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UNDERWATER ACTIVITIES IN THE SOVIET UNION

Lee H. Boylan

Informatics, Incorporated

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San Diego, California  
19--20 November 1974

by

Lee H. Eoylan  
Informatics, Inc.

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## INTRODUCTION

The purpose of this paper is to review significant past, present, and future development of undersea research vehicles by the Soviet Union, and to provide as much insight as possible into the safety and support aspects of the operation of these vehicles.

Since 1965, the author has attempted to collect as much open-source information as possible on Soviet and East European developments in undersea research vehicles, underwater laboratories and habitats. Although over 800 references were available for this report, this obviously does not represent the total published literature. The reader is cautioned, therefore, that the information contained in this paper is based solely on sources available to the author. It is very probable that other information pertinent to the Workshop theme has been published in the Soviet Union, but it is simply not readily available in the U. S. It should be noted that following the discussion of each vehicle a numerical listing of references to that vehicle has been included. Not all of the citations in the bibliography are referenced in the article; however, it is felt that all the citations contain meaningful information on submersibles, either in the form of discussion or illustrations.

Since the completion of the original paper in November 1974, additional information has become available which either clarifies or expands on earlier information. The revisions affect the following items: Okcaniya, the Atlant-2 towed vehicle, the Tetis towed vehicle, Kal'mar, and the section on diver transfer systems.

The author welcomes any opportunity to discuss or exchange information on Soviet and East European submersible development, in the hopes that deeper specific knowledge of developments in those countries will advance man's ability to work safely and economically on and under the sea.

Lee H. Boylan  
March 1975

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## PART I. SIGNIFICANT ASPECTS IN THE HISTORY OF SOVIET SUBMERSIBLE DEVELOPMENT\*

If one requires a point in time to which to attribute the official beginning of Soviet submersible development, then 17 December 1923 stands out as the best date. On that date, Lenin signed into law a decree founding the EPRON\*\* diving and salvage organization, with F. I. Krylov appointed its first director. The first project undertaken by EPRON was the construction of the Danilenko diving chamber to be used in an attempt to salvage £2,000,000 in gold rumored to be lying on the bottom of Balaklava Bay. No gold was found, but Soviet submersible development was under way.

From 1923 to 1941, EPRON flourished as an organization and published a very respectable journal entitled Epron. During the war, EPRON was renamed the Main Military River Administration, and was responsible for explosive ordnance disposal and salvage in the USSR's extensive system of rivers. After the war, this organization was absorbed by the Podvodrechstroy\*\*\* organization of the Ministry of the River Fleet to work on reconstruction of the war-damaged inland navigation system.

In the 1930's, Soviet interest in deep submergence seemed to increase. More and more articles on medical research involved in increasing the depth limits for hard-hat divers began appearing in Epron. An interesting sidelight in this respect was that the last article written by K. E. Tsiolkovskiy, the father of Soviet astronautics, was on the calculation of the depth limit of a deep submersible. Tsiolkovskiy died before he had a chance to approve the final edit of his article.

Later, in 1937, Yu. A. Shimanskiy, a full professor, a Corresponding Member of the Soviet Academy of Sciences, and a member of the editorial staff of Epron, published an article on the design of an un'ethered submersible intended for depths to 2500 m. The seriousness of the Shimanskiy project can be attested to in part by the fact that Academician A. N. Krylov was project consultant. It is not fully known why Shimanskiy's submersible was not built; however, the impending war was probably the determining factor. Shimanskiy eventually went on to become one of the foremost specialists in the theory and methods of calculating the strength of hull structures.

Historically speaking, the failure to build the Shimanskiy submersible either before or after the war could be considered the turning point in Soviet submersible development. Had this submersible been built, the Soviets would have had an impressive early lead in deep submergence and, influenced by the heady wine of success, Soviet submersible development could well have taken on different proportions than those to be reviewed below.

\* Revised and abridged from: Boylan, L. Soviet-Bloc Submersible Development. Marine Technology Society Journal, v. 3, no. 2, 1969, 21-44.

\*\* Ekspeditsiya podvodnykh rabot osobogo naznacheniya - Expedition for special-purpose underwater operations

\*\*\* probably, Podvodnoye rechnoye stroitel'stvo --[Administration for] Underwater Construction in Rivers



While the Shimanskiy submersible was not built, the concept lived on and was eventually embodied in a low-mobility vehicle called Gvidon, which made its appearance in 1970-71.

In the post-war period, revived interest in submersibles began to emerge in the late 1950's, with the conversion of the research submarine Severyanka and the designing of the Sever-1 (GG-57) diving chamber. Articles began to appear in Soviet newspapers and journals on plans for the development of bathyscaphs and other deep submergence vehicles. By the mid 1960's, a number of vehicles were on the drawing boards, and one, Sever-2, had a promised delivery date of 1965-66. This vehicle was finally delivered in mid-1971.

The most prominent group involved in submersible design is Giprorybflot\*, headquartered in Leningrad, with a branch in Klaipeda, Lithuania. This organization was established in 1931 and eventually was responsible for the designing of many research vessels and a number of the vehicles and submersibles to be discussed throughout this review. With few exceptions, Giprorybflot acts only as a design function responding to the requests of fisheries and oceanography oriented institutions throughout the Soviet Union. It evidently has no voice in establishing priorities or construction schedules for the vehicles under design.

In the late 1950's and early 1960's, many articles on Western achievements in submersible developments appeared regularly in Soviet publications. This served to forcibly demonstrate the development gap existing between the Soviet Union and the West in the area of undersea vehicles. In an attempt to coordinate research and design facilities involved in Soviet penetration into the sea, on 14 April 1960, the Oceanographic Commission of the USSR Academy of Sciences established the Section for Underwater Research. Since its founding, the Section has sponsored a number of conferences devoted primarily to the development of undersea research vehicles and habitats. However, despite its impressive list of members and stated goals, it too seems to lack the decision-making capacity that will take a vehicle off the drawing board and put it in the water. This is not so true for the Section's coordinating ability in developing and supporting habitat and sealab programs.

So far, we have looked briefly at the growing pains of Soviet undersea research vehicle development. Before reviewing the inventory of operational Soviet undersea vehicles, it might be worthwhile looking at a few milestones in this development area. The vehicles described below represent the state to which Soviet submersibles have developed over the past 50 years and vehicles planned for the future. In some instances, the information on a given vehicle, available from many sources, is somewhat contradictory. Therefore, in these cases, we have tried to present that information which appears to be most generally accepted or logical.

---

\* Gosudarstvennyy proyektnyy institut rybopromyslovogo flota -- State Planning Institute of the Fishing Fleet



### A. Danilenko Tethered Diving Chamber

In 1923, the EPRON diving and salvage organization built the Soviet Union's first diving chamber (see Fig. 1). It was designed by engineer G. I.

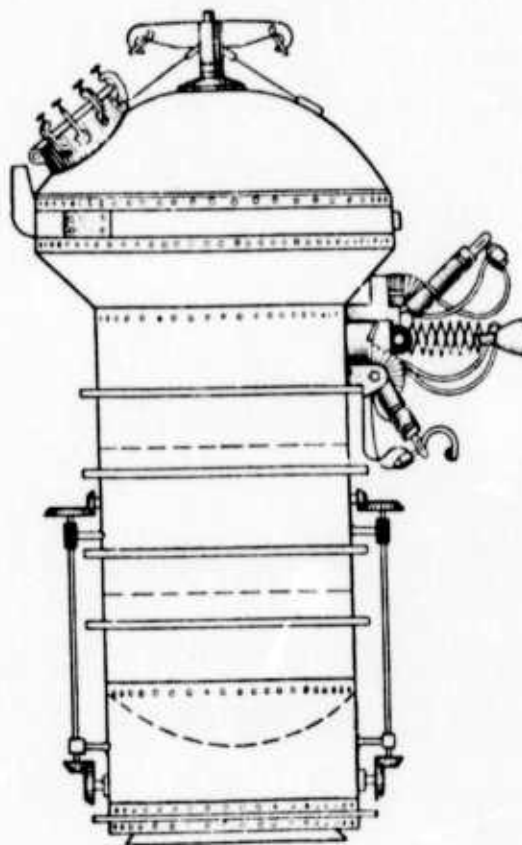


Fig. 1. Danilenko Diving Chamber [84].

Danilenko and is reported to have been capable of accommodating up to three observers at one time. The hull consisted of a riveted cylinder with spherical ends, incorporating a single view port and external lighting. External manipulators consisting of pincers and levers were controlled from within the chamber by the operator. In case of emergency, ballast in the lower part of the chamber could be jettisoned by the operator. This was most probably provided by the system of gears and rods shown on the lower half of the chamber in Fig. 1. This chamber was first used in a salvage operation organized by EPRON to recover £2,000,000 in gold which had supposedly gone down with the British vessel Black Prince in Balaklava Bay during the Crimean War. The vessel was found, but no gold was aboard. Later, the Danilenko chamber was used in salvage work at depths to 150 m in the White Sea. In 1931, it was used to locate the Rusalka, which had gone down in 1893 in the Gulf of Finland. This was the last reported use of the Danilenko diving chamber [31, 35, 36, 43, 84, 178, 229, 392, 646, 753, 755].

B. Articulated Hard Suit

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The photograph shown in Figure 2 appeared as an insert between



Fig. 2. Soviet Diver in Articulated Hard Suit [101].

two articles in a 1936 issue of the salvage and diving journal Epron. This photo and another appearing 120 pages later showing the assembly of the hard

suit by EPRON personnel are not referred to in any of the articles in the journal. One article in the journal does mention, however, that in 1929, the British Admiralty acquired an articulated hard suit from the Germans for testing. Due to poor watertight integrity and diver mobility, the British found the suit unsuitable for the quick, dexterous activity required of a rescue diver.

In 1959 and 1964 editions of their book Conquest of the Depths, Diomidov and Dmitriyev describe a 450-kg hard suit apparently developed by two Germans named Neufeldt and Kunke (see Fig. 3). This suit has a

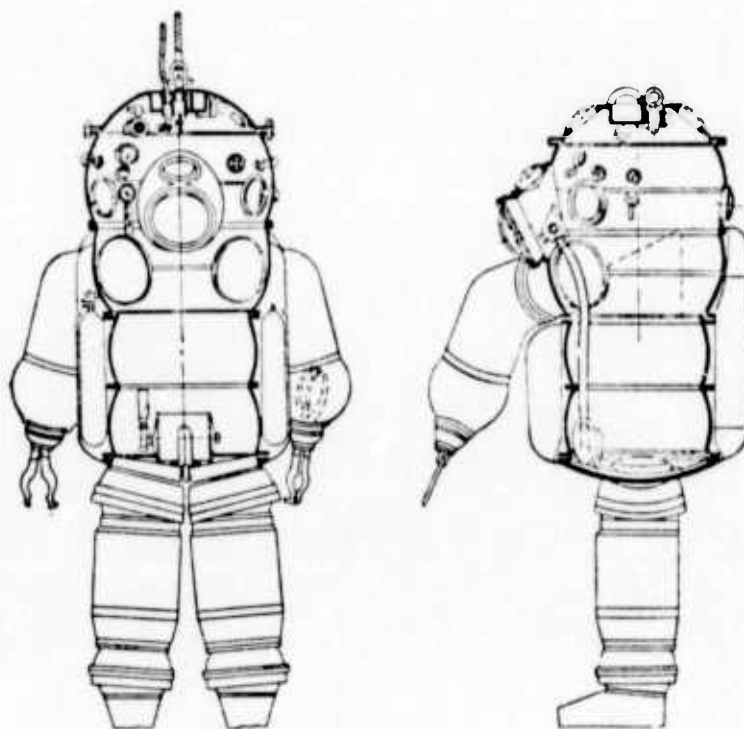


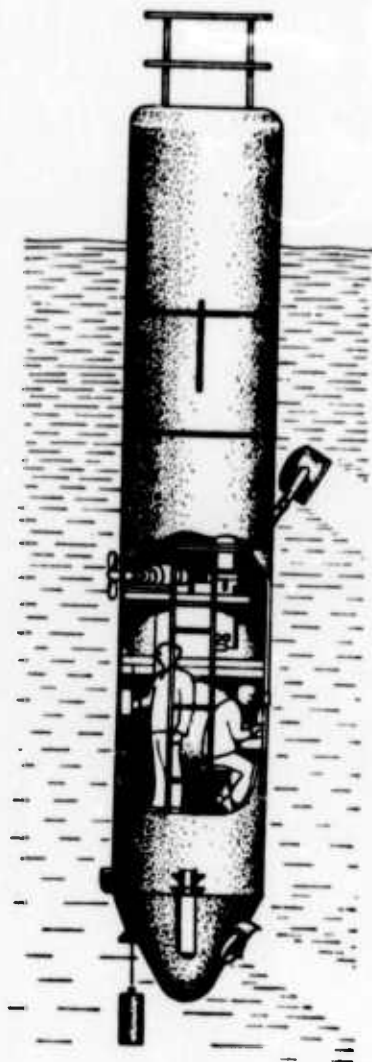
Fig. 3. Neufeldt and Kunke Articulated Hard Suit [37].

1 - Hoisting-cable release; 2 - telephone-cable release; 3 - microphone; 4 - air-bottle pressure gage; 5 - suit air inlet valve; 6 - thermometer; 7 - air bottle valve; 8 - air bottles; 9 - depth gage; 10 - ballast blowing valve for rear tank; 11 - ballast blowing valve for front tank; 12 - valve for air release from front and rear ballast tanks; 13 - light outer hull; 14 - flexible tubing 15 - chemical CO<sub>2</sub> absorber; 16 and 17 - rear and front water-ballast tanks.

rated depth capability of 150 m. With two exceptions (the straight, tubular arms and legs), the suit bears a striking resemblance to the one in Fig. 2. While it cannot be stated positively that the suit in Fig. 2 is of Soviet manufacture, it was definitely a part of their inventory of diving equipment, and probably gave the Soviets a diving capability of about 150 m in the late thirties [36, 37, 101].

### C. Shimanskiy Submersible

The most noteworthy of early Soviet attempts at submersible development was the design for a two-man, 10.5-ton untethered vehicle (see Fig. 5) designed by Yu. A. Shimanskiy in 1937 and intended for



#### Specifications

Pressure-hull diameter . . . . .	1.4 m
Height . . . . .	9.15 m
Displacement . . . . .	10.5 tons
Rated depth . . . . .	2500 m
Crew . . . . .	2--4
Life-support endurance . . . . .	10 hr
Speed . . . . .	0.3 m/sec
Pressure-hull volume . . . . .	8.6 cu m

Fig. 4. Shimanskiy Submersible [35].

operation at depths to 2500 m. Unfortunately for the Soviets, this submersible was not built. The pressure hull of the Shimanskiy submersible is in the form of a long cylinder with cones tapering into round caps at the upper and lower ends. The upper end is covered with a cylindrical structure which provides buoyancy and stability while on the surface. Storage batteries are located in the lower part of the hull, below the observers' compartment. As shown in Fig. 4, one man sits and performs visual observations through the view port. From this position, he can control the horizontal, vertical, and rotational propulsion systems. The submersible can descend at a rate of up to 2.2 m/sec; maximum ascent rate is 4.0 m/sec. Horizontal and rotational speeds are

0.3 m/sec and 45 deg/min, respectively. A 2-hp electric motor provides horizontal propulsion up to a distance of 3 km. Rotation is imparted by a large flywheel on a vertical axis, driven by a 0.4-hp electric motor. Both liquid and solid ballast are used to control vertical motion, and a 100-m-long guide rope with a 100-150 kg anchor prevents impact on the bottom. Buoyancy is controlled with a variable-ballast system, and two 150-kg weights can be jettisoned to increase the ascent rate.

Under normal conditions, the life-support system would maintain two observers for 10 hours. However, the number of observers could be increased to four and the endurance to several days.

Visual and photographic (still and motion-picture) observations can be conducted through two or three view ports, with lighting provided by two external illuminators and a strobe light. Little is known about the kinds of instruments and equipment that were to be carried in the Shimanskiy submersible; however, one Soviet source states the research equipment aboard was to weigh 600 kg. Radio and other signalling equipment was to be carried also [35, 84, 96].

#### D. Severyanka

As one of the world's first conventional fleet submarines converted for scientific research work, the Severyanka has attracted some world-wide attention and has been written up fairly well in both Soviet and Western literature. What follows will be limited primarily to the history and efforts involved in the Severyanka's conversion.

On 20 April 1957, the Ministry of Fisheries granted its final approval for the transfer of a fleet submarine to the All-Union Scientific Research Institute of Marine Fisheries and Oceanography, to be converted and recommissioned as the research submarine Severyanka (see Fig. 5).

Concurrent to the conversion work, the specially created Laboratory for Underwater-Research Equipment began work on several instruments and systems to be installed on the Severyanka. These included a photometer, the "Termosolemer-2" salinity-temperature-depth measuring system, and an underwater television unit. Adaptation of other existing equipments to the Severyanka's requirements was also undertaken at this time.

Regarding the Severyanka herself, almost all of the conversion work was done in and around the forward torpedo room. The port and starboard tubes and associated equipment were removed and were replaced with view ports; another view port was installed in the overhead. All three ports are 130 mm in diameter, 30 mm thick, and consist of two parallel plates of optical glass mounted in the pressure hull. The side view ports are canted 15° downward, while the overhead port looks directly upward. A truncated cone with a 90° angle leads from the outer flange of each view port through the main ballast tank to the outer hull or deck in the case of the overhead port. The view ports and seals were tested to 65 atm. The overhead port also has a mirror attachment which can be mounted at a 45° angle to the deck, thus



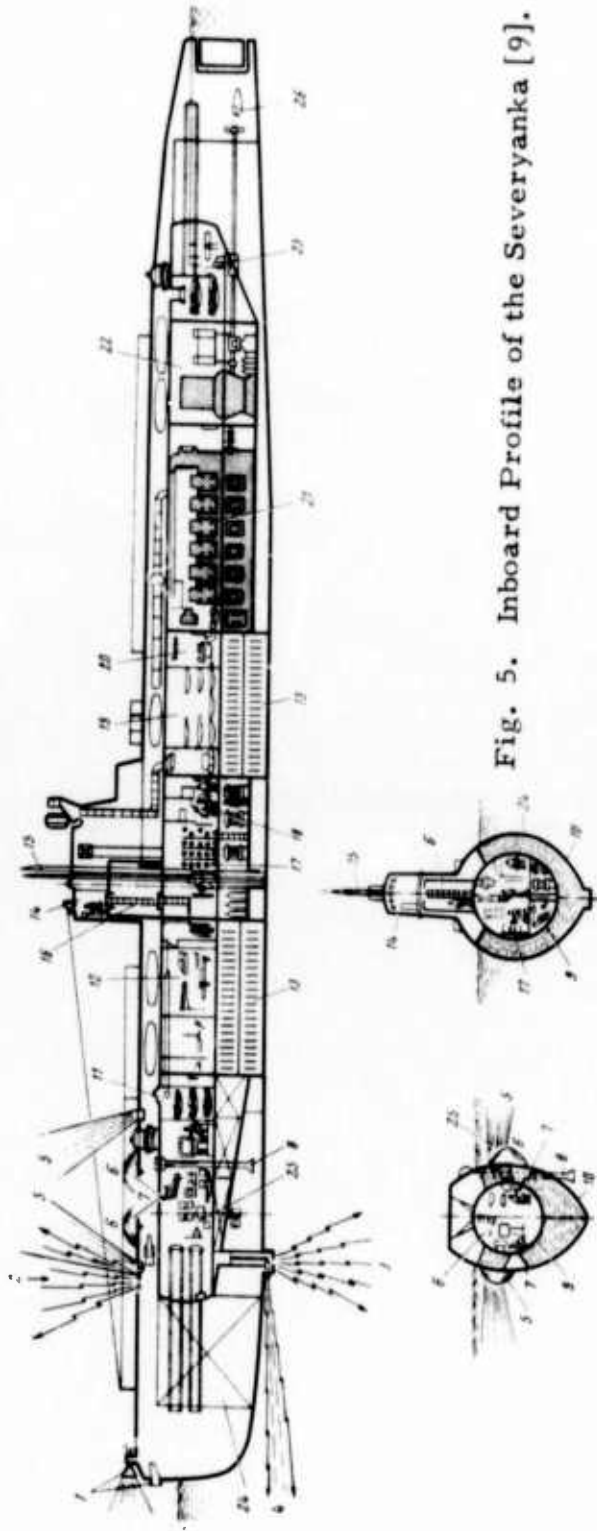


Fig. 5. Inboard Profile of the Severyanka [9].

1 - Floodlight and underwater TV camera; 2 - up-looking echo sounder; 3 - lower echo sounder; 4 - sonar; 5 - long-range illuminators; 6 - short-range illuminators; 7 - view ports; 8 - corer and housing; 9 - pressure hull; 10 - outer hull; 11 - forward sleeping quarters; 12 - wardroom and mess; 13 - storage batteries; 14 - bridge; 15 - periscopes; 16 - conning tower; 17 - control room; 18 - sonar room; 19 - sleeping quarters; 20 - galley; 21 - engine room; 22 - motor room; 23 - stern compartment; 24 - main ballast tank; 25 - research compartment; 26 - stern planes.



### Specifications

Class (former). . . . .	W III seagoing patrol
Length, o. a. . . . .	73 m
Weight . . . . .	1180 tons
Operating depth (max) . . . . .	180-200 m
Pressure hull length . . . . .	60 m
Beam, maximum. . . . .	4 m
Height . . . . .	7 m
Speed surfaced (diesel) . . . . .	17 kts
Speed submerged (electric) . . . . .	14 kts
Range (combat) . . . . .	16,500 miles
Ship's complement (combat) . . . . .	60

providing viewing forward. At each port there is a movable mount for a still camera or a motion-picture camera. Each port has lights for long- and short-range illumination. Prior to Severyanka's 5th cruise, a 4-m-long removable boom fitted with a PPS-1000 floodlight was developed to improve viewing from the starboard observation port. Before submerging, this boom is rigged out from a mounting on the deck.

One interesting innovation on the Severyanka was the mounting of a TV camera in the bow. A TV camera was used since the distance between the pressure hull and the stem made it impossible to add another view port. The camera used is a "3/80" modified by VNIRO for underwater use. The viewing angle is 60° and the receiver is located in the forward compartment. Illumination for the camera is provided by another SG-1000 light.

One of the other major modifications was the addition of a shaft on the port side for housing the GOIN-3 corer which is suspended on a line in the shaft. Core samples are taken as the sub hovers 20-25 m above the bottom. The corer is operated from the forward compartment.

Besides the Severyanka's regular acoustic systems (active sonar, passive sonar, and a navigational echo sounder), two NEL-5r fish-finding sonars have been installed aboard as echo sounders. One has its transducer mounted topside with the pattern directed upwards. The display and recorder units for these sounders are in the forward compartment. The other sonars and sounders are operated from the control room. The up-looking echo sounder is also used to study waves and to control running depth within close limits.

Other laboratory equipment includes a current meter and equipment for measuring sea-water radioactive contamination, dissolved oxygen content, and phosphorous content. Water samples for hydrochemical analyses are taken through a valve penetrator in the research compartment. Eight extra sealed hull penetrations are incorporated into the redesign should additional outboard sensors be required at any time.

With reference to Figure 5, a Polish model-building magazine [442] published a set of plans for building a scale model of Severyanka. As can be seen in Figure 6, these plans differ slightly from the design commonly accompanying Soviet articles on Severyanka.

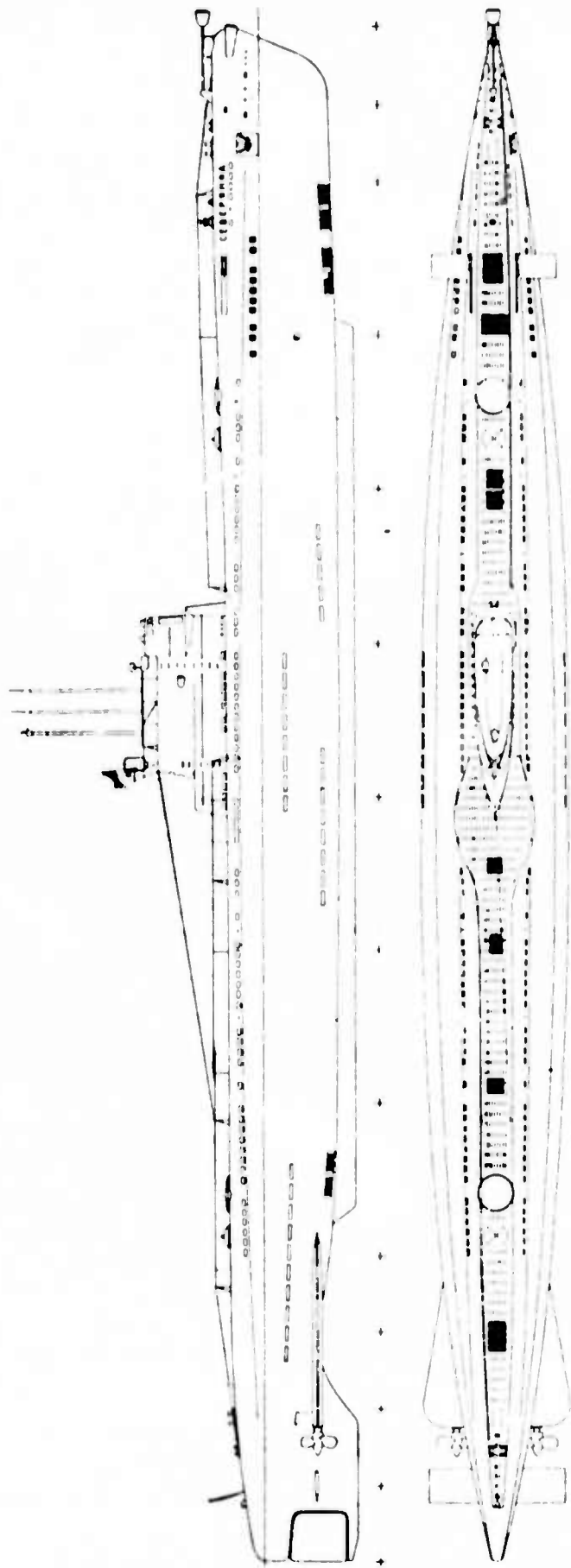


Fig. 6. Polish Plans for Model of Severyanka [442].

