOR-2 underwater laboratory

- 1 - working bench with a control panel for the watch member of the crew;
- 2 - breathing mixture purification system;
- 3 - bulkhead between compartments;
- 4 - bulkhead door;
- 5 - rack for stowing diving gear;
- 6 - sanitary space;
- 7 - bilge drainage pump;
- 8 - assembly hatch;
- 9 - hatch for the diver access trunk;
- 10 - porthole;
- 11 - air heater of the dehumidifying system;
- 12 - laboratory bench;
- 13 - bilge ceiling;
- 14 - collapsible table in the crew space;
- 15 - bunk.