Despite the Severyanka's relatively large size (pressure-hull length-60 m), the maximum number of scientists which reportedly can be accommodated is six. Since becoming operational on 30 November 1958, the Severyanka has made ten cruises. Perhaps the most interesting paper [134] resulting from two-years operation of the Severyanka is a blow-by-blow description of what a research submarine should be capable of and how it should be equipped [8, 9, 31, 35, 44, 45, 58, 59, 84, 111, 125, 134, 135, 148, 168, 170, 171, 172, 178, 223, 247, 381, 404, 430, 442, 443, 554, 607, 645, 646, 651, 746, 750, 752, 753, 755].

#### E. Vega

In mid 1970, a Krasnaya Zvezda (Soviet armed-forces newspaper) article [796] carried the announcement that the Vega, a hydrographic submarine, had returned to the Soviet Far East from an 8-month, 32,000 nm research cruise which included stops in two non-Soviet ports, one of them at the island of Mauritius. The Vega returned for repairs to a fleet submarine base at (or near) Vladivostok, following a 249-day cruise which covered more than 31,000 nm. Accompanying the Vega were the tanker Dunay and the motor-ship M. Uritskiy. The surface ships were used for resupply purposes, although it is mentioned that there were scientists aboard both. Rear Admiral S. S. Khomchik commanded the three-ship squadron, of which the Vega was the flagship. The Vega operated primarily in the Pacific and Indian Oceans; it is mentioned that she cruised in eight seas, crossed four climatic zones, made two crossings of the Equator, and spent a great deal of time in the "Roaring Forties." During the cruise, continuous bathymetric profiling was conducted.

During the Indian Ocean portion of the cruise, a number of severe storms and cyclones were encountered. In one, the Vega heeled to 50° in 160 m/sec winds. Pieces of the outer hull were torn off and superstructure fittings were damaged.

Besides the hydrographic missions of the Vega, emphasis is put on the amount and value of the hydrometeorological information gathered on the Pacific and Indian Oceans.

None of the references reviewed gives any physical description of the Vega and, although operational in 1970, she is not listed in the 1972-73 Jane's Fighting Ships which does have a section on surface and subsurface research vessels. However, Jane's does list another submarine, the Slavyanka, reported to be a sister ship to the Severyanka. This has yet to be confirmed in the open literature. The Slavyanka is stated to be a converted Whiskey-class fleet submarine. Since the Whiskey-class appears to be popular as a conversion, it is possible that the Vega also is a Whiskey-class sub which has been refitted and transferred to the Soviet Navy's Hydrographic Service.

Extensive review of Soviet open literature from late 1970 to present has yielded no additional information on the Vega or its activities. Since the ship is obviously a Soviet Navy Hydrographic Service vessel, it is not to be expected that relevant information would be in profusion [796, 797].

F. Sever-1 (GG-57) Tethered Diving Chamber

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In 1957, the plans for the design of the GG-57 diving chamber (see Figs. 7 and 8) were completed for PINRO\* by Giprorybflot, under the supervision of P. I. Serdyuk. This chamber later became known popularly as Sever-1. The basic design (see Fig. 9) consists of two cylinders joined by a truncated cone, five view ports, and a "piano stool." In September 1959, news of the completion of Sever-1's construction at Baltiyskiy Shipyard in Leningrad first appeared in the Soviet press.



Fig. 7. Sever-1 Tethered Diving Chamber [34].

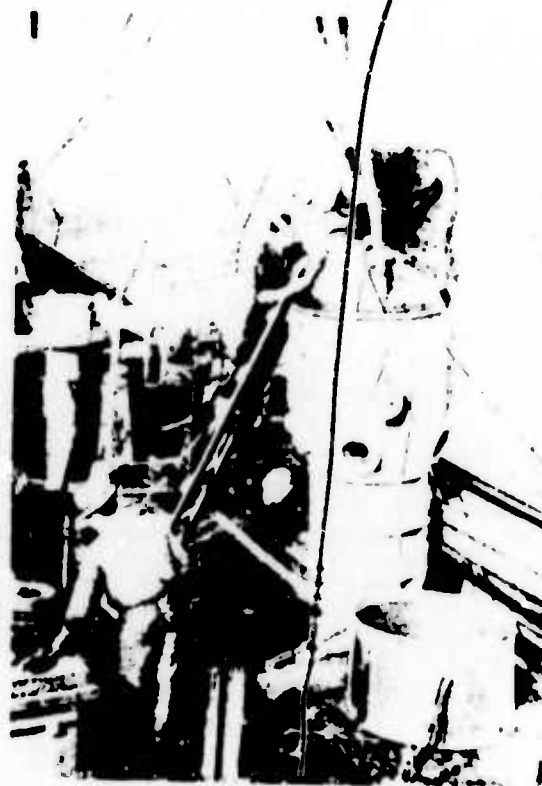


Fig. 8. Sever-1 on Deck of Support Ship Tunets, with Cylindrical "Cradle" in Lower Right Foreground [73].

The Sever-1's hull is additionally stiffened with rings and ribs, and the stresses calculated for the critical points for a hydrostatic pressure of  $78 \text{ kg/cm}^2$  do not exceed 80% of the hull-material yield-point value. A special test chamber was built to test the components and vehicle for strength and watertight integrity. The access hatch, view ports, and cable penetrations were tested to  $100 \text{ kg/cm}^2$ , and the illuminators, strobe light, and photometer were

\* Polyarnyy nauchno-issledovatel'skiy i proyektnyy institut morskogo rybnogo khozyaystva i okeanografii -- Polar Scientific Research and Planning Institute of Marine Fisheries and Oceanography.

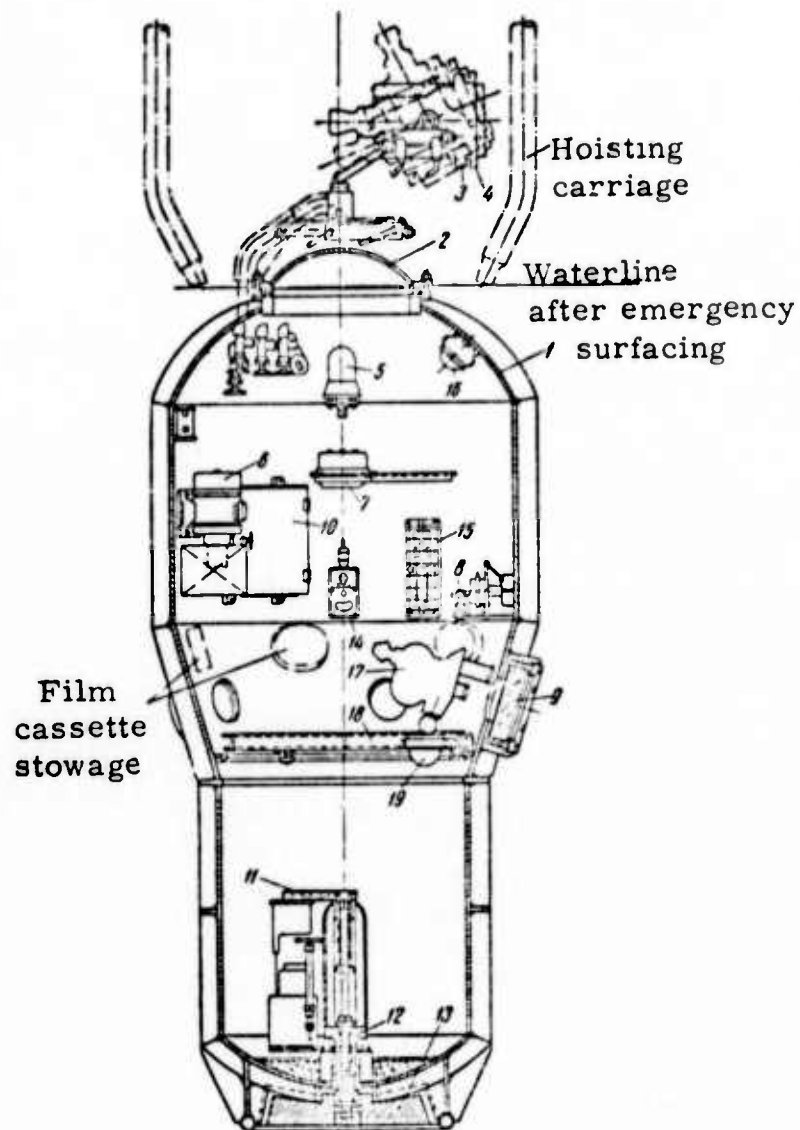


Fig. 9. Inboard Profile of Sever-1 Tethered Diving Chamber [33].

1 - Welded alloy steel pressure hull with external rib stiffeners; 2 - access hatch; 3 - rotatable illuminator unit; 4 - photoflash light; 5 - tether release mechanism; 6 - electric oil pump for hydraulic drive of illuminator rotation system; 7 - electromagnetic compass; 8 - compass repeater; 9 - view port; 10 - electric switchbox; 11 - rotating stool; 12 - emergency ballast release; 13 - emergency ballast (iron plate); 14 - photometer scale; 15 - Forel-Ule scale; 16 - interior light; 17 - movie camera; 18 - circular camera track; 19 - rolling camera-mount clamp.

## Specifications

Height . . . . .	3.25 m
Weight with iron ballast and float . . . . .	2368 kg
Upper hull diameter, i. d. . . . .	1.10 m
Lower hull diameter, i. d. . . . .	0.80 m
Maximum diameter across ribs . . . . .	1.25 m
Rated depth . . . . .	600 m
Maximum safe submergence depth. . . . .	750 m
Crew . . . . .	1
Life-support endurance . . . . .	6 hrs
Volumetric displacement during emergency surfacing. . . . .	2.21 cu m
Positive buoyancy during emergency surfacing. . . . .	70 kg
Normal negative buoyancy . . . . .	103 kg
Iron ballast weight. . . . .	246 kg
Access hatch diameter. . . . .	450 mm
View ports . . . . .	5
View-port diameter . . . . .	140 mm
View-port thickness . . . . .	60 mm
Hull material . . . . .	SKhL-4 alloy steel
Hull-steel yield point . . . . .	4000 kg/cm <sup>2</sup>
Hull thickness. . . . .	12 to 16 mm
Initial metacentric height surfaced, without iron ballast. . . . .	0.06 m
Research-equipment weight. . . . .	60 kg

subjected to 70-75 kg/cm<sup>2</sup>. The assembled chamber with an occupant was finally tested at 60 kg/cm<sup>2</sup>. The five view ports mounted in the transition cone have a 15° downward angle from the vertical. Quartz glass (40 mm thick) and optical glass (60 mm thick) were tested for the view ports, but plexiglass was eventually used. A circular track running below the view ports holds a rolling camera mount which facilitates quick switching of a still- or motion-picture camera from one view port to another. Two loudspeakers also are mounted on the inside of the pressure hull.

A special electrical cable housing four power conductors and two telephone conductors was developed for Sever-1. This cable has a breaking strength of 1000 kg and is capable of hoisting Sever-1 to the surface should the main tether snap. For an emergency ascent, this cable is severed near the hull penetration, and it will keep its lengthwise watertight integrity up to pressures of 70 kg/cm<sup>2</sup>. The tether consists of a 25-mm-diameter wire rope fitted with a spring-type shock absorber.

The research and environment control equipment in Sever-1 include the following: 1) a photometer (visible in Fig. 8) for measuring horizontal illumination; 2) a Forel-Ule water-color scale for visual comparisons; 3) a thermometer; 4) a gas analyzer for determining O<sub>2</sub> and CO<sub>2</sub> content in the chamber; 5) a psychrometer for determining humidity; 6) a barometer; 7) a depth gage; 8) a still camera; 9) a movie camera; 10) a gimbal-mounted electro-magnetic compass centered in the vertical axis of the chamber; 11) an air regenerator for absorbing CO<sub>2</sub> and generating O<sub>2</sub>; and 12) a special first-aid



kit. Despite the absence of an interior heater, the chamber temperature does not drop below 10° C for an ambient water temperature of 3° C; however, the observer must dress warmly. Hull insulation is provided by a layer of cork.

The information available on the emergency surfacing system, while not overly contradictory, is confusing. The sequence of operations is somewhat hazy; however, it appears to be as follows: In an emergency situation, the observer turns a handle connected to a threaded shaft running through the base of the stool into a nut welded on the bottom of the ballast plate. After a few turns, the ballast is dropped. If the chamber is deep enough, a hydraulically operated system can be used to sever the electrical cable and release the hoisting carriage and tether. In this system, a piston exposed to the ambient water pressure is held in check by oil and a bleed valve. When the valve is opened, the oil is forced into an empty reservoir and the piston is driven forward by the water. A rod on the piston is connected to the hoisting-carriage shackle pins and as the rod moves with the piston, the pins are removed and the carriage and tether float free. The electrical cable is severed simultaneously by a cable cutter, apparently actuated by the same hydraulic system. At shallow depths, manually operated mechanical versions of these same systems are available to the observer. When the chamber reaches the surface, the observer may not open the hatch, since the waterline is at hatch level. Two tubes fitted with ball-type one-way valves admit air to the chamber but keep out water. In addition, if Sever-1 should become entangled or stuck at a depth accessible to divers, air hoses can be attached to these tubes.

A 608-meter record depth for a Soviet diver was set by V. P. Kitayev on 22 July 1960 during the Sever-1's acceptance test in the Barents Sea. Based on open-source literature, this record held for many years for non-military equipment, until the Sever-2 acceptance tests. The record may have been broken by a military bell known as the RK-680 which is described below.

Mention of the actual use of Sever-1 has been decreasing in recent years, and there are vague indications that its last use may have been in 1972. Several research vessels were outfitted to carry Sever-1 and perhaps four to six Sever-1's were actually constructed. Sever-1's cost has been put at about \$140,000. [6, 29, 33, 34, 35, 36, 37, 69, 71, 72, 73, 84, 103, 109, 110, 131, 133, 143, 151, 152, 156, 167, 169, 205, 211, 213, 284, 286, 293, 335, 392, 405, 426, 486, 501, 554, 604, 607, 651, 671, 673, 709, 733, 751, 753, 755, 781].

#### G. Atlant-1 Towed Undersea Vehicle

In response to a request by AtlantNIRO\*, the Atlant-1 one-man towed undersea glider (literally "bathyplane" in Russian) was built in 1963. The vehicle (see Figs. 10 and 11) was designed by members of the Klaipeda (Lithuania) Section of Giprotybflot, under the supervision of A. P. Ryabchikov and V. N. Potapov. Atlant-1 has reserve buoyancy and submergence must be accomplished under tow through a combination of removable bow-mounted

\* Atlanticheskiy nauchno-issledovatel'skiy institut rybnogo khozyaystva i okeanografii -- Atlantic Ocean Scientific Research Institute of Fisheries and Oceanography.

depressor foils and stern-mounted diving planes. The low-alloy steel pressure hull is a 0.98-m-diameter cylinder with rounded ends; it is covered on the inside with insulating material to reduce heat loss to the surrounding water. Removable light stainless-steel fairings are attached to the pressure hull, which has been tested to pressures of 32 kg/cm<sup>2</sup>. Ballast tanks are welded to the upper portion of the pressure hull; these tanks have access panels permitting inspection of the pressure hull. Solid ballast in a detachable fairing is mounted on guides on the bottom of the hull.

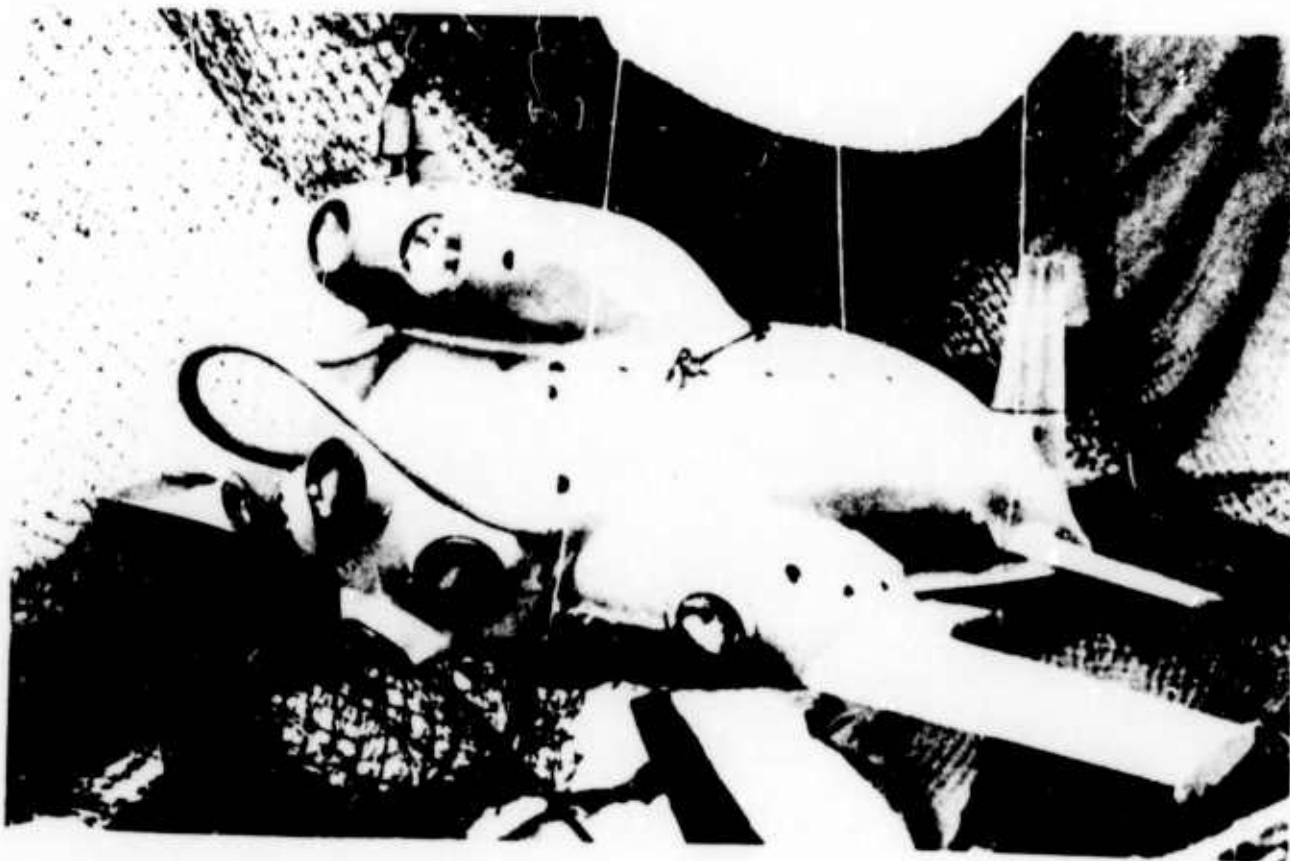


Fig. 10. Atlant-1 Towed Undersea Vehicle [12].

Specifications

Length, o. a. . . . .	4.45 m
Maximum height . . . . .	1.45 m
Submergence depth:	
Rated . . . . .	200 m
Operating . . . . .	100 m
Weight with observer . . . . .	about 2.0 tons
Beam across foils . . . . .	4.30 m
Beam without foils . . . . .	2.30 m
Volumetric displacement . . . . .	1975 dm <sup>3</sup>
Reserve buoyancy . . . . .	55 ± 5 kg
Total emergency positive buoyancy . . . . .	150 kg
Access hatch diameter . . . . .	450 mm
View ports . . . . .	4

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View-port diameter . . . . .	140 mm
View-port thickness . . . . .	40 mm
Depressor foil area . . . . .	0.5 m <sup>2</sup> each
Rudder area . . . . .	0.26 m <sup>2</sup>
Rudder travel . . . . .	+ 35°
Diving-plane area . . . . .	0.28 m <sup>2</sup> each
Diving-plane travel . . . . .	+ 18°
Illuminators . . . . .	5
Cost (approximate) . . . . .	\$330,000

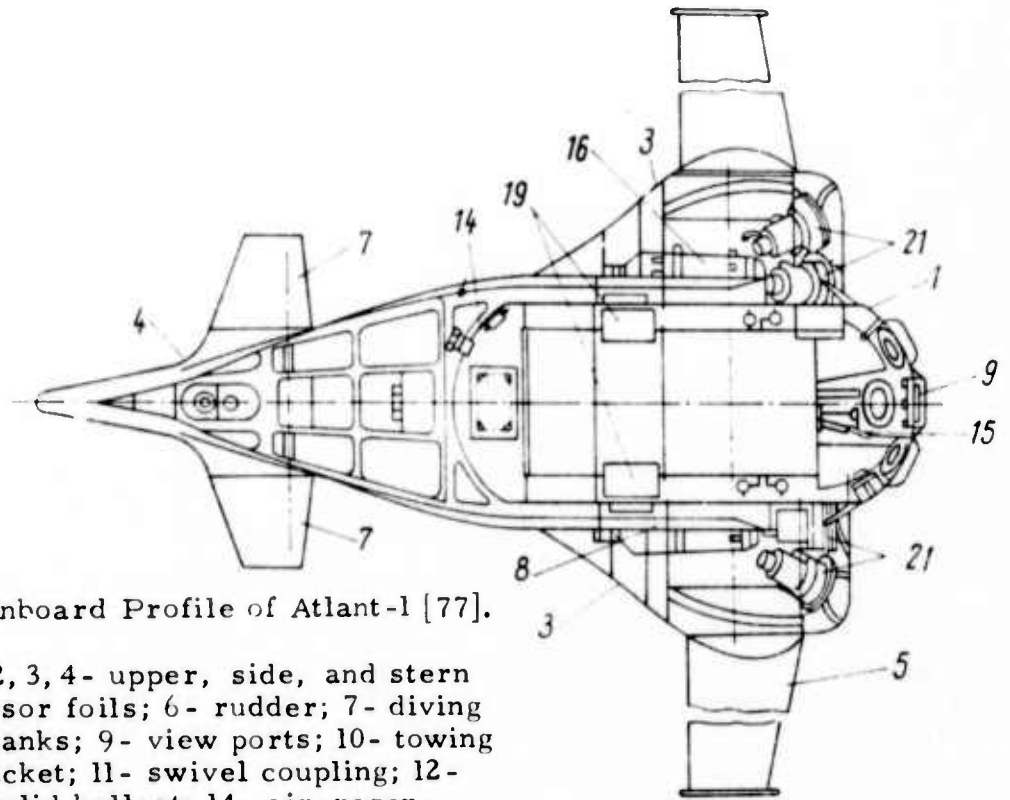
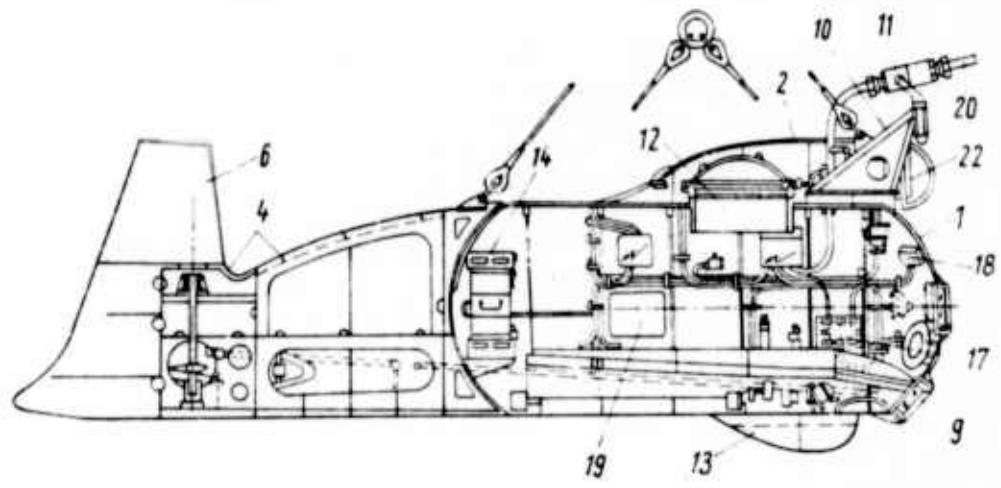


Fig. 11. Plan and Inboard Profile of Atlant-1 [77].

1- Pressure hull; 2, 3, 4- upper, side, and stern fairings; 5- depressor foils; 6- rudder; 7- diving planes; 8- ballast tanks; 9- view ports; 10- towing cable mounting bracket; 11- swivel coupling; 12- access hatch; 13- solid ballast; 14- air-regeneration unit; 15- steering unit; 16- air tank; 17- panel with illuminator switches; 18- photoflash switchbox; 19- transformers; 20- electrical towing cable; 21- side illuminators; 22- photoflash light.



The four view ports in the lower half of the bow give the pilot a field of vision of 120-130°. Mounting brackets for a Zenit still camera and an AKS-1 movie camera are installed near the view ports. Five illuminators and a synchronized flash light are used during visual and photographic observations. The photo flash light is aligned with the optical axis of the center view port. Internal lighting is provided by two 26-volt lights, with a 6-volt emergency system.

The vehicle is operated by a pilot in a prone position. Maneuvering control is provided by a single stick through a shaft drive which is force compensated to reduce pilot fatigue. Pilot instruments include a trim indicator, a heel indicator, a depth gage, and two pressure gages for monitoring the ballast-blowing system. This system consists of two 20-liter tanks filled to 150 kg/cm<sup>2</sup>, with reduction valves to bring this pressure to 15 kg/cm<sup>2</sup> for blowing. A small, tiltable Yaz' sonar is mounted in the starboard bow. An RUKT-4 air regenerator, a blower, and a barometer with a built-in GMU-2 gas analyzer and thermometer comprise the life-support system used to monitor and regulate the cabin environment. The rechargeable air-regeneration system is said to provide a life-support endurance of 12 to 16 hours per charge.

Atlant-1 is towed on a 1000-m-long electrical cable with a breaking strength of 6000 kg, generally at distances between 200 and 600 m astern. The towing ship for Atlant-1 is the converted trawler RT-202 Muksun, which also transports the vehicle to the operating area on a special cradle. Stable vehicle operation is maintained at towing speeds up to 6 knots with a 5-7° trim by the stern. As an additional safety feature, streamlined floats are secured along the towing cable to give it positive buoyancy should it snap. Electric power for the Atlant-1's various systems is provided through the towing cable, which also houses a line for the TN-B sound-powered phone. Electrical systems other than those mentioned above include a switchbox for external and internal illumination, a photoflash-lamp switch panel, a step-down transformer, an electric-power distribution panel, etc. An emergency storage battery is carried aboard, however. All the electrical equipment operates on 220-volt single-phase a. c. current.

Several references published in 1972-73 indicate that Atlant-1 was corroding badly and probably would be withdrawn from use, to be replaced by Atlant-2 which is described in Part II of this paper.

One of the principal uses of Atlant-1 has been in observing and filming the behavior of trawling gear. During the period 1965 - 1966, Atlant-1 made more than 100 descents in support of fisheries research. Regionally, Atlant-1 has been operated in the Baltic Sea (sea trials), the Mediterranean Sea, and in the equatorial Atlantic off the coast of Africa. [12, 31, 35, 57, 66, 77, 82, 84, 94, 99, 128, 129, 155, 185, 207, 219, 221, 233, 254, 255, 274, 283, 293, 321, 342, 363, 392, 403, 405, 426, 430, 431, 448, 501, 522, 535, 540, 555, 563, 576, 588, 604, 607, 618, 645, 646, 649, 651, 653, 654, 682, 686, 687, 689, 717, 721, 743, 750, 752, 755, 757].



## PART II. OPERATIONAL SOVIET MANNED AND UNMANNED VEHICLES

### A. Deep Submergence Vehicles

#### 1. Sever-2 (GA-2000)

In early 1962, PINRO requested Giprorybflot Institute in Leningrad to work up a pilot design for a deep submergence vehicle. The Institute responded four months later with plans for a 2000-meter URV designated GA-2000 (later to be known as Sever-2). This vehicle evidently underwent several early design modifications and the delivered vehicle barely resembles the earlier versions which we will provisionally call GA-2000 (Mod 1) and GA-2000 (Mod 2); the final (delivered) version will be called Sever-2.

a. GA-2000 Mod 1. Several 1964-65 sources discussing GA-2000 were illustrated with the artists conception shown in Figure 12, which we

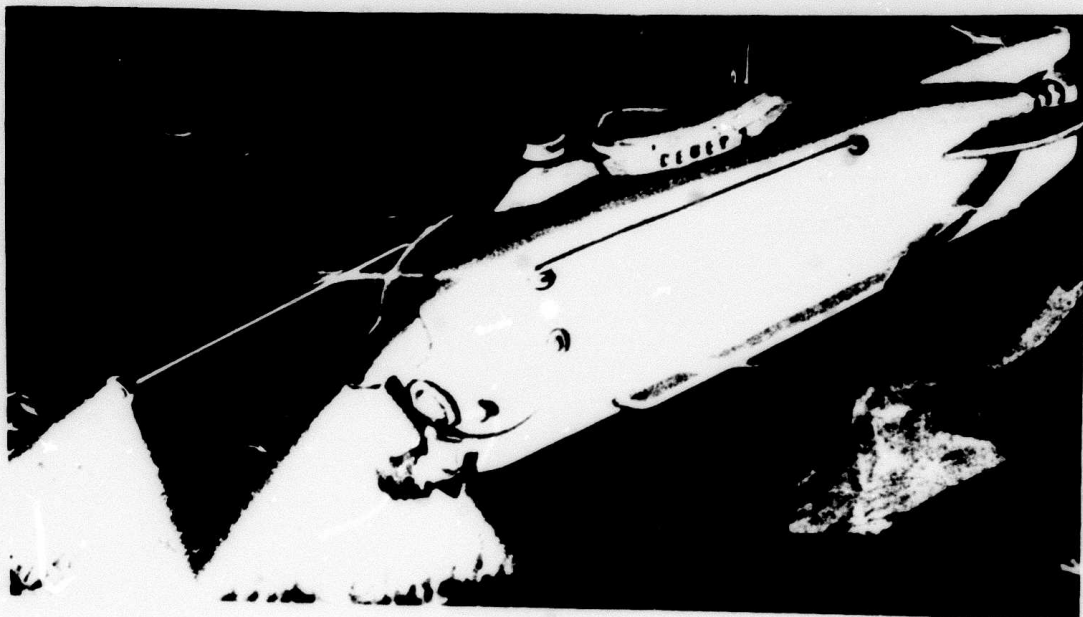


Fig. 12. Artist's Conception of GA-2000 Mod 1 [15].

have termed Mod 1. An inboard profile of GA-2000 Mod 1 is shown in Figure 13. These early references stated that this vehicle was under design, but would be operational by 1965-66. GA-2000 Mod 1 was to be equipped with manipulators, extendable lights, a bioacoustic recording system, etc., and would be used primarily for fisheries research support.

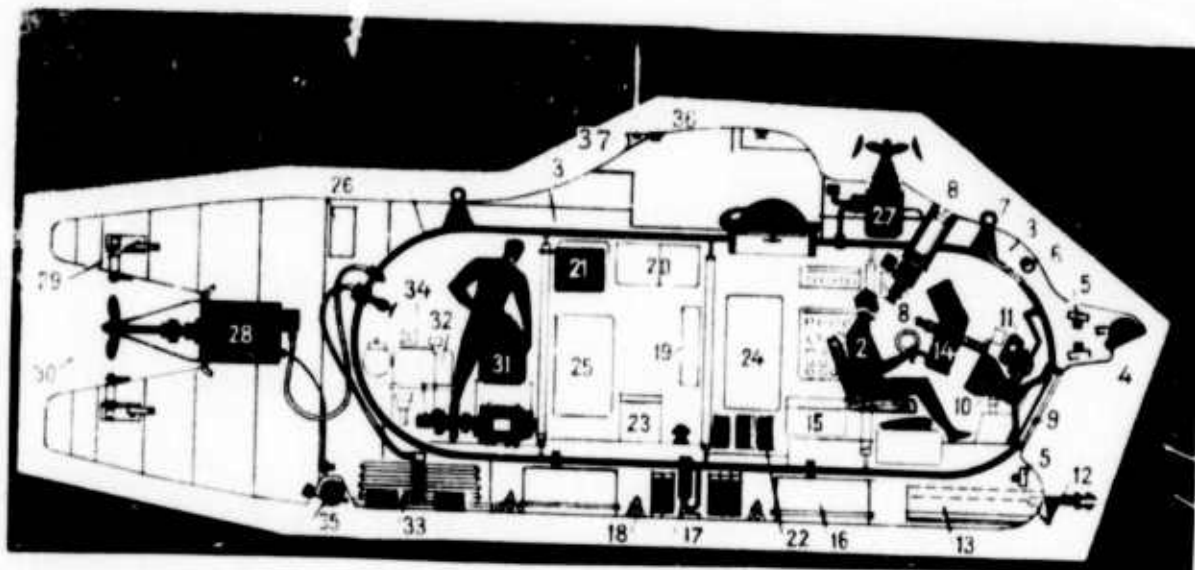


Fig. 13. Inboard Profile of GA-2000 Mod 1 [15].

1- Pressure hull; 2- pilot; 3- ballast tanks; 4- outboard illuminator; 5- sonar transducer; 6- hydrophone; 7- towing/lifting eye; 8- viewing scope; 9- view port; 10- electrooptical converter; 11- movie camera; 12- manipulator; 13- bottom-sample stowage; 14- vehicle control console; 15- wideband tape recorder; 16- battery box; 17- electrical penetrator; 18- explosive bolt; 19- sonar recorder; 20- food storage; 21- drinking-water tank; 22- air-regeneration system cartridges; 23- head; 24- electric power panel; 25- hydroacoustic communications unit; 26- hydroacoustic communication transducer; 27- electric vertical propulsion motor; 29- rudder drive; 30- Kitchen rudder; 31- gyrocompass; 32- variable (water) ballast bellows; 34 - hydraulic system; 35- guiderope; 36- signal light; 37- radio antenna.

#### SPECIFICATIONS

Length	8.7 m
Beam	1.8 m
Height	3 m
Operating depth, max	2000 m
Endurance, submerged	80-90 km
Life-support endurance	6 days
Hull thickness	70 mm
Speed	5 kn

The pressure hull was to be steel and plastic was to be used for the outer hull [3, 15, 117, 618].

b. GA-2000 Mod 2. Almost concurrent to early information on Mod 1, information began to appear on a different GA-2000 design, which we have called Mod 2. The Mod 2 design (see Figs. 14 and 15) seemed to dominate the more authoritative literature in 1964-65, and it appeared that the design evolution of Sever-2 was over.





Fig. 14. Artist's Conception of GA-2000 Mod 2 [37].

In a detailed article [39] on GA-2000 Mod 2, A. N. Dmitriyev states that non-Soviet experience in such matters as selection of hull materials, fabrication technique, and research equipment was made use of in resolving some basic problems.

The capacity of the water-ballast tanks in the outer hull was chosen to ensure vehicle stability with all solid ballast jettisoned. The solid ballast consists of a 350-kg droppable keel and 200 kg of steel shot (used primarily for descent control) in two tubs. Electromagnets were to be used for solid-ballast jettison. The use of the two solid ballast systems is considered mandatory.

The two propulsion units are driven by a single watertight hydraulic pump exposed to ambient water pressure and over-compensated by internal air pressure. Assuming pump efficiency as 0.5, 13 kwt provide 6.5 kwt to either propulsion motor. The same hydraulic pump also powers the rudder drives, manipulators, the rotatable/extendable illuminators, etc. The pump itself is powered silver-zinc batteries, despite the high cost (approximately \$10,000 for a battery bank measuring 1.5 x .7 x .26 m and weighing 520 kg). Consideration was given to mounting the batteries outboard in an oil-filled tank. All power consuming systems are capable of 12 hours continuous operation for voltage fluctuations of +10 to -15% of normal. The emergency communication system has an auxiliary 4-hour power source.

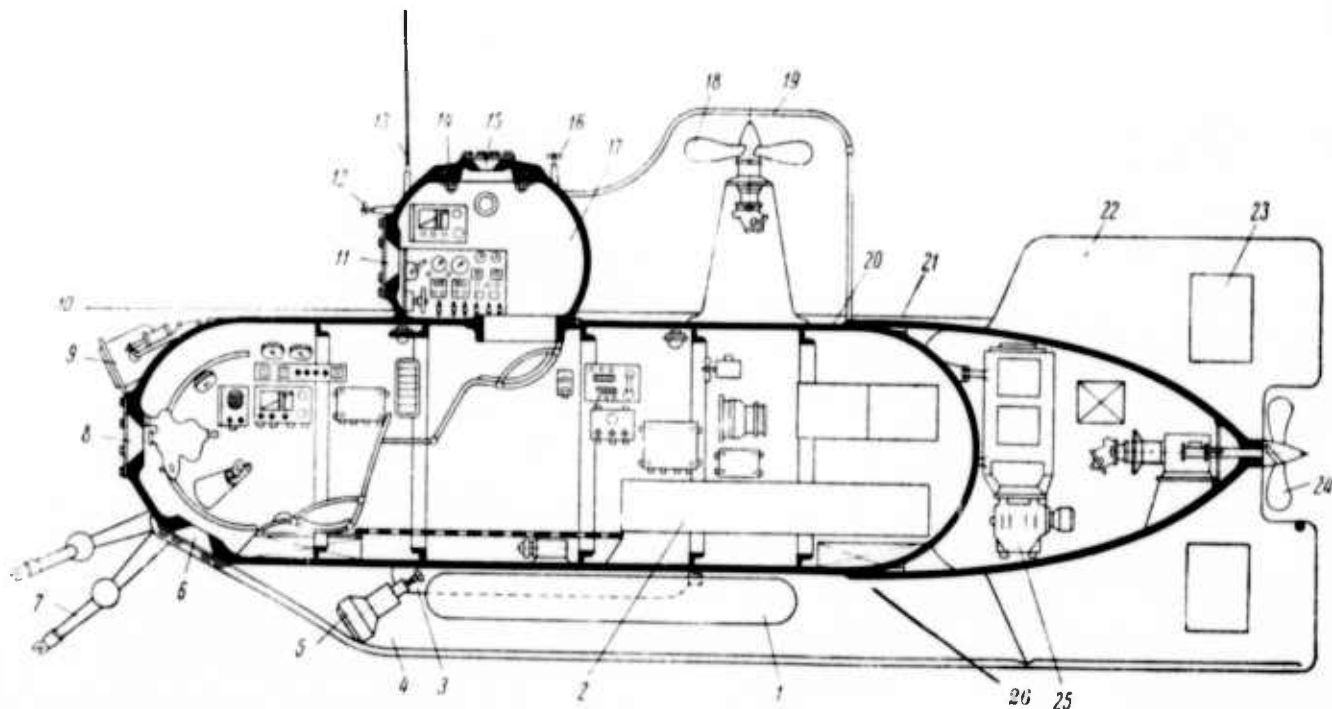


Fig. 15. Inboard Profile of GA-2000 Mod 2 [39].

1- Droppable ballast; 2- storage batteries; 3- high-pressure air tank; 4- keel; 5- lower illuminator; 6- lower view port; 7- manipulators; 8- forward view port; 9- extendable upper illuminator; 10- outer hull; 11- dome view port; 12- horizontal speed log; 13- antenna; 14- access hatch; 15- upper view port; 16- vertical speed log; 17- pilot's dome; 18- vertical propulsion prop; 19- prop guard; 20- pressure hull; 21- deck; 22- vertical stabilizer; 23- diving planes; 24- main prop; 25- hydraulic pump; 26- trim tank.

#### SPECIFICATIONS

Length, o. a.	6.5 m
Beam, max	1.8 m
Height	3.0 m
Displacement, surfaced	6.5 tons
Displacement, submerged	7.0 tons
Operating depth	2000 m
Endurance:	
at 5 knots	12.5 nm
at 2.5 knots	50 nm
Crew	2
Life-support endurance, max	48 hours
Research-equipment weight	400 kg

Pressure hull:	
length	4.7 m
diameter	1.3 m
weight	4 tons
thickness	2.5 mm
safety factor	1.4
dome thickness	16 mm
dome height	0.9 m
dome diameter	1.2 m
Outer hull thickness	5-7 mm
Outer hull weight	200 kg
Battery capacity	400 amp-hrs

Due to weight and space considerations, the air-regeneration system consists of oxygen tanks and chemical absorbers.

A 1965 preliminary cost estimate for the planning, design, research, and construction of GA-2000 Mod 1 in was about \$1,650,000.

From 1965 to mid 1968, mention of GA-2000/Sever-2 appeared in the literature with some regularity. However, there were no indications that any major changes in Mod 2 were contemplated. Then, in August 1968, a new version of Sever-2 was exhibited at the INRYBPROM-68 fishing industry exhibit held in Leningrad [31, 37, 39, 84, 221].

c. Sever-2. By October 1968, the first photos of a model of the new version of PINRO's Sever-2 undersea research vehicle began to appear (see Fig. 16).

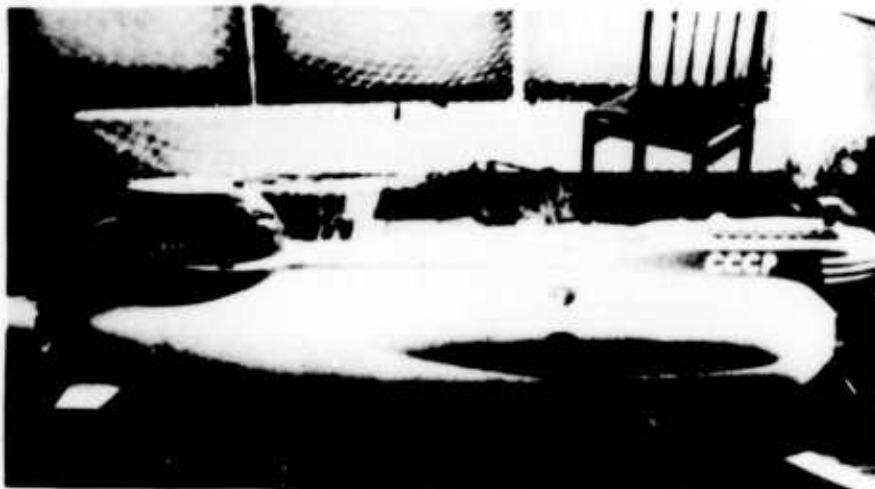


Fig. 16. Model of Sever-2 [221].

Specs data accompanying some sources indicated that Sever-2 now had the following characteristics:

Length, o. a.	12 m
Beam	2.5 m
Height	7 m
Weight	28 tons
Displacement	40 tons
Life-support endurance, max	72 hours
Crew	3-4
Endurance	10 hours
Speed, max	4 knots
Cost (approximate)	\$7,000,000

In other words, most of the dimensions doubled, the weight was increased by almost five times, and the cost had gone up by about four and half times.

One and one-half years later, in March 1969, the Soviet press [217] announced the unmanned Black Sea tests of the Sever-2 pressure hull. In these tests, the 20-ton externally ring-stiffened pressure hull (containing all permanent inboard systems and equipment and carrying 12 tons of auxiliary ballast) was lowered on wire rope to 2185 m from the R/V Persey III\*. Even though the vehicle was unmanned, the test procedures called for an emergency surfacing capability built into the auxiliary ballast system.

After being brought aboard ship, inspection showed no leaks around the "tens" of cable penetrations or in the seals of the 7 view ports or hatch. X-ray inspection of the "tens of meters" of welded seams showed no defects. Following a spell of bad weather, the hull was tested again in the Black Sea. Following the tests, A. Dmitriyev, head of the Department of Underwater Research Equipment of the Giprorybflot Institute, said that special arrangement of the propeller makes it possible for the vehicle to turn in place about its vertical axis. Several powerful illuminators and a floodlight mounted on an arm provide visibility. A manipulator closely modelled after the human arm and hand will be used to collect bottom samples and place them in a container. This copying manipulator was developed by Dr. V. S. Yastrebov, chief of the Underwater Research Equipment Laboratory of the Institute of Oceanology. It has seven degrees of freedom. The operator's hand is fitted with sensors that control the manipulator's seven hydraulic drives. It has been used to pick up objects from the sea bottom, tie knots, tighten and loosen nuts, and to turn handles and valves.

In December 1970, the completed Sever-2 (see Fig. 17) was put aboard the R/V Odissey for sea trials in the Black Sea.

As can be seen, Sever-2's design is quite faithful to the model photo (Fig. 16), with the exception of four pot-like housings on the deck, which comprise the port and starboard vertical-propulsion systems. The after housing consists of what appears to be either a watertight electric motor or gear box, a four-blade propeller, and a Kort nozzle mounted on a shaft. This shaft allows the vertical propulsion systems (port and starboard) to be swung outward 90° into their operating positions or "tucked in" over the hull during launch or recovery. It is not yet known whether this motion can be controlled from within Sever-2 or whether it is performed manually on deck by the launch/recovery team.

\* The tests probably took place in early to mid-January 1969, since the Persey-3 made a visit to the "Oceanology 1969" conference held in Brighton, England, between 14 and 21 February 1969. The Persey-3 is a fisheries-research stern trawler, and the Sever-2 was probably launched on a cradle down the stern ramp, using the trawl winches.





Fig. 17. Sever-2 [515].

The Sever-2 support ship (see Fig. 18) is a converted BMRT

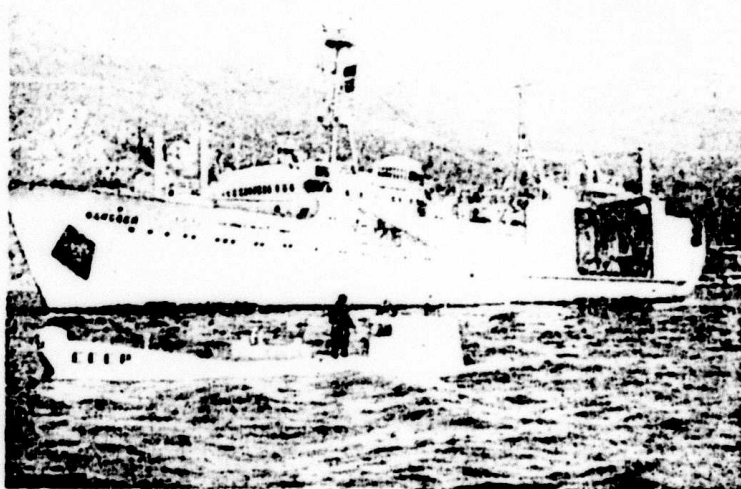


Fig. 18. Sever-2 Support Ship R/V Odissey [598].

(large freezer/trawler) which has been fitted with a large "hangar" on the port side near the stern. This hangar houses Sever-2 in a controlled environment and is equipped with large doors giving access to the port side. In launching Sever-2, the travelling crane operator, sitting in a glass enclosure over the hangar, controls the entire launch procedure, including control of the

Odissey's ballast tanks, selectively flooded to provide a righting capability as the 28-ton Sever-2 is lifted outboard during launching.

Following four months of sea trials (21 dives), the official Soviet government acceptance test began at the end of March 1971.

The acceptance program was kept simple and amounted to submerging vertically to a specific depth, measuring water parameters from the surface to that depth, and checking the operation of the instruments and the integrity of the hull and penetrations.

Two principal figures associated over the years with the development and designing of Sever-2 and other Soviet URV's were involved in the acceptance tests. The first, A. N. Dmitriyev, served as the Chairman of the State Commission for the Sever-2 tests, while the second, M. N. Diomidov, was the vehicle pilot.

Although earlier indications were that Sever-2 was to carry a crew of three, the vehicle now reportedly accomodates four crewmen. Other equipment includes movie cameras, a video-taping system, manipulators, and other systems capable of monitoring about a dozen ocean parameters. All the machinery has been mounted outside the pressure hull and inside the fiberglass outer hull. An attempt was made to adapt all the machinery to exposed operation in the water in order to gain experience for future development of deepsea robots.

Prior to launching, Sever-2 undergoes a pre-dive check-list inspection, including the emergency surfacing systems, fire-suppression devices, power and seal-integrity checks of the outboard equipment, etc. The check list is said to be quite extensive since there are more than 1000 conductors passing through the hull penetrators. After the hatch is sealed, communication with the submersible is by a plug-in telephone system and radio. The telephone is unplugged as Sever-2 moves over the side. The last radio communication from Odissey consists of a present position report. As an additional safety measure, Sever-2 is to communicate with the Odissey every 20 minutes during a dive. In the event communication cannot be established, Sever-2 is to surface immediately.

As Sever-2 submerged, it was tracked by the Odissey's echo sounder and graphic recorder. Aboard Sever-2, an open-mike tape system was used to record all commands and other sounds throughout the vehicle, and hydro-acoustic communication was used between Odissey and Sever-2. At a depth of somewhere below 1000 meters, when Sever-2 reached equilibrium in the denser water, it was decided not to risk additional ballast-tank flooding by pump. At this point, the vertical propulsion system was used to drive Sever-2 downward to the final test depth (it is mentioned that the last 50 meters took a half an hour). Recorders plotted current speed, water temperature, salinity, density, transparency, and other parameters. After reaching the desired depth, the Odissey was informed that Sever-2 showed no leaks or damage and was ready to ascend. During ascent, the vertical-propulsion motors were used again. At 1000 meters, ballast-discharge pumping began and continued to about 300 meters, at which point Sever-2 began horizontal movement. After a brief excursion, the vertical-propulsion motors were used to bring Sever-2 to the surface.

Several times during these early dives, Sever-2 scraped bottom, trying to avoid obstacles. Once, she ran into a steep slope when the motor overload protection failed during an all-up - all-back emergency maneuver.



Very little detailed information is available on the Sever-2's interior and equipment. The pilot and engineer sit side-by-side near the center of vehicle; each has his own control panel. A vertical periscope with a built-in movie camera rises between the two panels. Current transformers, an emergency storage battery, head, food storage, fans, and electrical panels are located aft. There is a portable control panel in the bow area which the pilot can use for fine maneuvering and station-keeping for the observer or manipulator operator. To ease the pilot load, the navigational system has an autopilot with a relief follower to keep Sever-2 at a desired distance above the bottom. Sonar and measurement sensors are mounted in the bow area. Storage batteries, hydraulic machinery, electric drives are mounted in the keel. The batteries serve as droppable emergency ballast. Other heavy outboard systems can also be dropped if necessary. The Kort nozzle used with the horizontal propulsion system apparently can be rotated about 90° in the horizontal to provide rotation about the vehicle's center. Other systems said to be available on Sever-2 are: a bottom profiler; still and motion-picture cameras, a guiderope, overhead view port, and an up-looking sonar.

Later operations in shallow water were observed and supervised by diver specialists from the Group for Experimental and Professional Underwater Work (PEER) of Giprorybflot, founded in 1970. The Group experiments with and tests underwater equipment, prepares operating manuals, and trains submersible operators and crews. For Sever-2, the divers filmed the operation and maneuvering of the vehicle and its outboard systems.

Sever-2 will be used primarily to support Soviet fisheries research; although oceanographic, geological, and archeological research will most likely also be scheduled.

Lastly, during a dive in the Yalta Basin, a record depth of 2020 meters was set for a Soviet submersible on 28 March 1971 [3, 15, 31, 37, 39, 53, 54, 83, 84, 105, 117, 132, 205, 210, 217, 218, 219, 220, 221, 225, 284, 286, 347, 392, 435, 439, 464, 465, 475, 477, 486, 515, 521, 528, 538, 550, 552, 568, 573, 588, 598, 605, 607, 618, 620, 634, 635, 651, 660, 671, 680, 692, 709, 710, 715 756, 766, 771, 776, 777, 781].

## B. Limited-Depth, Towed, and Diver Transport Vehicles

### 1. TINRO-2

In August 1965, the completion of the preliminary plans for TINRO-2 (see Fig. 19) by Giprorybflot Institute was announced. The design was undertaken at the request of the Pacific Ocean Scientific Research Institute of Fisheries and Oceanography (TINRO) and the vehicle bears the Institute's Russian acronym. Not long after the initial announcements, a modified design for TINRO-2 was being touted by Giprorybflot (see Fig. 20).

TINRO-2's primary mission is to support fisheries research and fish reconnaissance at depths to 300 m. A recent press article [799] states that during a familiarization dive, TINRO-2 submerged below 400 m. It is possible, therefore, that TINRO-2's depth capability has been significantly up-graded.

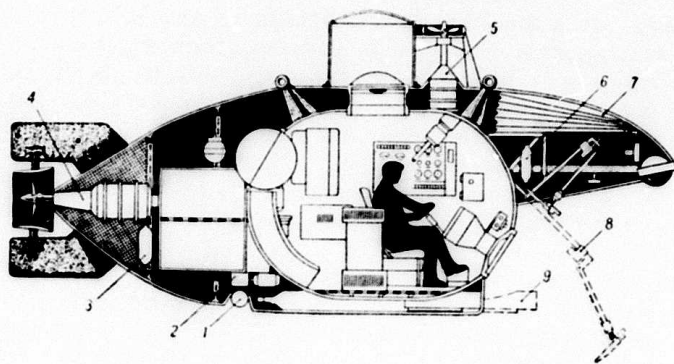


Fig. 19. Preliminary Design for TINRO-2 [35].

1- Guiderope weight; 2- guiderope winch; 3- mercury trim tank; 4- propulsion system; 5- vertical propulsion motor; 6- mercury trim tank; 7- variable ballast tank; 8- manipulator; 9- retractable sample storage container.

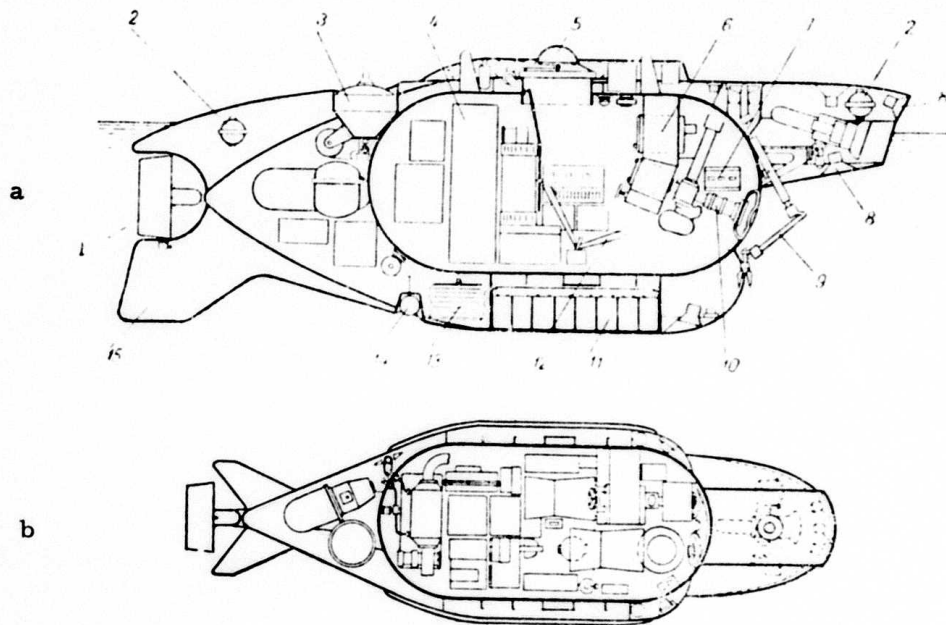


Fig. 20. Inboard Profile (a) and Plan (b) of TINRO-2 [259, 35].

1- Horizontal propulsion system; 2- trim tanks; 3- radio buoy; 4- hydrological measurement instrumentation; 5- inflatable navigating bubble and access hatch; 6- central control console; 7- tape recorder; 8- illuminators; 9- manipulator; 10- viewing scope; 11- main storage battery; 12- seats; 13- variable ballast tank; 14- guiderope; 15- stabilizer.

## SPECIFICATIONS

Length, o. a.	6.5 m
Beam	2 m
Height	2.4 m
Pressure hull:	
length	3.3 m
diameter	1.5 m
thickness	10 mm
Displacement	6.8 tons
View ports	9
Operating depth	300 m
Crew	2
Life-support endurance	2-4 days
Speed, max	4.5 knots
Endurance	20-25 nm at 3 knots
Battery capacity	200 amp-hrs
Cost (approximate)	\$2,200,000

Most of the machinery is located between the fiberglass outer hull and the rib-stiffened steel pressure hull. As designed, the access hatch is covered with an inflatable plastic bubble or dome for visual navigation on the surface. The bubble is deflated before submerging.

Submersible lead-acid batteries and high-pressure air tanks are located under the pressure hull. These also serve as droppable emergency ballast. Horizontal maneuvering is provided by a hydraulic motor powering a prop in a rotatable Kort nozzle. Vertical maneuvering is with the vertical lift prop, assisted by the variable-ballast and trim systems.

The life-support system consists of an air-regeneration and conditioning system. On the surface and for a few meters below, a plug-in telephone is used for communication. Hydroacoustic communication is used when fully submerged. The emergency communication system includes an automatic emergency signal transmitter, a releasable radio buoy, and a [droppable] acoustic marker beacon.

View ports, optically magnifying viewing scopes, underwater TV, lights, and sonar make up the vehicle's "eyes". Still and motion-picture cameras are carried. Navigational equipment includes a gyrocompass, log, clinometer, trim gage, echo sounder, clock, sonar, acoustic-beacon homing system, etc.

Research instrumentation carried by TINRO-2 includes a hydrological parameter measurement system, a water sampling penetration, wideband hydrophone with mag tape recording for bioacoustic research, and previously mentioned optical equipment.

In December 1973, the Soviet press announced that the completed TINRO-2 (see Fig. 21) would be tested in the Black Sea. The support ship for TINRO-2 was to be the R/V Ikhtiandr, which was converted or launched in June or July 1973 and assigned to the port of Kerch'.

As the photos indicate, the completed TINRO-2 design remained relatively close to that shown in Figure 20. It appears, though, that she now has vertical lift motors running through the main ballast tanks. Also, much of



Fig. 21. TINRO-2 [726].

the fiberglass outer hull seems to have been done away with, leaving perhaps only the brow and stern fairing. The ballast-tank and bottom fairings seem to be riveted metal.

Following the 1973-74 Black Sea tests and some pilot familiarization dives, TINRO-2 was to operate in the Atlantic and Indian Oceans.

Although TINRO-2 was originally designed for the Pacific Ocean Scientific Research Institute of Fisheries and Oceanography (TINRO), she is reportedly being operated by the Southern Commercial Fisheries Reconnaissance Administration (Yugrybpromrazvedka). At some later date, TINRO-2 and the R/V Ikhtiandr may be transferred to Vladivostok and TINRO [35, 127, 178, 216, 219, 259, 318, 645, 657, 708, 722, 723, 726, 729, 740, 760, 773, 778, 781, 799].

## 2. Okeaniya [see also Kal'mar, Part III, para. 4]

A brief 1970 article in a popular source mentioned the development of the Okeaniya URV (see Fig. 22) by a diving club sponsored by the Ukrainian Academy of Sciences. At that time, the Academy's Submarine Works Club was in the construction stage of Okeaniya which was to be used in biological research. The only photograph of Okeaniya shows two men working on the partially completed vehicle. Flaw detection marks can be seen on the vehicle's pressure hull. Okeaniya was to be highly maneuverable and was to be able to move in water almost as freely as an airplane does in air. No further mention



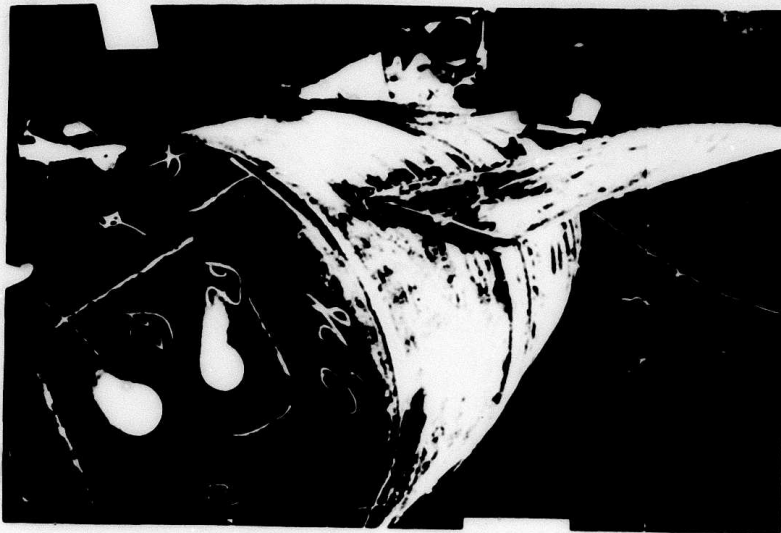


Fig. 22. Partially Completed Okeaniya URV [308].

of this vehicle has appeared in the available open literature. Since three and a half years have passed since the article was published, and judging by the degree of partial completion, this vehicle should be operational or nearly so by now.

In the same article discussing Okeaniya, a drawing of a quite similar vehicle named Kal'mar was shown, but not discussed. A recent article [815] by the Soviet Union's foremost URV designer, A. Dmitriyev, mentions the existence of a vehicle named Kal'mar, which very probably is the vehicle shown in Figure 22 and referred to originally as Okeaniya [308, 815].

### 3. Afalina

In August 1971, Soviet and Czech press articles [436, 437] announced the development of Afalina by the Student Design Bureau of the Leningrad Shipbuilding Institute, and showed a model of Afalina at a student exhibit (see Fig. 23). According to [436], Afalina was still in the project stage and would be used to study trawl and fish behavior and would be capable of underwater bioacoustic recording, water sampling, photography, and fisheries related research. The Czech article [437] indicated that Afalina had already been built and was being used in the Gulf of Finland. Afalina's operational status was later confirmed in [516] which stated that this two man vehicle was being used for "topographic" surveying of the sea floor and for studying bottom life.

The information on Afalina is still too scant to determine when construction actually began, but if it is indeed operational, this should constitute some sort of record for getting a vehicle off the drawing board and into the water. The fact that it was a student project, possibly not subject to conventional government red tape, may have contributed to the apparently short development time.





Fig. 23. Model of Afalina [436].

In this regard, it should be mentioned that Sever-2 was through its design phase (first model) in 1963, had a projected delivery date of 1965, and was finally delivered in 1971 [436, 437, 516].

#### 4. Gvidon

Thirty-three years passed from the time of the Shimanskiy submersible to the testing of the Gvidon submersible in 1970 in the Black Sea. It is difficult to say at this point whether Gvidon was born out of hindsight or not, but the result is a full justification and rebirth of Shimanskiy's concept and a rather interesting vehicle though limited in its mobility and versatility.

Gvidon (see Figs. 24 and 25) was designed by the All-Union Scientific Research Institute of Fisheries and Oceanography (VNIRO) and was built by the Scientific Research and Design Institute for Fabrication Technology.

Gvidon's cylindrical pressure hull is externally rib stiffened overlain by thin metal plating. The upper space between the hulls serves as a three-section, interconnected ballast tank with a 0.36 cubic meter capacity. The access hatch is 0.6 m in diameter and its trunk provides 0.8 m of freeboard on the surface. There are 28 seven-liter air tanks in a bank surrounding Gvidon's lower hull. Tank pressure is 150 kg/cm<sup>2</sup>. Removable battery packs are housed beneath the air tanks. Lead or steel shot ballast is stored in a tub between the battery packs.

Gvidon has three hollow support legs which also serve as the variable ballast system (capacity 0.12 cubic meters). Not shown in the figure are two reversible, rotatable propulsion motors. Prop reversal is by a toggle switch on the control panel, while rotation is performed with the same device used to jettison the shot ballast.

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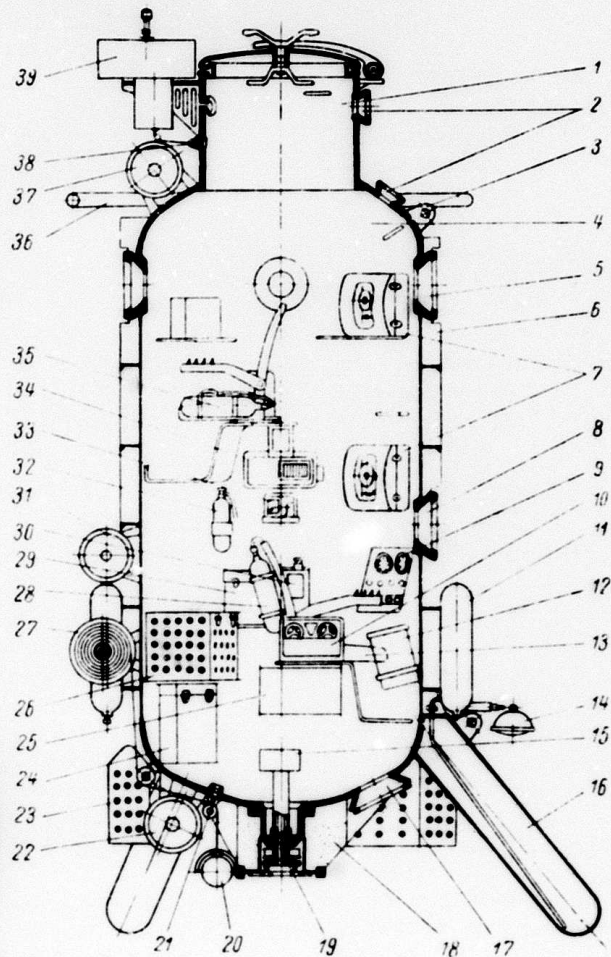
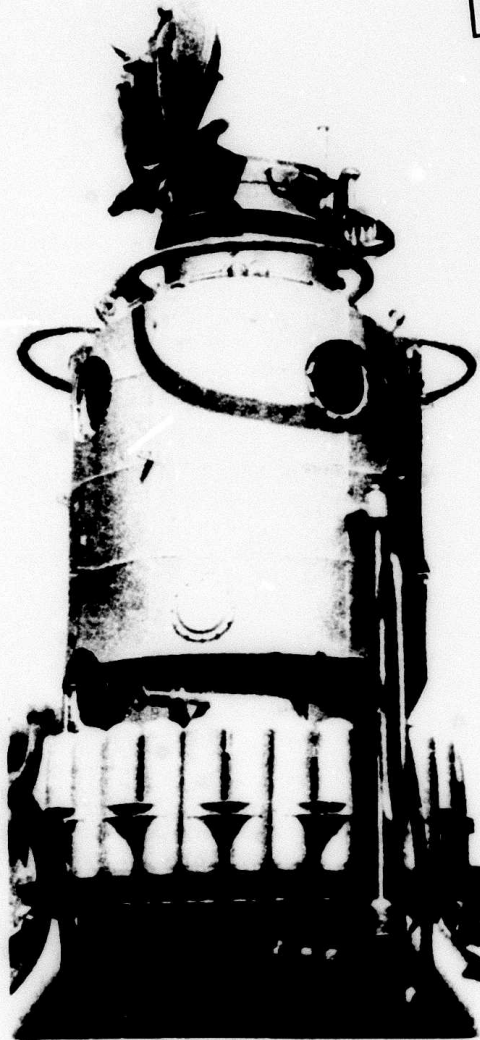


Fig. 24 and 25. Photo and Inboard Profile of Gvidon [594].

1- Access hatch; 2- view port; 3- lifting eye; 4- pressure hull; 5- observer's view port; 6- ballast tank; 7- echo sounders; 8- pilot's view port; 9- control panel; 10- dictaphone; 11- air tanks; 12- directional gyro; 13- pilot's seat; 14- extendable illuminator; 15- ballast-jettison and propulsion-motor-rotation drive; 16- variable ballast tank (support leg); 17- lower view port; 18- emergency ballast; 19- ballast-jettison mechanism; 20- guiderope; 21- guiderope release mechanism; 22- electrical circuit box; 23- submersible batteries; 24 and 25- spare air-regeneration cartridges; 26- air-regeneration unit; 27- guiderope winch; 28- emergency breathing gear; 29 and 30- gas analyzers; 31- electrical circuit box; 32- fire extinguisher; 33- barograph; 34- radio transmitter; 35- observer's seat; 36- guard rail (fender); 37- electrical circuit box; 38- emergency-buoy release mechanism; 39- emergency buoy.

## SPECIFICATIONS

Height	4.5 m
Beam	2.45 m
Displacement:	
surfaced	3.9 tons
submerged	4.3 tons
Draft	3.2 m
Pressure hull height, o. a.	3.42 m
Pressure hull diameter, i. d.	1.22 m
Operating depth	250 m
Crew	2-3
Speed	0.7-1.0 knot
View ports	10
Endurance:	
energy	5 hrs
life-support	48-72 hrs
Battery capacity	400 amp-hrs
Reserve buoyancy	17%
Shot-ballast weight	300-320 kg

The crew generally enters and leaves the vehicle when it is aboard the support ship; however, in an emergency, this may be accomplished while Gvidon is afloat in sea state 4 or less. View port size and placement facilitate all-around viewing, and the pilot and observer both have still and motion-picture equipment available to them. Other internal equipment includes an air-regeneration system, environment monitoring instruments, a log, two echo sounders, an emergency power source, a measuring instrument recording system, two adjustable depth gages which signal the preset depth, etc.

In 1970, Gvidon's ability to break away from the bottom was tested. Air was blown (from the support legs?) under the hull and an air cushion of 140-150 kgf was created. Usually, Gvidon uses the guiderope for stationary observations, particularly over rough or sloping bottom.

Because of its slow speed, Gvidon's role in fisheries research support is somewhat limited, when compared with faster or towed vehicles. She is capable of observing the behavior of drift nets, purse seines, and gill nets. In addition she will be used to study fish behavior, bottom life, etc. One of Gvidon's main advantages is the fact that any vessel with a five-ton or more cargo boom can serve as a support ship. She also can be deployed from a shore base from a pier or down a launching ramp on a cradle [31, 49, 371, 391, 413, 414, 415, 416, 423, 439, 497, 501, 561, 562, 572, 577, 594, 605, 607, 615, 616, 617, 634, 635, 644, 651, 666, 710, 737, 749, 771, 781].

## 5. Atlant-2 (Tetis) Towed Vehicle

Early Soviet references to this vehicle referred to it as Tetis, stating that it was intended for fisheries and biological research at sea, in lakes, and in estuaries. Tetis was designed in 1967-68 and, unlike its predecessor, Atlant-1, it would have view ports on all sides of the vehicle to allow its use as a stationary or drifting observation chamber. Given below are the early specifications for Tetis.

### SPECIFICATIONS

Length, o. a.	3.5 m
Beam	2.2 m
Height	1.5 m
Displacement	1.7--2 tons
Operating depth	200 m (600 m [604])
Crew	1-2
Life-support endurance	6 hr
Cost (approximate)	\$70,000

The vehicle design is attributed to Giprorybflot. One source [604] indicated that Tetis was to be equipped with a manipulaotr.

In mid 1972, popular Soviet sources began publishing brief accounts of the testing of the Atlant-2 two-man towed vehicle (see Figs 26 and 27). Although more than a dozen articles on Atlant-2 were published between 1972 and early 1974, no reference to Tetis was made and no vehicle specifications were given. The only concrete information available at the time was several photos of Atlant-2 being tested off the R/V Zund.

In late 1974, East German references published detailed articles on "Thetis-II" (Tetis) and a comparison of photos revealed that Tetis and Atlant-2 are the same vehicle. For purposes of this report, this vehicle will be referred to as Atlant-2, although Tetis may prove to be the "official" name and has appeared on the vehicle itself.

Atlant-2 was built in Leningrad in 1972 for the fishing industry. She was recently displayed at the 1974 Baltic Sea Fair held in Rostock, East Germany. Atlant-2's main use is the observing of trawl net and fish behavior.

### SPECIFICATIONS

Length	4.4 m
Beam across foils	3.2 m
Height	1.8 m
Pressure hull:	
inside diameter	1.32 m
length	2.46 m
Weight	3 tons
Towing speed, max	6 knots
Operating depth:	
under tow	200 m
stopped	300 m
Crew	2
Endurance, normal	4-6 hrs
Life-support endurance, max	24-28 hrs

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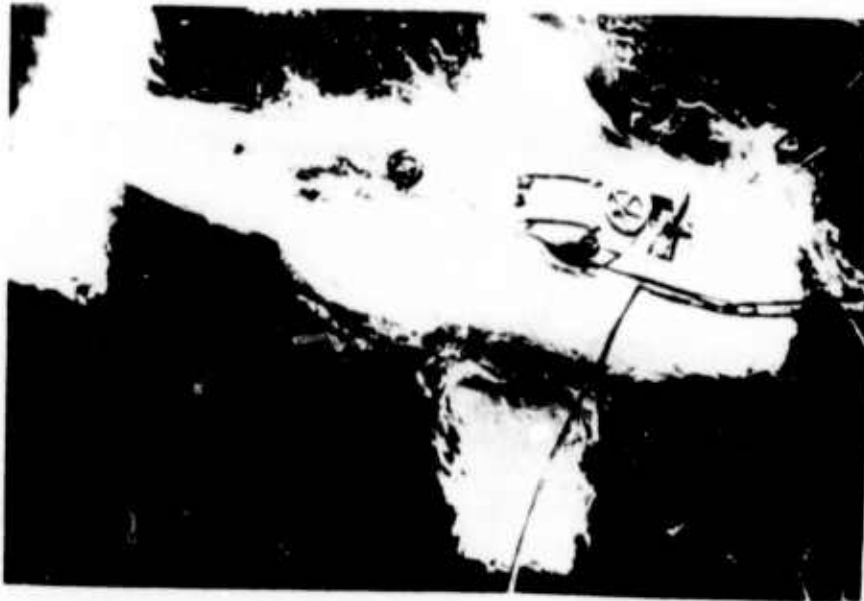


Fig. 26. Atlant-2 Towed Vehicle [638].



Fig. 27. Thetis-II (Atlant-2) at Baltic Sea Fair  
1974 [803].



Atlant-2 is 150 kg positively buoyant and, like Atlant-1, submersion must be accomplished under tow using the diving planes and bow-mounted depressors. The vehicle is generally towed about 200 m astern, although the special towing cable is 1000 m long. As a safety feature, floats are attached to the towing cable at 12-meter intervals. The towing cable also houses a line to power the vehicle systems and a telephone communication link.

The pilot and observer lie in a prone position facing six view ports 140 mm in diameter. Five 630-watt illuminators are available to improve viewing conditions. The pilot uses a single stick to actuate the vertical rudder and stern diving planes. A clinometer and curved bubble level provide a quick visual check of Atlant-2's attitude in roll and pitch (trim).

A closed cycle air regeneration system with CO<sub>2</sub> scrubber recycle the breathing mixture (air). The O<sub>2</sub> cartridges carried aboard provide a maximum of 28 hours of breathable air for the two-man crew. A CO<sub>2</sub> meter monitors the environment; however, it is not equipped with a warning signal.

Navigation and vehicle systems equipment include: vertical echosounder, two depth gages, two telephone sets, and a barometer. Additional power is available from a set of 6-volt batteries, probably used only in an emergency situation.

The support/towing ship for Atlant-2 is the R/V Zund, an Atlantik-type stern trawler built at Stralsund, East Germany.

Atlant-2 was first tested to a depth of 100 m in the Irish Sea in 1973. Fisheries research specialists from the USSR, Poland, East Germany, and Bulgaria were involved in the tests. The tests showed that a great deal of work and skill is involved in keeping the vehicle roll stabilized. When surfaced after the test dive, a manual pressure compensation was used to bring Atlant-2's interior pressure up 30 mm H<sub>2</sub>O to ambient before the hatch could be cracked [219, 545, 588, 595, 596, 597, 600, 603, 604, 608, 612, 637, 638, 642, 649, 713, 717, 737, 803, 814, 830].

#### 6. BaltNIIRKh Towed Vehicle.

In 1973, the Baltic Sea Scientific Research Institute of Fisheries (BaltNIIRKh) organized an underwater research section as a part of the Commercial Fisheries Laboratory. To support this research, the Laboratory built a towed wet vehicle which we have provisionally called BaltNIIRKh (its actual name is unknown). This vehicle's mission is to observe fish, trawl behavior, bottom relief, and bottom flora. The only source on BaltNIIRKh gives no specifications data. From a photo appearing in the original article, it looks as though it could accommodate two divers, one being the pilot and the other, an observer. Since the photo shows a diver with his own scuba gear entering the vehicle, it can be assumed that the vehicle has no integral or removable breathing system [724].

#### 7. MAI-3 Diver Transport Vehicle

Since the early 1960's, Moscow Aviation Institute has been involved in the design and construction of several towed and free diver transport vehicles. The MAI-1 and MAI-2 towed vehicles were developed in 1963, and gave way in 1967 to the MAI-3 prototype diver transport vehicle (see Fig. 28). The prototype

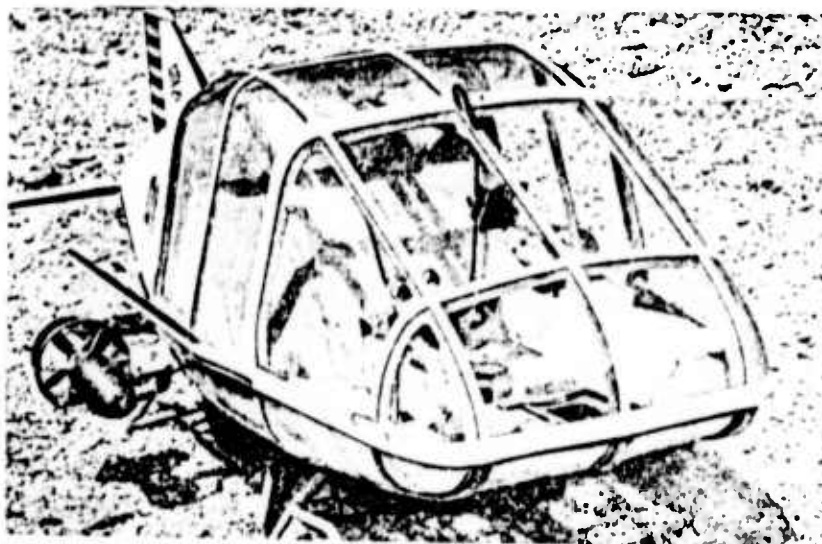


Fig. 28. MAI-3 Prototype Diver Transport Vehicle [408].

vehicle can be identified by the "01" designation painted on the hull aft of the plexiglass cockpit. The MAI-3 (01) is equipped with two reversible electric propulsion motors which can be rotated 90° into an up or down position. The vehicle weighs 60 kg, has a cruising speed of 2 kts, and a maximum speed of 5 kts. Endurance at 20 m is 1-1/2 hours and the maximum operating depth is 50 m.

The second vehicle in this series, the MAI-3 (02) (see Figs. 29 and 30), is a significant up-grading of the prototype. Both models utilize a flooded cockpit which also contains two emergency scuba sets. The 5-mm-thick transparent plexiglass canopy slides rearward for diver entry and egress through a 1.2 x 0.6 m opening. The canopy also has an emergency jettison lever.

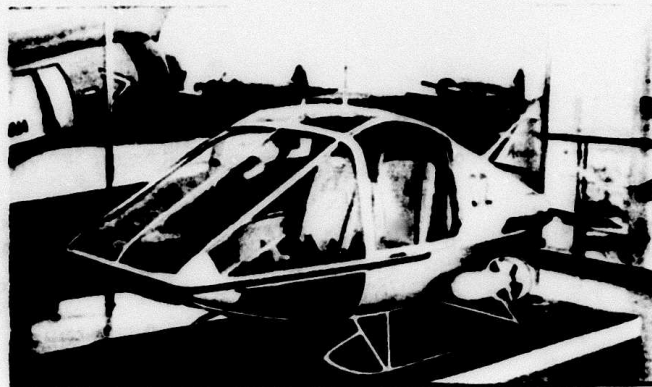


Fig. 29. MAI-3 (02) Diver Transport Vehicle [11].

#### SPECIFICATIONS

Length, o. a.	3.06 m
Beam across motors	1.42 m
Beam across cockpit	1.1 m
Height, o. a.	0.98 m
Operating depth	40 m
Rated depth	70 m
Weight, in air unmanned	380 kg
Speed	1.5 or 3 knots
Endurance	3 hrs
Crew	2

MAI-3's framing and bearing members are of coated aluminum alloy, while plastic and plexiglass are used everywhere else. The vehicle is centrally divided by a bulkhead. The after section contains batteries, air tanks, piping, and ballast tanks. With the ballast flooded, MAI-3 has a 15-kg positive buoyancy.

The crew breathes an air mixture stored in six 7-liter tanks charged to 150 kg/cm<sup>2</sup>. The emergency scuba sets are 1.5-liter tanks at the same pressure. The vehicle air system can also be used to blow the ballast tanks.

MAI-3 has been used as a diver reconnaissance vehicle in support of the 1969 Chernomor underwater laboratory program and in a variety of other practical underwater tasks. One source mentions that 50 orders for

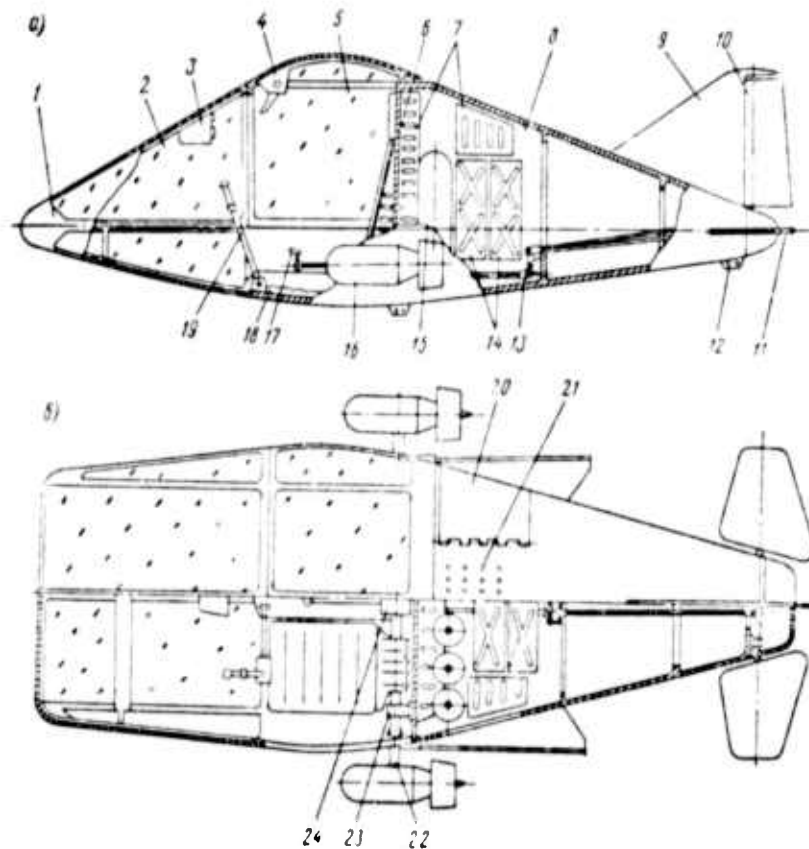


Fig. 30. Inboard Profile and Plan of MAI-3 (02) Diver Transport Vehicle [251].

1- Cockpit; 2- plexiglass fairing; 3- instrument panel; 4- emergency canopy jettison; 5- sliding canopy; 6- bulkhead; 7- air-filled cavities; 8- battery compartment; 9- vertical stabilizer; 10- vertical rudder; 11- diving planes; 12- load mounting bracket; 13- rudder tie rod; 14- storage batteries; 15- air tanks; 16- rotatable propulsion motor; 17- motor rotation lever; 18- pilot's seat; 19- rudder/diving plane control stick; 20- service access panel; 21- air-escape holes; 22- motor rotation shaft; 23- motor rotation shaft support bracket; 24- shaft angle indicator.

MAI-3 vehicles have already been placed with Moscow Aviation Institute [4, 64, 95, 140, 154, 158, 160, 163, 188, 200, 238, 243, 251, 261, 277, 282, 289, 304, 315, 344, 378, 408, 530, 556, 581, 744].

## 8. MAI-7 Diver Transport Vehicle.

Reinvolvement of Moscow Aviation Institute (MAI) in diver vehicle development became apparent recently with the showing of its newest vehicle, MAI-7 (or perhaps, MAI-07). This two-man diver transport vehicle was exhibited in the early summer of 1974 at the All-Union Exhibition of the Achievements of the National Economy held in Moscow.

Detailed information on MAI-7 is not yet available, but, based on appearances, the students at MAI have been doing their homework. The brief descriptions available state that MAI-7 is a wet vehicle powered by two water-jet propulsion nozzles streamlined into the hull. Vertical rudders in the discharge flow provide horizontal maneuvering, while bow-mounted planes are used for vertical maneuvering. Like MAI-3, this vehicle apparently has a built-in diver breathing system. Efforts have been made to make MAI-7 as close to neutrally buoyant as possible [745, 765, 769, 782].

### C. Observation Bells, Personnel Transfer Capsules, and Lock-Out Systems.

Since the Danilenko chamber (1923) the Soviets have been consistent users of non-lockout observation bells. Based on sources published over the last ten years, the Soviet Navy seems to have the most diversified recent inventory. With very few exceptions, detailed information on current military diving systems is not generally available.

Unlike the U. S. Navy, the Soviet Navy employs observation chambers of the types shown in Figures 31, 32, and 33 to assist in the location of sunken submarines and supervision of crew rescue by conventional rescue bell. The procedure is basically as follows: When sonar indicates that the rescue ship is approximately over the sub, the sub is commanded to release its emergency telephone buoy. This is retrieved by the crew of a whaleboat, which determines the attitude of the sub, the degree of flooding, and air reserves. At the same time the rescue ship begins positioning anchors which will hold it directly over the sub. When this is accomplished, the observation chamber is lowered overboard. After the observer has the sub in sight, two hard-hat divers are sent down to attach air hoses and the rescue-bell guide line to the sub. When these operations have been completed, the observation chamber and divers are brought up and the rescue bell is then sent down. At this point, the rescue operation proceeds according to well-known practices [202].

#### 1. NK-300 Observation Bell [670].

This one-man bell (see Fig. 31) is used for underwater observations and photography at depths to 300 m. The hull is welded steel and the entire bell (with droppable ballast) weighs 850 kg in air. The view ports also have removable glass covers which reduce sweating.

The air regeneration system consists of three boxes holding 2.3 kg of regeneration agent.



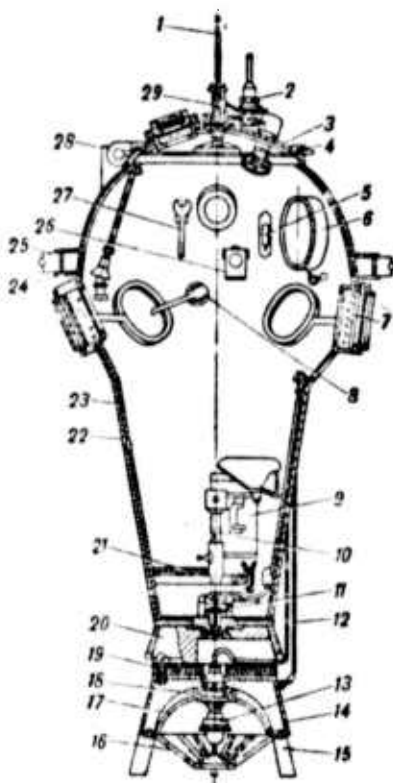


Fig. 31. NK-300 Bell [670].

1- Wire rope; 2- electrical connector; 3- access hatch; 4- rubber seal; 5- thermometer; 6- depth gage; 7- view port; 8- release ring [?]; 9- air-regeneration agent box; 10- adjustable seat; 11- emergency-ballast release; 12- emergency-ballast tether; 13- illuminator; 14- illuminator enclosure; 15- support leg; 16- illuminator guard; 17- reflector; 18- reflector seat; 19- adjustable ballast; 20- iron ballast; 21- footwell; 22- hull; 23- insulation; 24- fender mount; 25- fender; 26- flashlight; 27- wrench; 28- hatch hinge; 29- device for releasing wire rope and cutting electrical cable.

#### SPECIFICATIONS

Height	2.27 m
Diameter, max	1.15 m
Weight, in air	850 kg
Weight, in water w/observer	150 kg
Operating depth	300 m
Endurance	6 hrs
View ports	10
Crew	1
Internal volume	650 liters

The ballast jettison system is a little confusing, but probably works as follows: In an emergency, the observer first releases the two ballast elements at the bell bottom. These fall away from the bell, but are still held by a tether and the illuminator power cable. Next, the observer actuates

the upper wire-rope/electrical cable release which also severs the ballast tether and electric wire. This procedure would keep the bell essentially vertical until it is capable of free ascent. The release ring mentioned in the caption (8) also may have some role in the ballast jettison procedure.

## 2. RK-680 Diving Bell

No detailed information is available on the RK-680 bell (see Fig. 32). This chamber is termed a working chamber and may be equipped with



Fig. 32. RK-680 Diving Bell [421, 507].

a manipulator. The "680" in the designation may indicate a 680-m depth capability [421, 507].

## 3. Soviet Owned Galeazzi Bells.

The article on the sub crew rescue procedures [202] cited above, was accompanied by the photo shown in Figure 33. Other photos showing partial views of similar bells (see Figs. 34 and 35) have also appeared over the last few years. In 1957, Galeazzi, Ltd, sold five bells and two armored diving suits to the Soviet Union. Quick comparison of the photos shows some minor differences among them, particularly, the view ports.



Fig. 33 and 34. Soviet-Owned Galeazzi Bells [202, 200].



Fig. 35. Soviet-Owned Galeazzi Bell [355].

#### 4. Diver Transfer Systems

Shown in Figures 36, 37, and 38 are elements of a typical deep-sea diving system.

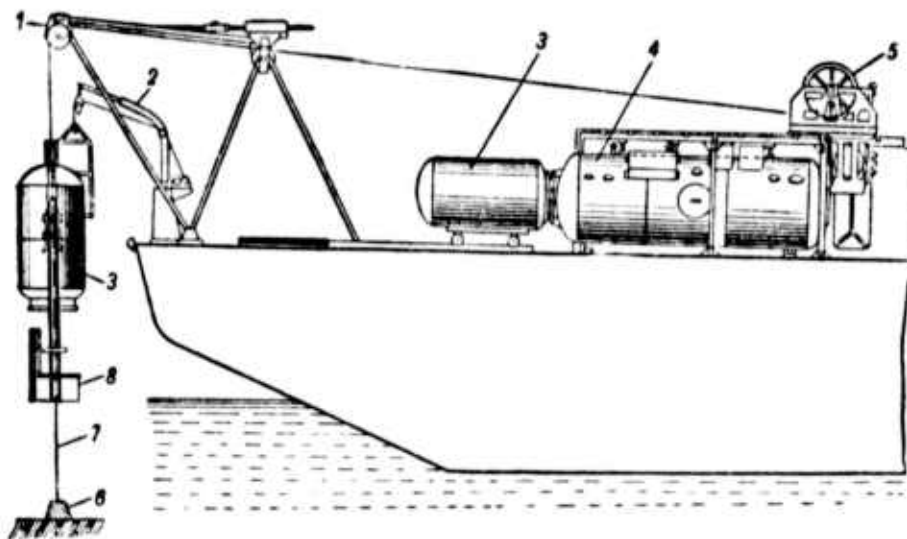


Fig. 36. Stern Diver Recovery System [670].

- 1- Boom; 2- davit with diver stage; 3- diving bell;
- 4- deck decompression chamber (2 or 3 compartments);
- 5- winch; 6- ballast clump; 7- guide line; 8- bell platform.

A larger version of the above system, including a rescue bell and multiple below-deck DDC's is shown in Figure 37. This system involves launch and recovery from the sides of the salvage/rescue vessel.

The bell shown below is used only with the stern-launching system shown in Figure 36 above. This bell bears a slight resemblance to the personnel transfer capsule used in the Sadko-3 habitat program in 1969.

A typical sectional DDC used with the above systems is shown in Figure 39. A two-section DDC of this series was used in the 1969 Sadko-3 habitat experiment and may also have been used in the Chernomor underwater laboratory program.

Information on lock-out diving not related to Soviet habitat programs has been fairly sparse. However, a unique article on lock-out saturation diving from a specially modified fleet submarine appeared in early 1972 in Pravda [511]. According to this article, a three-compartment hyperbaric chamber with a sea access was installed in a fleet submarine. Four divers lived in the chamber for a two-week cruise, breathing helium-oxygen mixtures and working outside for several hours at a time. No lock-out depth is mentioned, except to say that it is in the three-digit category. One of the major work tasks performed by the divers was the assembly of a "complicated metal structure" on the bottom.

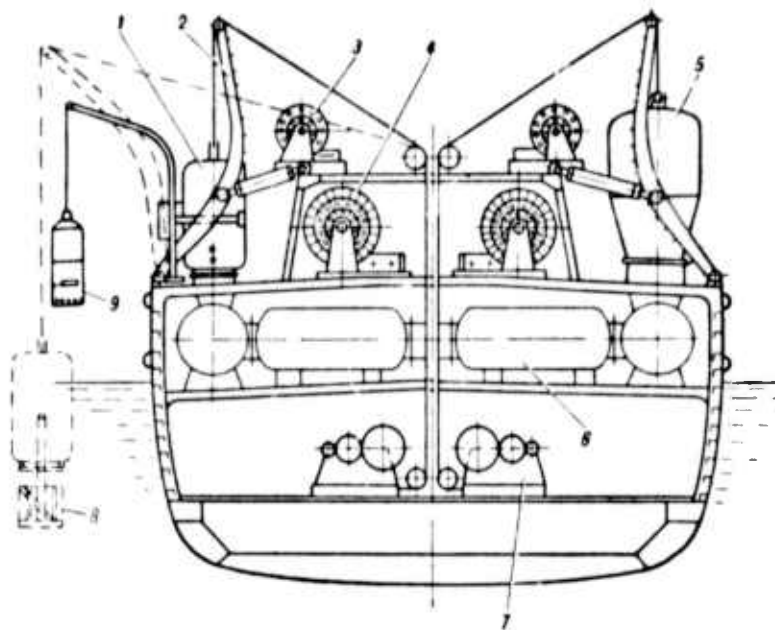


Fig. 37. Side Launched Diving System [670].

1- Diving bell; 2- A-frame; 3- single-drum winch; 4- three-drum winch; 5- rescue bell; 6- decompression chamber; 7- winch; 8- bell platform; 9- diver stage.

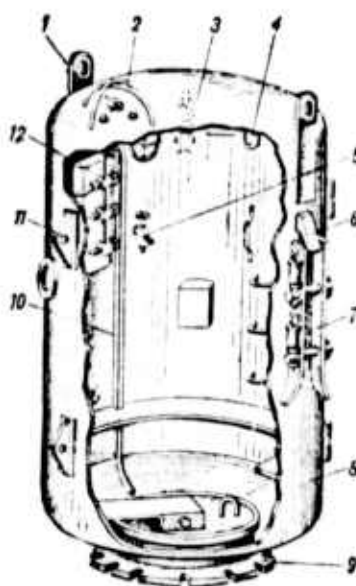


Fig. 38. Soviet Diving Bell [670].

1- Lifting eye; 2- penetrator guard; 3- sheave; 4- eye; 5- flooding valve; 6- stopper; 7- guides; 8- hull; 9- mating flange; 10- dryer piping [sic]; 11- eye for tilting bell; 12- master valve.



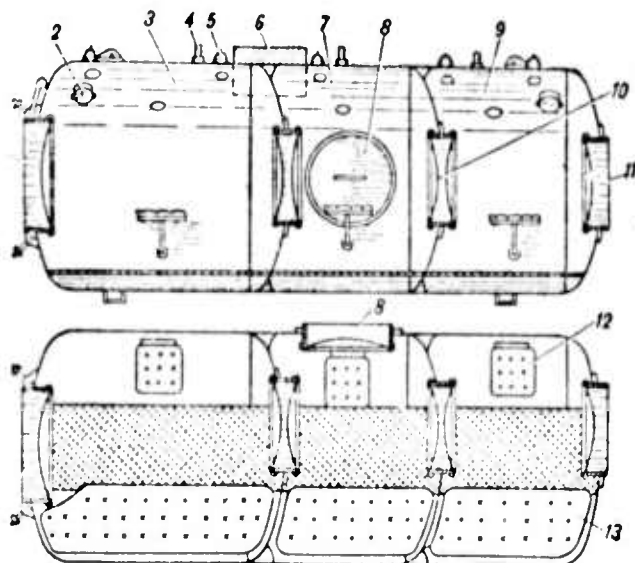


Fig. 39. Typical DDC [670].

1 - Entrance hatch; 2 - small transfer lock; 3 - first compartment; 4 - safety valve; 5 - light; 6 - control panel; 7 - second compartment; 8 - entrance hatch to second compartment; 9 - third compartment; 10 - hatch; 11 - exit hatch; 12 - seat; 13 - bunk.

Despite the use of electrically heated suits, the divers experienced quite a bit of cold, and they took prolonged hot showers upon returning to the chamber. Continued experimentation with the sub was mentioned [511].

Although not much has been written about deep saturation diving by the Soviet Union, some insight is provided by a recently published diving manual [670]. In 1935, a group of physicians headed by Academician L. A. Orbeli began investigating the use of helium as an additive to diver breathing mixtures. By 1946, a number of saturation dives to 200 m had been made. The next few years saw the development of heliox diving equipment and a tethered lock-out bell with a DDC mating capability. In 1956, research dives to 300 m were made by a number of divers. It is pointed out that it wasn't until six years later that Hans Kelle reached the 300-meter mark.

#### D. Drones

##### 1. Skorpena

In 1971, the Experimental Workshop of the USSR Academy of Sciences' Siberian Branch (Novosibirsk) built the Skorpena drone (see Fig. 40) for the Underwater Research Laboratory of the All-Union Scientific Research Institute of Fisheries and Oceanography. Skorpena was built to overcome disadvantages in the use of cable-lowered and free-fall camera equipment, i. e., camera motion due to ship roll frightening bottom life and the camera striking the bottom.

Skorpena is used to carry a variety of optical and other research equipment (still and motion-picture cameras, stereophotogrammetric cameras, video tape recorders, optical sensors, etc) to depths of 1000 m.

The watertight "hull" of the vehicle consists of a number of modules, each representing an independent functional unit. Some modules are used as flotation or buoyancy units while others contain the power and automatic control systems. The modules are in the form of cylindrical casings stacked horizontally one on top of the other in ascending order (bottom to top) of buoyancy magnitude.

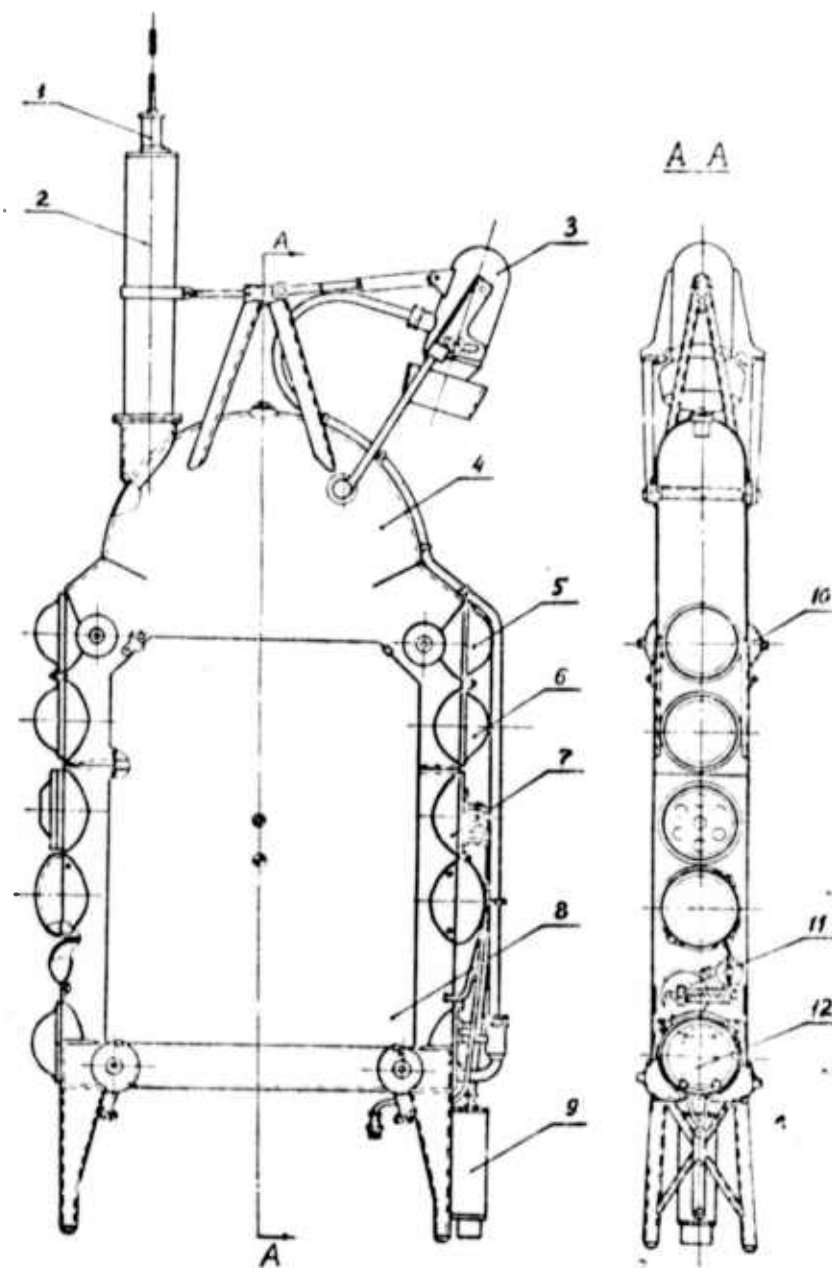


Fig. 40. Skorpena Instrumented Drone.

1- Flashing signal light; 2- radio beacon; 3- rotatable propulsion motor; 4- ballast tank; 5 and 6- flotation (buoyancy) units; 7- modules containing automatic control units; 8- protective cover plate which also serves as droppable solid ballast; 9- bottom pinger; 10- mounts for horizontal assembly of the vehicle; 11- high-pressure air tanks and ballast-jettison mechanism; 12- power modules.

Besides providing relative compactness and a small cross sectional area (deemed important for not disturbing bottom fauna), this design facilitates static trim and replacement of individual modules. Likewise, the drone can be easily disassembled for transport. The modular design also makes it

possible to adjust the positive buoyancy to meet the varying weight requirements of different instrument combinations and to vary the drone-operation programs by changing the automatic-control modules. The descent rate is controlled by varying the negative buoyancy before descent.

#### SPECIFICATIONS

Height, without antenna	3.25 m
Width	1.5 m
Thickness	0.38 m
Weight, in air	410 kg
Displacement, submerged and ballasted	515 kg
Operating depth, max	1000 m
Freeboard to flashing light	1.2 m
Emergency-ballast weight	40 kg
Research equipment weight, max	100 kg

The rotatable propulsion motor (the motor is probably rotated by hand to the desired angle and is then locked into this fixed position) on the Skorpena is set at an angle to the drone's vertical axis. By changing the motor's operating-time sequence and rpm's, the drone can be made to follow a variety of trajectories. When the ballast tanks are flooded to the desired amount the vehicle sinks until it reaches a predetermined depth. At this time a conventional depth gage or a bottom pinger actuates the camera (or instruments), the photo-flash unit and the propulsion motor simultaneously. As the measurement cycle completes itself, the drone again begins to descend, and the cycle repeats itself. The pinger is sensitive enough to trigger instrument and motor operation from schools of fish.

The battery capacity for the power circuit is one hour, assuming continuous propulsion-motor operation at a moderate speed. The motor (500 watts-shaft) is powered by silver-zinc batteries with a capacity of 45 amp-hrs at 27 volts. Continuous motor operation cycles ranging from 6.5 to 20 minutes are preset before launching.

In operation, the drone follows a saw-tooth trajectory which can be varied from sharp peaks to an almost flat trajectory (see Fig. 41). The program cycles repeat until the surfacing program is actuated. An emergency surfacing system has been built into the Skorpena. This system can be actuated by any of the following: water seepage into any of the modules; attainment of a critical depth; excessive time under water; a drop in the feed voltage, air pressure, etc; or attainment of a dangerous trim angle. In an emergency surfacing situation, the ballast tanks are blown and the solid ballast is jettisoned. In addition to the above described emergency surfacing systems and in the event none of them work, a tethered radiobeacon/flashing light capsule can be released to aid in drone recovery if it sinks [415, 800, 801].

A cryptic newspaper article published in mid 1974 mentions the use of a drone used to study fine structure of the upper ocean layers. According to this TASS article, the drone apparently tows a sensor chain and transmits sensor readings [acoustically] to a surface buoy which, in turn, relays the data to the mother ship. The depth capability of this drone is at least 100 m [780].

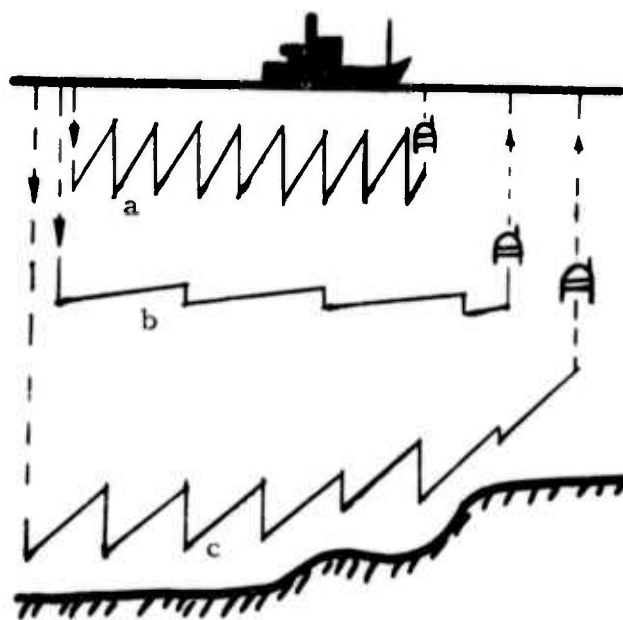


Fig. 41. Typical Skorpena Trajectories.

a - sharp sawtooth; b - horizontal; c - near-bottom.

## E. Remote-Controlled Platforms

### 1. Krab

In the 1967-68, the original Krab geological sampler (see Fig. 42) was tested. This remote-controlled platform has TV and motion-picture cameras housed in two pressure spheres. These spheres, together with two clam-shell hydraulic manipulators, train  $\pm 30^\circ$  in the horizontal and vertical. The platform responds to 22 commands from the surface ship, with all signals transmitted through a three-conductor copper logging cable with a breaking strength of 8000 kg.

#### SPECIFICATIONS

Length	2.6 m
Width	2.0 m
Height	0.8 m
Weight	
in air	500 kg
in water	200 kg
Operating depth:	
rated	4000 m
actual, max	3200 m

Work on improving the Krab was continued under the direction of Dr. V. S. Yastrebov, head of Institute of Oceanology's Underwater Research

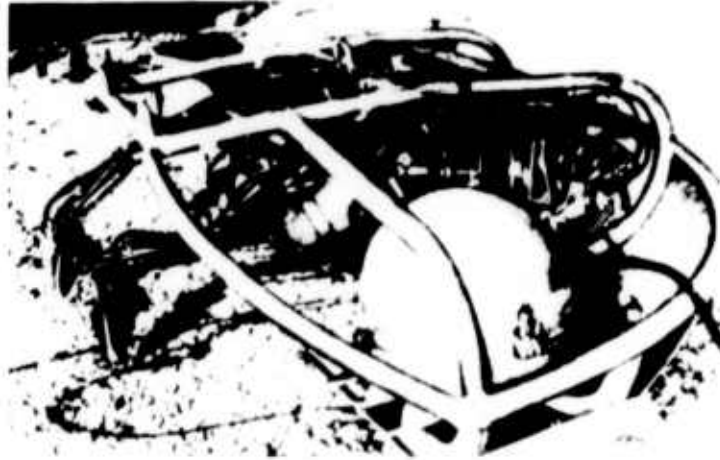


Fig. 42. Krab Remote-Controlled Geological Sampler (first model).

Equipment Laboratory. The result of these efforts was the improved Krab sampler shown below in Figure 43.

The principal problems with the original Krab were limited reach of the manipulator (the platform did not rotate) and loss of visual contact with a desired sample when Krab struck bottom or the manipulator scraped the bottom. This led to a number of interesting innovations in the newer Krab.



Fig. 43. Improved Krab Sampler.





The new Krab has three support pads which keep Krab above the bottom and permit it to rotate  $330^{\circ}$ . A single hydraulic manipulator with tactile sensors has replaced the two simple clam-shell grabs. The major improvement involves a computer-controlled sampling routine which eliminates the requirement of operator visual contact with the sample. The sampling procedure is as follows: As Krab approaches the bottom, the operator selects a landing site near objects of interest. Following landing and improvement of visibility, the operator uses a light pencil to instruct the computer on the sampling sequence by outlining the objects on a cathode ray tube. With the start command, the manipulator searches out each object in sequence, "feels" it to determine its shape, dimensions, movability, and whether or not it is a sample which the operator wants. If the sample can be moved, the manipulator picks it up and puts it in a storage container, and then moves on to the next object. When the manipulator touches the first object, operator visual contact with the desired sample is lost; nevertheless, the programmed search and sampling procedure goes on without any operator involvement. This sampler has been used to depths of about 2000 meters.

## 2. Manta Experimental Remote-Controlled Platform.

Following the development of Krab, the Institute of Oceanology began work on the Manta swimming platform (see Fig. 44). This platform is an experimental device which is used to depths of 250 m to test stabilization systems, control systems, vehicle/operator communication systems, manipulator systems, etc. This platform has been used in the Pacific Ocean near Hawaii.



Fig. 44. Manta Remote-Controlled Platform.

One of the most interesting aspects of the Manta is the development of a special operator console. Early use of Manta involving a fixed operator console showed that the operator had no "feel" for the attitude, position, and relationship of Manta to an object or the bottom terrain. To improve operator control of the platform, a special gimballed console chair was developed. This chair operates on feedback from the platform and repeats all the motions of the platform, i. e., rotation, pitch, roll. Thus, the operator is given a sense of actual participation and his ability to precisely control the platform are greatly enhanced.

### 3. BK-600 and BKT-600.

A popular press article [61] appearing in 1967 announced the planned development of a towed fish-spotting vehicle designated BK-600 and described as a "cinesonar camera." Tubes jutting forward from the "wings" would house lights and the tail assembly would contain sonar transducers. Subsequently, plans for the BKT-600 (see Fig. 45) were revealed [219] and specs data for both became available.

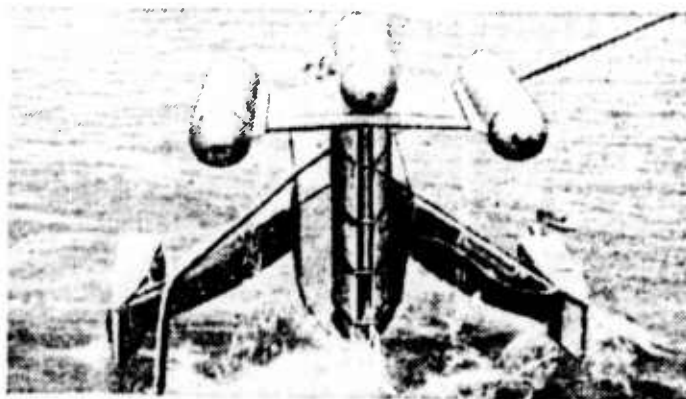


Fig. 45. BKT -600 [?] Unmanned Towed Fish-Reconnaissance Vehicle [717].

#### SPECIFICATIONS

	<u>BK-600</u>	<u>BKT-600</u>
Length, o. a.	2.8 m	3 m
Beam	2.15 m	1.5 m
Height	0.8 m	0.8 m
Displacement	0.32 tons	0.4 tons
Operating depth	600 m	600 m
Towing speed	2-4 kn	2-4 kn
Cost (approximate)	\$264,000	

The photo shown above appeared in an article on the Atlant-series vehicles and was referred to as an Atlant vehicle. Although there is no information confirming this photo as BKT-600, the earlier description of BK-600 describes the vehicle quite accurately, and comparison of the height-to-beam ratio would indicate that it is the BKT-600. No textual information is available on BKT-600; however, it is probably similar in appearance and equipment to the BK-600, with the addition of an underwater TV viewing system [72, 219, 717].

## PART III. PLANNED AND CONCEPTUAL VEHICLES

### A. Deep-Submergence Vehicles

#### 1. B-5 and B-11 Bathyscaphs

In 1959, Giprotybflot Institute designed the B-5 and B-11 bathyscaphs (see Fig. 46), capable of descending to 5 km and 11 km, respectively. The major differences between the two designs are the pressure hull thickness, the strength characteristics of critical elements, and the flotation material.



Fig. 46. B-5 and B-11 Bathyscaph Designs [35].

Lithium and aviation gas will be used as flotation material in B-11, and hollow titanium spheres and aviation gas, in B-5. The pressure hull will be steel alloy and the outer hull will be either thin shipbuilding steel or magnesium-aluminum alloy.

#### SPECIFICATIONS

Length, o. a.	15.4 - 17 m
Beam, max	3.2 m
Height	8.45 m
Operating depth	5 and 11 km
Pressure hull diameter	2.0 m
Pressure hull thickness	15 cm
Life-support endurance, normal	24 hrs
Speed	2 knots
Endurance	10 nm
Propulsion	2 hp

Two rotatable propulsion motors will provide horizontal and vertical maneuvering. Other equipment and systems include: a manipulator; echo sounder; gyrocompass; electromechanical log; air-regeneration system; etc. Mention of the B-5 and B-11 bathyscaphs has ceased in recent years, and preference seems to have been given to a two-sphere bathyscaph described below [1, 2, 25, 124, 138, 139, 140, 148].

## 2. DSB-11 Bathyscaph

In 1965, Giprotybflot Institute unveiled the design for a new bathyscaph-- DSB-11 (see Fig. 47). The fiberglass outer hull is streamlined to reduce drag submerged and under tow. This bathyscaph is to have two pressure spheres. The forward manned sphere will house the control panel, communication equipment, research equipment, and life-support systems. The after sphere will contain other systems which do not require crew monitoring and control.

Maneuvering is by two horizontal propulsion motors built into the stern horizontal stabilizers. A vertical propulsion motor is located aft of the surface navigating bridge. There are no rudders or diving planes, and maneuvering is by motor and maneuvering ballast.

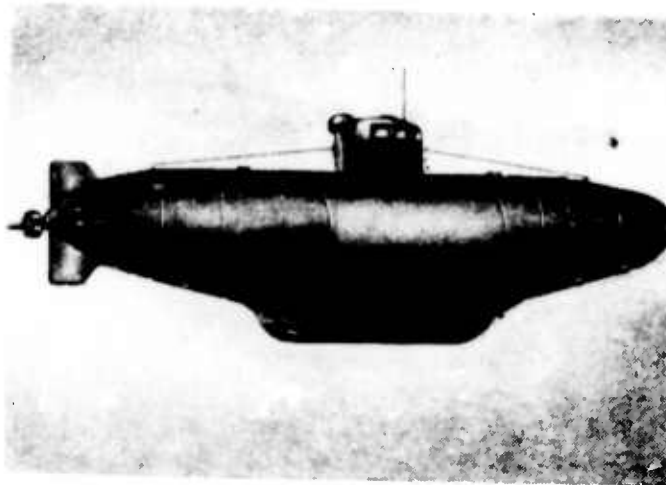


Fig. 47. DSB-11 Two-Sphere Bathyscaph [216].

### SPECIFICATIONS

Length, o. a.	15.5 m
Beam, max.	3.1 m
Height	5.3 m
Operating depth	11 km
Pressure hull diameter	2.0 m
Displacement	71 tons
Crew	2
Life support endurance, normal	144 hrs
Speed	3 knots
Endurance	20 nm
Propulsion, total	4 hp

Encapsulated lithium (9.8 tons) and aviation gas will provide flotation. Ballast spaces for the lithium and gas are  $18.5 \text{ m}^3$  and  $36 \text{ m}^3$ , respectively. Four tons of steel-shot maneuvering ballast and 2.2 tons of emergency ballast will be carried. Other equipment and systems designed into DSB-11 are: a manipulator; guiderope; underwater TV; image converter; and devices for measuring water parameters, gravity, speed of sound, magnetism, seismicity, ocean noise, etc.

High-pressure air tanks and an electric pump will be available to blow ballast tanks and pump water out of the sphere access trunk, when surfaced after a dive.

A 1970 East German source [303] stated that DSB-11 was in construction; however, there are no indications in the Soviet literature that construction is under way [1, 124, 216, 262, 303, 314, 646].

### 3. Sever-3

Virtually nothing has been written about Sever-3, and the only substantive information on plans for Sever-3 appeared in a specs table listing various fisheries research submersibles planned for construction between 1970 and 1980. The only data available on Sever-3 are given below.

#### SPECIFICATIONS

Displacement	80 tons
Operating depth	6000 m
Crew	3
Life-support endurance	3 days
Speed, submerged	3-4 knots
Cost (approximate)	\$7, 700, 000

According to the data table, lead-acid storage batteries will provide Sever-3's power [219].

### B. Limited Depth and Towed Vehicles

#### 1. Bentos-300

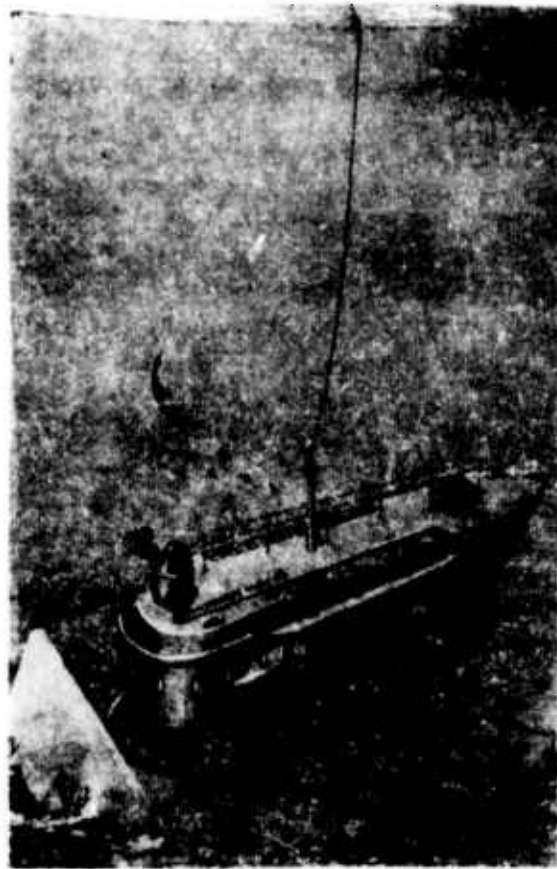
Plans for the most ambitious Soviet undersea laboratory project, Bentos-300, were first revealed by O. N. Kiselev at the 6--11 April 1966 meeting of the Section for Underwater Research of the Soviet Academy of Sciences' Oceanographic Commission. Early illustrations showing Bentos-300 were similar to the artist's conception shown in Figure 48 and based on the design shown in Figure 49.

As with many of the other vehicles discussed in this review, Bentos-300 also underwent significant design evolution. This can be seen from the most authoritative article on Bentos-300, which appeared in an early 1967 article [38]. In this article it is stated that the Giprorybflot Institute in Leningrad had completed the preliminary designs for the Bentos-300 underwater laboratory (see Fig. 50). The project was undertaken at the request of the Polar Scientific Research and Planning Institute of Fisheries and Oceanography im. N. M. Knipovich (PINRO), under the general supervision of O. N. Kiselev.

After being towed to the operation area, the sealab is capable of independent submergence, ascent, and movement for short distances at depth or near the bottom, using low-power propulsion gear.

The pressure hull is externally ring stiffened, and the bow and stern are in the form of elliptical bulkheads (see Fig. 51). The pressure hull is constructed of steel 32 mm thick with a yield point of 6000 kg/cm<sup>2</sup>, although one source indicates that the pressure hull may be 37 mm thick. Ballast tanks, trim tanks, high-pressure air tanks, and other equipment are mounted between the pressure hull and the outer hull.





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Fig. 48. Early Benthos-300 Design [392].

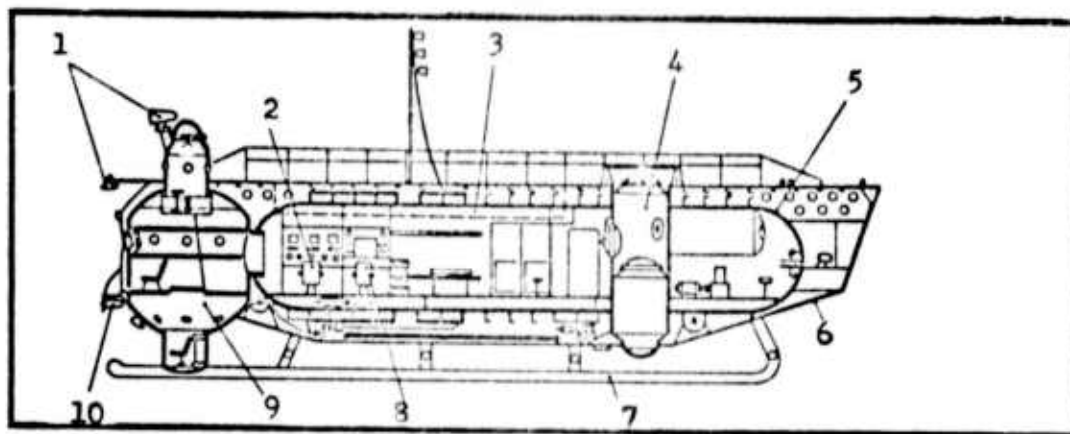


Fig. 49. Early Benthos-300 Design [20].

1- Rotating and extendable illuminators; 2- control console and research instrumentation compartment; 3- crew quarters; 4- diver access trunk and lock; 5- cylindrical steel pressure hull; 6- ballast tanks and outboard equipment stowage space; 7- skids; 8- instrument displays; 9- observation chamber; 10- propulsion unit.

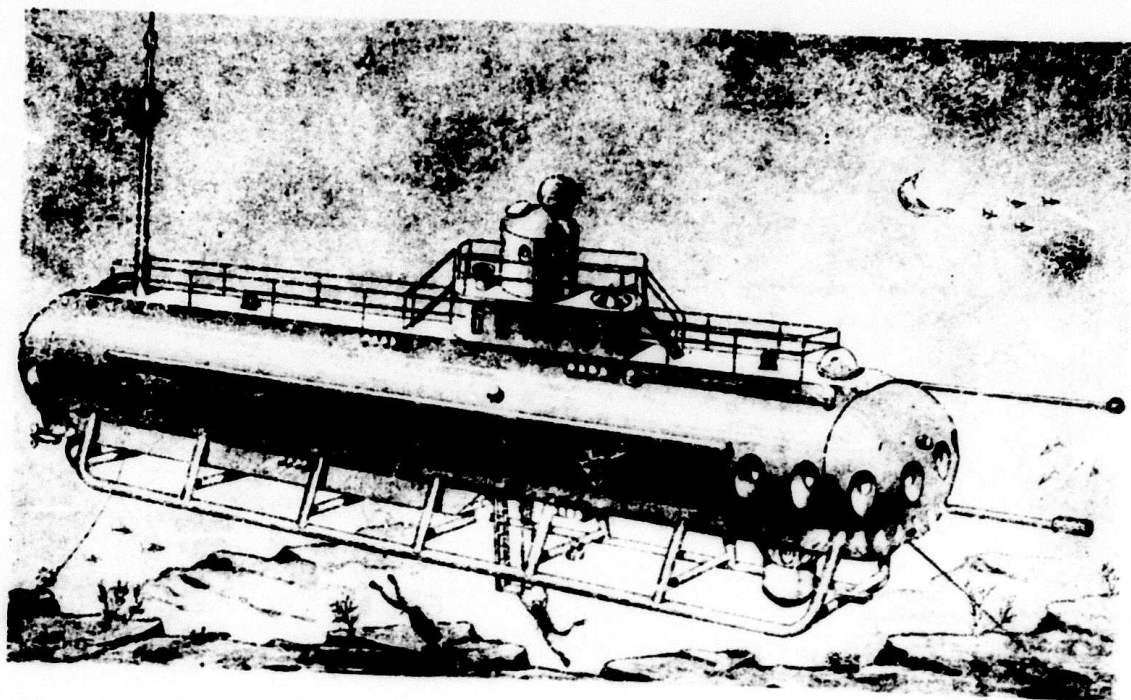


Fig. 50. Later Bentos-300 Design [38].

Electric power sufficient for two weeks of research is provided by storage batteries. Diving equipment in the sealab will permit short excursions by two divers at depths to 200 m. The scientific-research equipment aboard weighs about 3000 kg and is situated in the central post and observation compartment. Control and monitoring of the basic systems and equipment is performed remotely from the central control post. This space also houses helium-oxygen tanks and diver-support systems, and it is manned by a systems technician and an instrumentation operator-observer in 2-shift watches. The number and composition of the crew may be varied to include different types of research or working personnel.

The sealab's communications systems perform the following functions: a) two-way radio communication between the sealab and a surface ship or shore-based radio station; b) two-way hydroacoustic communication between the sealab and a surface ship or divers; c) telemetric transmission of data from measurements by probes and instruments installed on a surface buoy; and d) telephone communication within the sealab and with a ship through the surface buoy. This buoy will be equipped with light- and sound-signal equipment, and even a weather station and antenna.

In designing the Bentos-300, emphasis was placed on safety and reliability through system redundancy of the major components. In an emergency situation, the entire crew can ascend to the surface in the escape chamber, which doubles as a navigating bridge during towing and an observation chamber when

submerged. Other emergency features include automatic ballast-blowing and solid-ballast-jettison systems, which would activate due to excessive depth, fire, or dangerous change in the composition of the breathing mixture. Individual rescue equipment, as well as air, water, and food for 10 days, have been provided.

Laboratory equipment aboard includes instruments for measuring water temperature, current speed, salinity, pressure, density, transparency, light, radioactivity, and chemical composition. External illumination and observation equipment consists of fixed, rotating, and detachable floodlights, 180 degree view ports, telescopes, TV equipment, and still- and motion-picture cameras. Distant objects are observed with electrooptical converters, while television cameras and sonar are used to observe objects under poor water-transparency conditions.

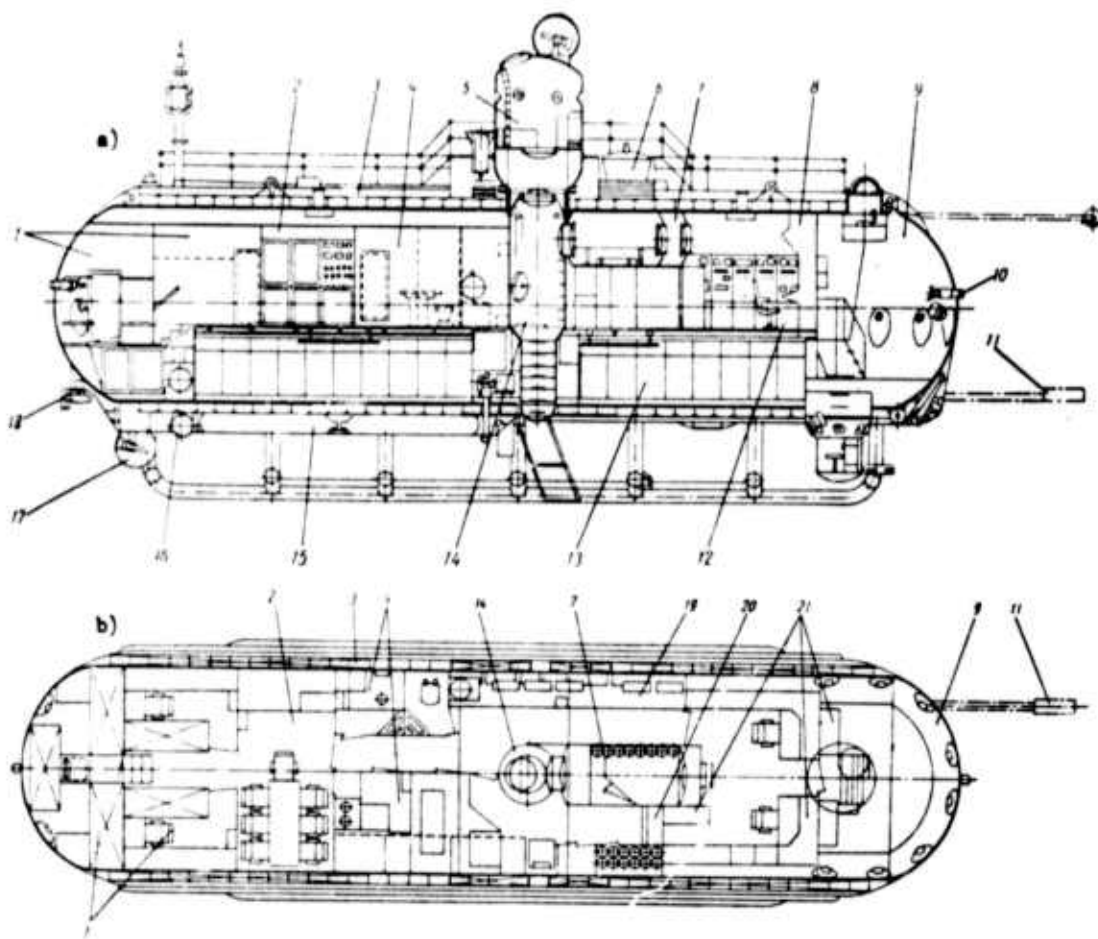


Fig. 51. General Layout of the Benthos-300 Underwater Laboratory. a) Inboard Profile, b) Plan View.

- 1- Crew quarters; 2- wardroom; 3- ballast tanks; 4- head and galley; 5- emergency escape chamber; 6- emergency marker buoy; 7- decompression chamber; 8- central control console; 9- observation compartment; 10- remote-controlled periscopic movie camera; 11- field-generator unit; 12- central control post; 13- battery well; 14- diver access trunk and lock; 15- high-pressure air tanks; 16- anchor gear; 17- sonar; 18- propulsion gear; 19- air-purification equipment; 20- diving compartment; 21- scientific equipment.

## SPECIFICATIONS

Length, o. a.	21 m
Beam, o. a.	5.5 m
Height, o. a.	11.2 m
Displacement	365 tons
Crew	10
Operating depth	300 m
Pressure-hull length	18.5 m
Pressure-hull diameter	4.5 m
View ports	26
Speed submerged	1.5 kt
Storage-battery capacity	14,500 amp-hr
Life-support endurance	15 days
Cost (approximate)	\$3,300,000

In an attempt to solve the problems of the artificial schooling of fish and the development of netless catching techniques, the sealab is to be equipped with a system of local field generators for producing light, sound, electric, magnetic, and other physical fields. This system will assist in studying fish reactions to fields of various types and intensity.

Additional research equipment carried by the Bentos-300 will be used in the following investigations:

- 1) The study of fish behavior, the process of fish-school formation, and the morphological structure of schools.
- 2) Observations in feeding, spawning, and wintering grounds, and along migration routes.
- 3) The study of fish reactions to light, sound, smell, and bait.
- 4) The study of the distribution and behavior of plankton, microplankton, and bottom life.
- 5) The continuous measurement of the speed of sound and attenuation constants, and the monitoring and tape recording of biological sounds and sea noise.
- 6) The continuous measurement of the basic physical-chemical parameters of water and its turbulence, and the study of underwater illumination from light sources having different spectral characteristics.
- 7) The study of bottom relief and sediments.
- 8) The study of the functional characteristics of fish-finding instruments and equipment.
- 9) The development and refinement of new methods of detecting commercially useful biological objects.
- 10) The development of new methods and equipment for catching commercially useful biological objects.

For on-the-spot information processing and analysis, the sealab will also include equipment for developing still pictures and motion-picture film, for analyzing water and sediment samples, for preserving marine life, etc.

In the conceptual design phase of this project, a number of engineering problems were encountered which must be solved in the final design stage. One of the most noteworthy of these is the development of an efficient power unit to replace the cumbersome, short-lived storage batteries called for in the conceptual design. It is suggested that this could be accomplished by using a compact nuclear power unit, a power buoy with an automatic diesel generator, or fuel cells. It is also proposed that the Bentos-300 be additionally supported by a two-man



diver transport vehicle to aid in collecting samples, installing various types of detachable equipment, reconnoitering the surrounding area, and communicating with the surface. This vehicle will be the AMS-200 described below.

No definite delivery date seems to have been set for Benthos-300; however, it will be sometime between 1970 and 1980. Interestingly enough, the Barents Sea has already been chosen as the sealab's first operating area [5, 13, 14, 20, 21, 29, 38, 81, 97, 141, 164, 209, 216, 219, 233, 237, 259, 322, 392, 409, 418, 419, 441, 455, 456, 488, 525, 553, 560, 645, 685, 688, 733].

## 2. AMS-200 (Nekton)

In 1968, the Giprorybflot Institute in Leningrad completed the preliminary design of the AMS-200 two-man undersea vehicle (see Figs. 52 and 53) intended for operation at depths to 450 m. This vehicle will carry out fisheries reconnaissance at depth and on the bottom, still and motion-picture photography of underwater objects, observations of fishing gear behavior, and the monitoring and interpretation of the readings of fish-finding instruments. The AMS-200 will be transported to the operating area aboard a fishing vessel.

The welded-steel pressure hull has a yield point of  $800 \text{ kg/cm}^2$  and consists of a cylindrical shell, two conical transition pieces, spherical fore and aft bulkheads, a "bubble" in bow, and an access hatch coaming. In the pressure hull there are reinforced, sealed orifices to accommodate view ports, electrical cables, piping, and an optical viewing tube.

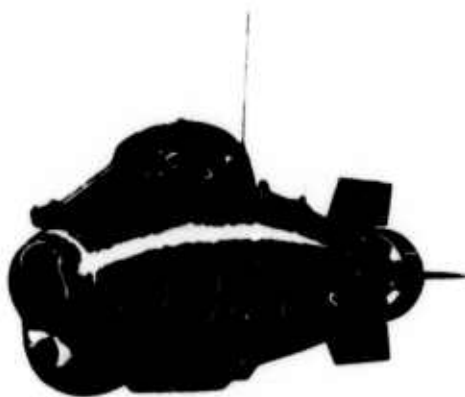


Fig. 52. AMS-200 Reconnaissance Vehicle [721].

The streamlined outer hull contains ballast tanks, high-pressure air tanks, storage batteries, an emergency signal buoy with a wire reel, electric propulsion motors, and equipment for extending the illuminators.

Submerged, the vehicle's neutral buoyancy provides easy maneuverability using the propulsion gear, the bow planes, and a trim weight which is operated manually. The trim weight also serves as droppable emergency ballast.



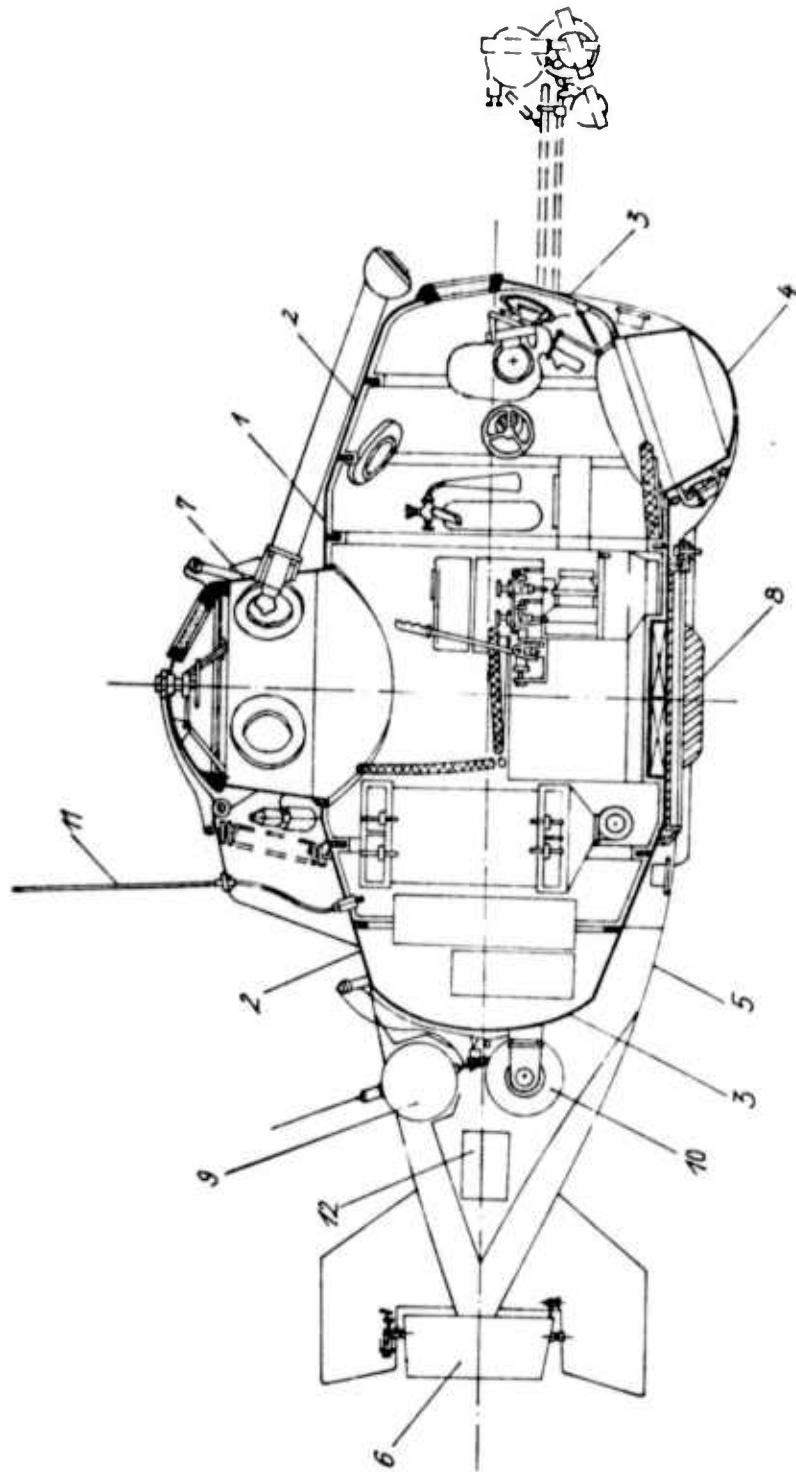


Fig. 53. Inboard Profile of AMS-200 [257].

1- Cylindrical portion of pressure hull; 2- conical transition of hull; 3- hemispherical end; 4- footwell; 5- fairing; 6- rotating Kort nozzle; 7- access-hatch coaming; 8- drop-pable trim weight; 9- signal buoy; 10- buoy payout winch; 11- surface communication antenna; 12- electric propulsion motor.

Specifications data for AMS-200 have appeared in a number of sources, with some minor and major differences. The data below indicate the spread.

### SPECIFICATIONS

Length, o. a.	3.5-3.7 m
Beam	1.10-1.80 m
Height	1.8-1.9 m
Weight	6.5 tons
Operating depth, max	450 m
Crew	2
Endurance, normal	4 hrs
Life-support endurance, max	48 hrs
Speed	6 knots
Battery capacity	10-13 kw-hrs
Cost (approximate)	\$330,000

To compensate for excess buoyancy caused by changes in water density or compression of the pressure hull, the AMS-200 is equipped with a variable-ballast system composed of two tanks. Excess positive buoyancy is compensated for by taking on water in one of the tanks. For excess negative buoyancy, the other tank, filled with water before descent, is blown.

Propulsion is provided by a twin-shaft drive unit with shrouded propellers. The 2-kw propulsion motors develop 600 rpm and drive the vehicle at 6.0 knots submerged. Maneuverability is provided in the horizontal by rotating the shrouded propellers and in the vertical by using the bow planes. A single stick and direct hydraulic transmission control the maneuvering gear.

Power aboard the AMS-200 is provided by submersible lead-acid storage batteries with a capacity of 200 amp-hr at 26 volts. Overall power available is 10 kw-hr, giving the vehicle a submerged-running endurance of 4 hours. An auxiliary 12-v storage battery with a capacity of 2.4 kw-hr is used to provide low speed and slow maneuvering.

Compressed air is stored at 200 atm in six 12-liter tanks connected by a manifold which runs through a controllable nonreturn-valve penetrator and is connected to a distribution unit. From here, the air is fed to the main- and variable-ballast tanks and also to the propulsion motors to provide pressure compensation against seawater entry. The ballast tanks have a total capacity of 400 liters, 150 liters of which can be blown at the maximum operating depth.

For underwater observations under poor natural lighting conditions, two exterior-mounted watertight lights are used. To improve overall illumination for still and motion-picture photography, a set of ISP-800 strobe lights has been incorporated into the design.

The navigation equipment of the AMS-200 includes a GPK-52 directional gyro, an echo sounder, and sonar. Communication with surface vessels is maintained with hydroacoustic comm gear.

Safety of operation is ensured by a pressure-hull safety factor of 1.4, an emergency ascent system equipped with warning signals for dropping the trim weight and batteries in case of uncontrollable descent, and an emergency signal buoy housing a radio transmitter which is released automatically from the control console. According to [216], the air regeneration unit can ensure 48 hours of breathable air in an emergency.

It is considered that the use of off-the-shelf equipment and the simplicity of the designs for the hull, components, and instruments will ensure low-cost vehicle construction and will reduce the design and construction time.

In connection with the above, in a popular article [72], several undersea vehicles being designed by the Giprotybflot Institute are discussed. The principal vehicle described in this article was the AMS-Nekton which, based on a halftone accompanying the article and the textual description, appears to be identical to the AMS-200. It is interesting to note that in this article, the AMS-200 is described as being intended for use as a reconnaissance vehicle to support Bentos-300 operations. In this role, it would reconnoiter the bottom and implant a submerged marker buoy prior to the deployment of Bentos-300. On the other hand, V. P. Speranskiy, described as being one of the project supervisors of the Bentos-300 design [38] makes no mention of the AMS-200 being involved in Bentos-300 operations. It would therefore appear that the AMS-200 has undergone a change of mission or mission priority before even getting off the drawing board [48, 61, 99, 159, 216, 219, 257, 455, 645, 650, 721].

### 3. Nekton PA-600

At a special exhibit on emerging fisheries technology, held in 1973 in conjunction with the Exhibition of the Achievements of the National Economy, a model of the Nekton PA-600 fisheries reconnaissance vehicle was shown. The only information yet available on this vehicle indicates that it will be used for visual and acoustic detection of fish. The "600" designation in the name probably denotes its operating depth [674].

### 4. Kal'mar

In the same article describing Okeaniya (Part II, para 2), one of the accompanying photos shows a drawing of the Kal'mar (see Fig. 54). Kal'mar greatly resembles Okeaniya, particularly in the placement of the view ports and the location of the side stabilizer fins. As mentioned previously, it is most probable that Kal'mar and Okeaniya are the same vehicle. However, no information other than the drawing and Dmitriyev's mention of Kal'mar's existence is yet available [308, 815].



Fig. 54. Kal'mar [308].

### 5. OSA-300

A 1968 East German article stated that the OSA-300 URV was under design by the Moscow Institute of Terrestrial Magnetism, the Ionosphere, and Radiowave Propagation. OSA-300 is to have a 300-m operating depth and a speed of 5 knots. It will be able to hover over objects, even in the presence of strong currents, and is to be equipped with a manipulator for taking bottom samples. No confirming information on this vehicle has appeared in Soviet open literature [235].

## 6. AMP-40 (Makrel')

Press articles published in 1967 announced Giprotybflot plans for the development of a two-man, flooded cockpit vehicle called, at that time, Makrel' (see Figs. 55 and 56). The missions cited for this vehicle run from sports through support of underwater engineering projects and applied oceanography to fisheries reconnaissance. This last application appears, however, to be Makrel's primary intended use. This vehicle is also known as "Akvamobil'" and "AMP-40", the latter seeming to be its "official" designation.

The forward hull area is primarily plexiglass to afford the greatest possible viewing. The stern fairing is aluminum alloy.

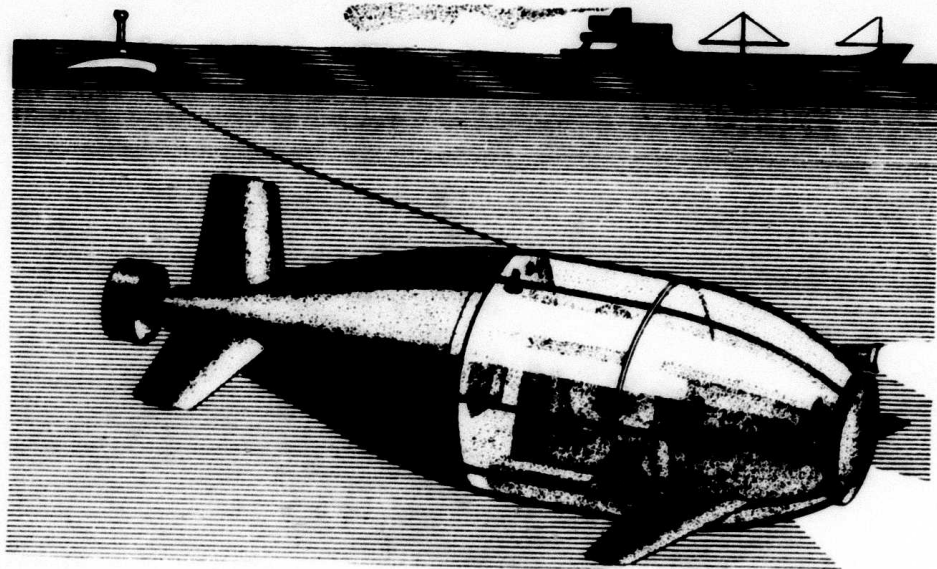


Fig. 55. AMP-40 (Makrel') [216].

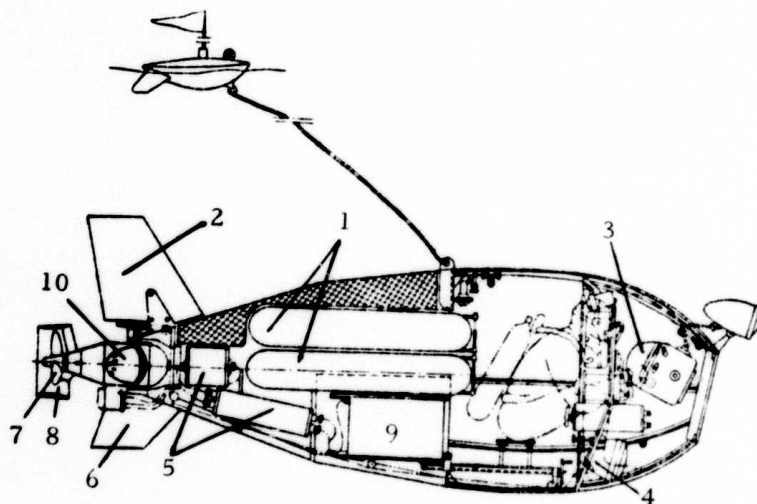


Fig. 56. Inboard Profile of AMP-40 (Makrel') [626].

1 - Air tanks; 2 and 6 - stabilizers; 3 - movie camera; 4 - illuminator; 5 - drive and control systems; 7 - prop; 8 - prop shroud; 9 - storage battery; 10 - electric propulsion motor; 11 - antenna buoy.

## SPECIFICATIONS

Length, o. a.	3.7 m
Beam	1.5 m
Height	1.2 m
Weight, in air	850 kg
Operating depth	40 m
Crew	2
Life-support endurance	2 hrs
Speed, submerged	6 knots
Battery capacity	200 amp-hrs
Cost (approximate)	\$88,000

In addition to the 14-liter scuba sets worn by the pilot and observer, extra breathing air is stored in two tanks behind the crew. They probably use a "hookah" arrangement similar to that used in MAI-3. The scuba/hookah system provides AMP-40 with a two-hour life-support endurance. This vehicle tows a small-antenna buoy on the surface for radioing findings to nearby fishing trawlers. For fish-scouting missions, AMP-40 is transported aboard a trawler. A number of fisheries and fisheries-research organizations have reportedly placed orders for AMP-40 vehicles [21, 61, 216, 219, 494, 510, 520, 526, 551, 582, 626, 645.

### 7. TINRO-1

The preliminary designs for TINRO-1 were completed by Giprorybflot Institute in 1965 (see Fig. 57). Like TINRO-2, this URV design was ordered by the Pacific Ocean Scientific Research Institute of Fisheries and Oceanography (TINRO).

TINRO-1 represents a departure from the vehicles discussed throughout this report. The major differences are as follows: 1) she is powered by a diesel generator which provides a 3-knot surface-cruising range (out and back) of 1200 nautical miles and simultaneous battery charge; 2) she is the only Soviet URV discussed which has a diver lock-out system; and 3) she requires no special support ship, since she can operate out of any port or harbor.

As can be seen in Figure 57 below, the first of the TINRO-1 designs did not include a diver lock-out system. She also appears to be substantially shorter, perhaps 10 meters long as cited in several references, as opposed to 16 meters, the most commonly mentioned length.

In the improved TINRO-1 design (see Fig. 58) a combination lock-out/rescue chamber has been added, her size has been increased, and the propulsion system has been greatly modified.

The 12-mm-thick rib-stiffened cylindrical hull has hemispherical ends, with the stern end removable to replace the engine or install large items of equipment. Circular tanks, running around the hull, hold fuel, variable-ballast water, potable water, waste water, etc.



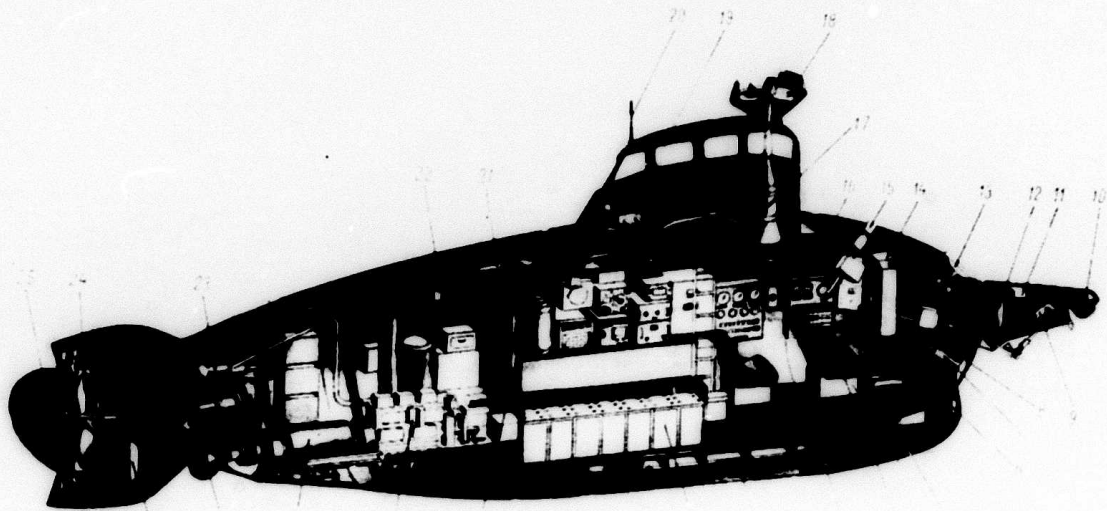


Fig. 57. Preliminary TINRO-1 Design [35].

1- Storage battery; 2- emergency ballast; 3, 6, 11- hydroacoustic transducers; 4- pilot's seat; 5- pull-out stowage space; 7- electro-optical converter; 8 and 13- view ports; 9- manipulator; 10- illuminator; 12 and 26- trim tanks; 14- control console; 15- camera-equipped view scope; 16- instrument-control panel; 17- vertical propulsion motor; 18- prop; 19- surface-running wheelhouse; 20- antenna; 21- pressure hull; 22- outer hull; 23- diesel-engine exhaust pipe; 24- horizontal-running prop; 25- rudder unit; 27- guiderope; 28- dc generator; 29- diesel engine/generator; 30- sound and heat insulating bulkhead.

The pressure-hull interior is divided into four functional sections or areas: 1) the bow section for the pilot, navigator, scientist and their electronic navigation, communication, vehicle-control, air-regeneration, and research equipment; 2) quarters, four bunks, table, lockers, etc; 3) galley, sink, shower, air-conditioning system, and breathing gear (perhaps hookah system for emergencies); and 4) the diesel-generator room with auxiliary machinery, engine-operation equipment, tool kit, scuba gear and other diving equipment.

The two-man diver lock has a rescue-bell mating flange. Diver decompression in the lock is controlled from the engine room, where the oxygen and breathing-mixture tanks are stored.

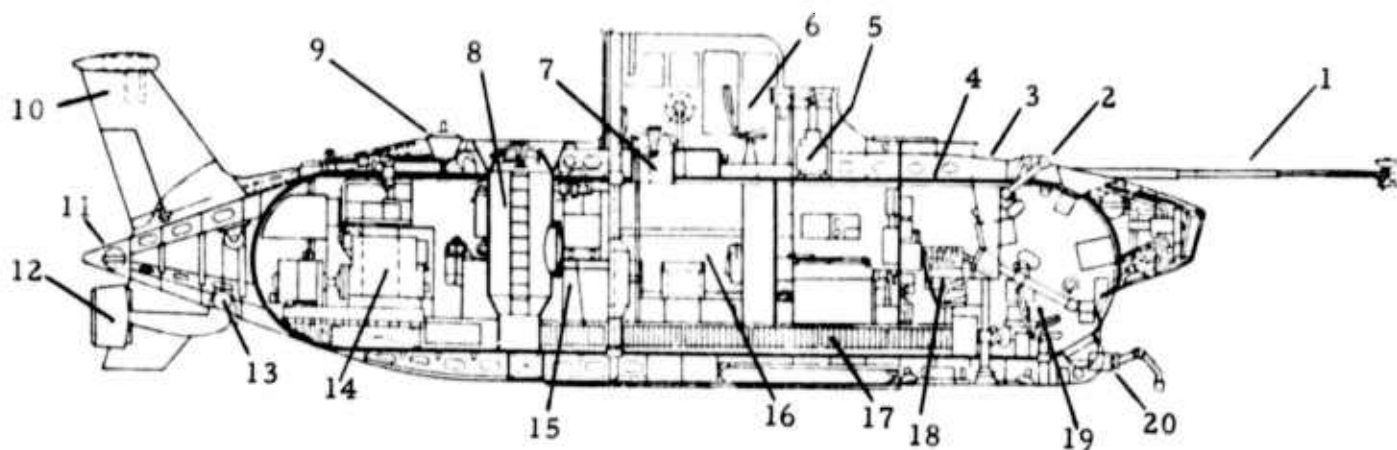


Fig. 58. Modified TINRO-1 Design [35].

1- Rotating illuminator boom; 2- viewing scope; 3- outer hull; 4- pressure hull; 5- vertical propulsion unit; 6- surface-running wheelhouse; 7- access hatch; 8- diver lock-out chamber; 9- signal buoy; 10- stabilizer; 11- mercury trim tank; 12- horizontal propulsion unit; 13- guiderope; 14- diesel generator; 15- galley; 16- crew quarters; 17- storage batteries; 18- central control post; 19- observer; 20- manipulator and extendable sample-stowage box.

#### SPECIFICATIONS

Length, o. a.	16 m
Beam	3.2 m
Height	4.3 m
Draft	2.3 m
Displacement	65 tons
Operating depth	300 m
Crew	6-7
Speed, submerged	5.7 knots
Endurance:	
life-support	20 days
range	1200 nm
submerged at 3 kn	36 nm
Pressure hull:	
diameter	2.4 m
thickness	12 mm
Diesel-fuel capacity	4 tons
Diesel generator output	50 kw
Cost (approximate)	\$3,300,000

High-pressure air tanks, storage batteries, emergency solid ballast, and measurement sensors are located below the pressure hull. On the surface, the vehicle is controlled from the floodable wheelhouse, using a portable control

unit. A 1970 East German source [316] stated that TINRO-1 was operational; however, this same source also stated that TINRO-1's length (o. a) was 10 meters and that the pressure hull was 12.6 meters long! Obviously, this source is of dubious reliability. In the literature available for this paper there is no confirming evidence that TINRO-1 is operational [2, 35, 103, 118, 124, 127, 178, 216, 219, 233, 259, 316, 625, 645].

## PART IV. DIVING SUPPORT AND SAFETY DEVELOPMENTS

Almost all the articles and references pertaining to the specific manned vehicles described above mention the availability of various types of safety systems --solid ballast jettison, shot release, etc. However, with very few exceptions, the make-up, operation, reliability, and testing of these systems is not discussed. Available surface support and rescue systems are described somewhat more specifically, but their capabilities and adaptability to crew/vehicle rescue in a URV accident are unknown. In articles describing the operational Sever-2, no mention is made of any surface search and rescue capability, either aboard R/V Odissey or available on short notice. Judging from the open literature, only the Krab TV- and manipulator-equipped remote-controlled platform could reach a distressed Sever-2 at her maximum depth and be useful in a rescue.

The best insight into some specific safety and life-support systems is provided by Soviet patent literature. Review of the patent abstract journal\* over the years has revealed a number of patents specifically applying to URV's and habitats, and many others which could apply or be adapted. It should be mentioned that, with very few exceptions, the author has made no attempt to chase down the more complete patent disclosures. For the most part, the information appearing below was taken from the Soviet patent abstract journal. The information contained in the abstracts is nonspecific and generally is only indicative of the purpose of the design and its concept.

The systems described below fall into two categories: systems used on or for testing submersibles or their components, and systems used on support ships or elsewhere, which have a bearing on submersible operation. Although the patents have been issued, there is no way of knowing whether or not they actually have been or will be used on any specific submersible. The number in parentheses following the patent number refers to the reference.

### A. Submersible Systems

1. Soviet Patent No. 307940[429]. This patent was issued for a device used to mount and jettison solid ballast or equipment.

In operation, fluid under pressure is forced into the tube which expands until the seal shown in Fig. 59 b is effected. To jettison, the hydraulic system

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\* Otkrytiya, izobreteniya, promyshlennyye obraztsy, tovarnyye znaki.

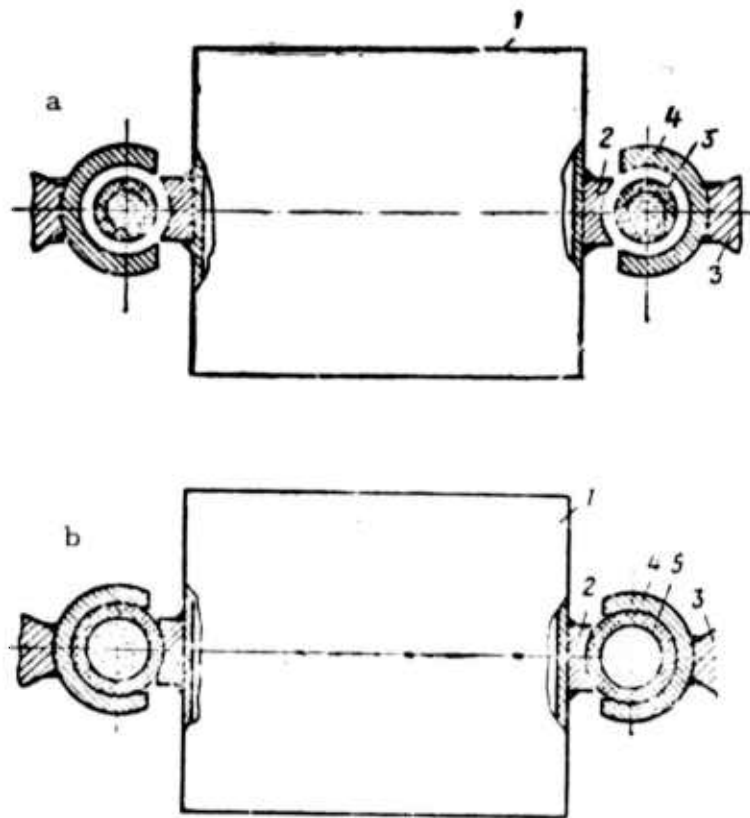


Fig. 59 a + b. Ballast/Equipment Jettison System.

1- Ballast or equipment; 2- pressure groove; 3- vehicle mount; 4- semicircular groove; 5- fluid-filled elastic tube; 6- hydraulic pressure line.

is opened, water pressure forces the fluid out of the elastic tube which collapses and releases the ballast or equipment (e. g. battery pack).

2. Soviet Patent No. 293930 [382]. This patent covers a habitat support-leg pad which has a system to help overcome bottom suction during ascent.

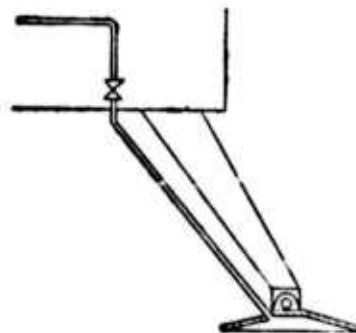


Fig. 60. Habitat Foot-Pad Release System.



High-pressure air, controlled from within the habitat, is released under the foot pad to break suction and provided some lift.

3. Soviet Patent No. 307936 [427]. This patent applies to a method for testing submersible view ports using hydraulic (water) pressure generated within the submersible. Identical view port seal seats are built into both sides (inboard and outboard) of the hull mounts. For the tests, the glass and seal system are mounted on the inboard side (see Fig. 61 a). The vehicle is flooded and pressurized

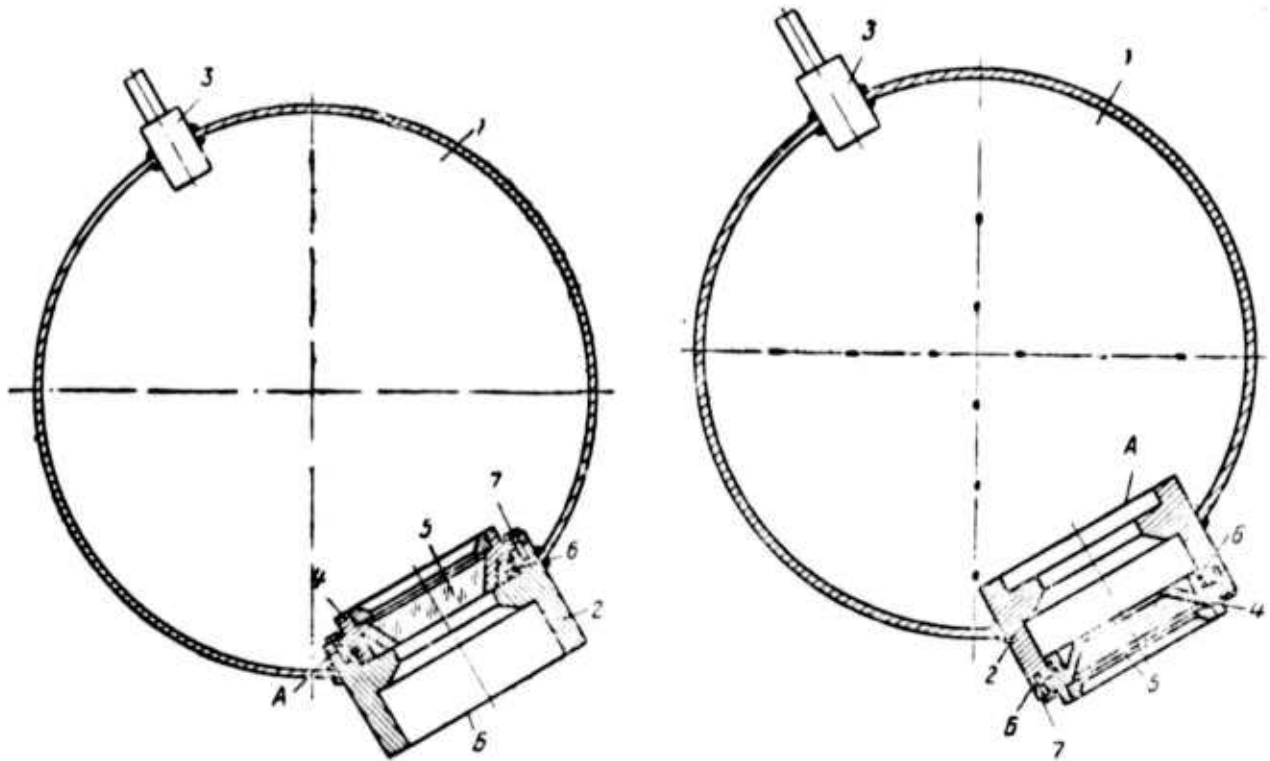


Fig. 61 a.

Fig. 61 b.

1- Pressure hull; 2- permanent hull view port mount; 3- hydraulic pressure valve; 4- view port glass seat; 5- glass; 6- seal; 7- bolt.

to the test depth and held at that pressure for 20 min. If no pressure drop is noticed, the vehicle is drained, the view port and seal are removed, and the view port is then installed in its normal outboard position (see Fig. 61b). This patent apparently pertains to simple, floodable submersibles or bells, since the patent mentions that the method is to be used on submersibles during servicing.

4. Soviet Patent No. 307937 [428]. This patent is for an electrical penetrator exposed externally to an outboard dielectric-filled vessel under ambient water pressure. The basis of the patent is the use of redundant self-sealing plugs to improve reliability and watertightness. If one of the upper plugs (7) leaks, the dielectric fills the space between the seat and the head, and pressurizes the lower plug (3).

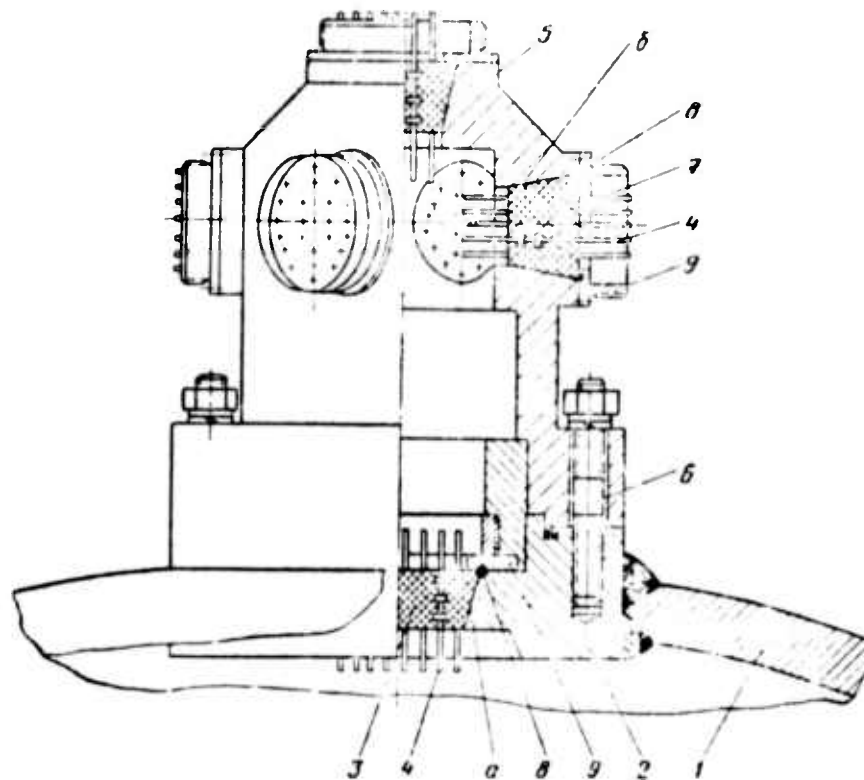


Fig. 61. Electrical Penetrator.

1- Pressure hull; 2- penetrator seat; 3- conical plug; 4- conductor pins; 5- penetrator head; 6- stud; 7- conical plug; 8- seals; 9- cover plate.

Other patents relating to different aspects of submersible systems and equipment have been issued.

#### B. Surface Systems

1. Soviet Patent No. 343895 [663]. This patent describes a catamaran support ship for a URV. In order to provide maximum working space between the catamaran hulls and to protect the submersible bottom from wave action, the support platform is capable of fore and aft movement and is equipped with locks to keep it in the working or recovery positions.

2. Soviet Patent No. 330067 [not referenced]. This patent was issued for a device used to secure to the lifting appendage on a floating object (or URV). The purpose of the patent is to reduce the weight of the lifting yoke and improve reliability. The unit apparently has an automatic engagement capability with the floating object. The standing end of the engagement line is attached to the lifting

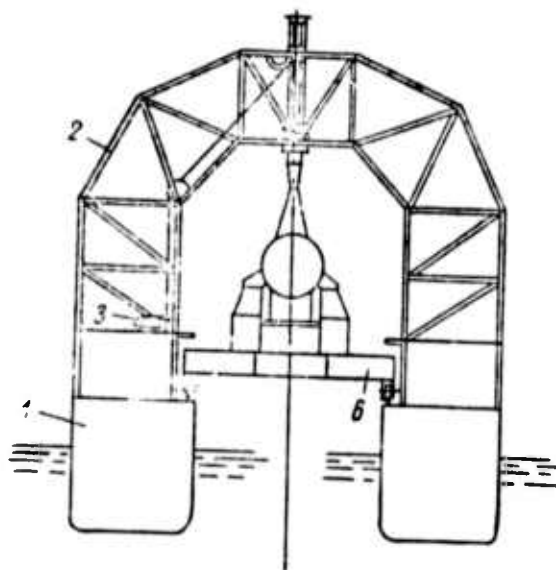


Fig. 63. Catamaran URV Support Vessel.

1 - Hull; 2 - frame; 3 - lift winch; 6 - moving platform.

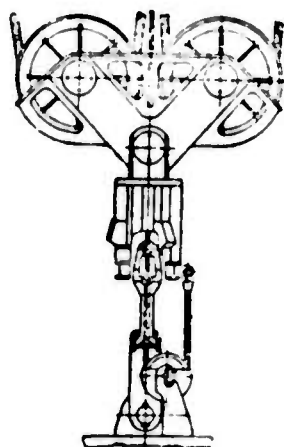


Fig. 64. Lifting Device.

sheave yoke; this line passes through a coupling which also engages with the floating object. The line then runs through lifting-sheave yoke to a winch or gypsy. When this line is taken in, the yoke is pulled down to the floating object, a coupling seats in socket, automatic engagement occurs, and the main lift winch takes in the line running through the yoke sheaves. Another patent (No. 278446) describes a very similar system in which the URV crew can release the connection from within the vehicle during launching.

3. Soviet Patent No. 335454 [629]. This patent describes a hydraulically or pneumatically operated device used to seal the mating flanges of a diving bell

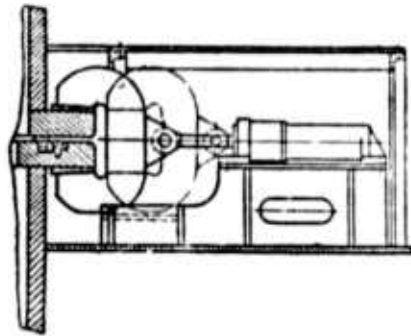


Fig. 65. Mating Flange Sealing Device.

and a decompression chamber. The operation of this device is apparent from the illustration.

The patents described above are a sampling of those available on many aspects of submersible/support systems development.

## CONCLUSIONS

In reviewing the above information, several points stand out:

1. Undersea-vehicle and support-system design is dominated by Giprotybflot Institute, a fisheries-technology design organization;
2. The past and current inventory of Soviet undersea vehicles belongs almost exclusively to fisheries-research organizations;
3. With exception of the modified fleet submarine, the Soviet Union apparently does not operate any lock-out vehicles;
4. With the exception of conventional submarines used or modified for research, the Soviet Navy does not operate free-diving undersea rescue or research vehicles;
5. There is no evidence of any preorganized rescue capability or equipment specifically intended for undersea vehicle rescue and recovery; and
6. There is no evident research or design interaction between the Soviet Navy and fisheries/oceanography organizations in the area of undersea vehicle and support/rescue development.

The first two points are accomplished fact; however, the following points do not seem reasonable. Lack of published information on these four areas makes any conclusions on any specific Soviet capability in these areas difficult, and puts any analyst in the position of having to make gross extrapolations or assumptions.

In reviewing the literature used to compile this paper, the conspicuous lack of detailed information on URV safety-related topics became very evident. There apparently is no available Soviet equivalent of the Marine Technology Society's Safety and Operational Guidelines for Undersea Vehicles or any other major Western work dealing specifically with safety, rescue, and accidents. It would be both naive and unfair to conclude from this that the Soviets have no particular interest in these areas. On the contrary, while they themselves may not be writing much on these areas, it can be easily demonstrated that they have a thorough awareness, professional knowledge, and domestic availability of Western information published on these topics.

During a recent visit to the U. S., Drs. V. S. Yastrebov and P. A. Borovikov (Chernomor-2 underwater laboratory designers) both demonstrated a vast up-to-date knowledge of U. S. and other Western achievements in URV, habitat, and remote-controlled platform development. They stated quite candidly that they had come to learn, and one of the areas in which



they showed interest was safety-related technology from the design standpoint.

Regarding accidents, in the literature reviewed for this paper, only one reference to accidents was made [560]. These accidents apparently involved amateur-built minisubs. It is not known whether any of these accidents involved loss of life. The medical literature and aerospace literature do contain a useful volume of information on diver accidents, diver physiology, diver medical problems, and life-support systems (spacecraft). The first three are discussed only in terms of free diving. Analysis of Soviet free-diver accidents generally concludes that inadequate training (sport diver accidents) and/or panic are the two major factors ultimately contributing accidents. Several of the Soviet habitat programs have involved medical and physiological research (generally, for depths not exceeding 45 meters) and some of the results have been published.

There has been an obvious lag in Soviet URV development for the scientific community. The reasons stated for this are many, but will not be reviewed extensively here; however, a contributing factor, which produces an "accordion" effect, has been the high cost of designing, building, and maintaining specialized URV support vessels and systems\*. Taking URV development costs, support ship development costs, and the cost of developing a non-military specialized rescue capability, we see not only a major financial commitment but a major science-policy commitment to manned-vehicle undersea research. To date, the Soviets have been hesitant to make this commitment on any scale even approaching the Western URV boom of the late sixties. Therefore, the small number of operational Soviet URV's must, for the time being, rely on the existing capability, which obviously resides in the Soviet Navy and probably to a less sophisticated extent, with the Soviet merchant-fleet salvage organizations. These capabilities are little publicized.

So far, the above assumptions seem logical as a generalization: however, when it gets down to specifics someone may ask: "If the Soviets are so concerned with URV development and support costs, why didn't they build the versatile, lock-out vehicle TINRO-1 rather than TINRO-2?" To that I must plead ignorance, and the answer probably lies in what isn't yet known about TINRO-2.

Finally, it is the author's hope that the information and extrapolation in this review will be helpful to others in refining their own conclusions, and that greater awareness and interest in the undersea capabilities and involvement of the Soviet Union has been stimulated.

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\* The vessels used to support the limited number of past and current Soviet URV's have been either conversions or "charters", and they have been cited as being inadequate from several standpoints.

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