BY

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Translation

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ANNOTATION

The author of this book--the first tester and commander of the TINRO-2 submersible--describes the stages of the craft's planning and construction and the unique features of its design, he offers recommendations on organizing the craft's dives and maintenance, and he shares his impressions on dives to different depths.

The book is of interest to specialists involved in the planning and operation of submersibles, as well as to all who are interested in underwater research.

FOREWORD

"We saw the bottom from a distance of 40 meters. The underwater scene literally astounded us. Before us was a jumble of huge stony lumps covered with exotic corals. We moved slowly through this stony maze, skirting obstacles cautiously. The fifth hour of our sojourn beneath the water was nearing its end."

This passage was written in my diary on 12 November 1974 following the first ocean dive of the Soviet self-contained underwater apparatus TINRO-2. The "we" referred to above included Marlen Pavlovich Aronov, science officer for the cruise of the scientific-fishing vessel "Ikhtiandr", and the author of this book, the captain-mentor of the TINRO-2 submersible, graduate of the Leningrad Shipbuilding Institute and, in the recent past, designer for the Giprorybflot [State Institute for the Planning of Fish Industry Enterprises] in Leningrad.

This dive was preceded by great and meticulous work by planners, designers, engineers, technicians, and laborers.

Underwater research began in fisheries back in 1953, when the hydrostatic vessel GKV-6, planned by A. Z. Kaplanovskiy for the emergency rescue service, was given to the Polar Institute of Fisheries and Oceanography (PINRO). Scientists made about 200 dives in this hydrostat, which was lowered by a cable from aboard the scientific research vessel "Persey-2". The obtained data had great significance to subsequent development of underwater fisheries research.

In 1958 the world's first scientific research submersible "Severyanka", a refitted battery and diesel powered submersible, was placed at the disposal of the All-Union Institute of Fisheries and Oceanography (VNIRO). It was used in 10 cruises in the North Sea basin. Colleagues of the Giprorybflot also took part in the work of the "Severyanka".

The experience of operating the GKV-6 served as the basis for a technical assignment to build a new, improved hydrostatic vessel, which was named the "Sever-1". The latter was planned in 1960 at the Giprorybflot, and it is still being used successfully today. It is outfitted with still and motion picture cameras, floodlights that may be rotated with the help of a hydraulic system, resources for communicating with the parent vessel, a depth gauge, and a gyrocompass. When lowered into the water, the hydrostat's negative buoyancy is 100 kg. Should the cable break, emergency ballast could be cast off, and the hydrostat would surface. A special shock absorber is mounted to the hydrostat's suspension in order to minimize the effects of the jerking cable in heavy seas.

In all, the hydrostat made more than 600 dives, producing valuable information on the composition of fish schools and providing explanations for the readings of fish detectors, making it possible to classify different forms of tape recordings, for example to distinguish recordings representing accumulations of plankton and fry from the recordings of fish schools. In addition, interesting observations were made of changes in the behavior of cod, herring, and haddock depending on time of day and season, and the distribution of algae in the White Sea was studied.

The rate of movement of such hydrostatic vessels relative to the bottom is limited to the drifting rate of the parent vessel, which reduces their potentials for exploration. This is why designers of the Klaypeda branch of the Giprorybflot planned the "Atlant-1" craft, specially adapted to be towed by a vessel. This made it possible to significantly increase the sea floor area surveyed in one dive, and to conduct operations with active fishing gear such as trawls. The craft carries a single passenger, its working depth is 100 meters, and its towing speed is 5 knots. Electric power is supplied to the craft by the towing cable. The course and depth of the craft are controlled by vertical and horizontal rudders. Ballast tanks assist in the lowering and surfacing of the craft.

The "Atlant-1" took part in many cruises on the Atlantic aboard the scientific research vessel "Muksun". Observations, photographs, and film obtained by hydronauts V. Korotkov and V. Martyshevskiy during dives in this craft helped designers to make better trawls having higher fishing effectiveness. A model of the craft was exhibited at Expo-67 in Canada and at the "Inrybprom-68" exhibition in Leningrad.

Control in complex conditions, for example near a moving trawl, still photography, and filming aboard the "Atlant-1" are concentrated in the hands of the sole crewmember, which of course significantly complicates his work, making it extremely tense. This is why the crew of the submersible "Atlant-2", which was designed and built in Leningrad with the direct participation of the Giprorybflot, consists of two persons. The diving depth was increased: The diving depth of the craft is 300 meters in hydrostatic mode and 200 meters in towing mode. It has a constant positive buoyancy of about 60 kg. Submersion occurs in response to a hydrodynamic force exerted upon the towed apparatus's fins, which are mounted at a slightly negative angle of attack in relation to the approaching current. As the towing speed drops, the craft rises to the surface, and when the towing vessel stops, the craft surfaces. Maximum towing speed is 6 knots.

Electric power is transmitted to the craft by the cable; the latter is also used for telephone communications.

Floating hydrodynamic buoys are attached at certain intervals to the cable in order to impart zero buoyancy to it. In an emergency situation the craft commander can sever the cable with a special pneumatic cutter. The craft may surface at any time--solid ballast is simply cast off for this purpose.

For work in hydrostatic mode, ballast is suspended beneath the hull of the craft, imparting the necessary negative buoyancy to it. The craft is lowered by a cable, but without the hydrodynamic buoys.

Aft portholes permit the underwater observer to watch the operation of a moving trawl, and floodlights and electronic flash allow him to take still and motion pictures.

The craft is delivered to the region of operations on the deck of an "Atlantik" class carrier vessel outfitted with a trawl winch and a special high-power winch used to tow the craft and stow the towing cable. The craft is lowered and raised by shipboard cranes.

The "Atlant-2" craft was exhibited at the international "Inrybprom-75" exhibition in Leningrad, and it elicited considerable interest among specialists.

Soviet scientists used these craft for the first time in world practice to conduct lengthy underwater observations of fish behavior and of the work of fishing gear.

When I first came to work at the Giprorybflot, there were plans for several self-contained submersibles in various stages of readiness in the undersea technology division, and construction of the "Sever-2" craft was nearing completion. This craft, which had a diving depth of 2,000 meters, was intended for work on the continental shelf and on the ocean floor.

The current task of the division, which was staffed by highly skilled specialists and enthusiasts of this new sector of technology, was to create a self-contained underwater craft that was simple to maintain and which would operate dependably. This was to be the TINRO-2, and I immediately joined in on the work on this craft. The craft was given this name quite recently in honor of the Pacific Institute of Fisheries and Oceanography in Vladivostok. The Pacific Ocean was to be its initial principal region of operations; the figure 2 means that the crew consists of 2 persons.

This work was started when many countries of the world were building submersibles of the most diverse designs and purposes, and when a new profession--that of the hydronauts--came into being. This was the name given to people working in submersibles having a pressure hull isolating the crew from the influences of the water outside.

The hydronaut's profession is similar in many ways to that of the cosmonaut. As with a cosmonaut, a hydronaut must have great courage, he must be quick to react, and he must be maximally self-controlled, so that he could quickly make the correct decision and insure the safety of the other crew-members in any situation, no matter how complex and unexpected.

The crews of practically all such modern underwater craft are small, consisting of two or three persons. This is why the captain of the craft must know not only the layout of all mechanisms and systems installed in the craft, but also submarine navigation, communication, and diving and piloting practice, and he must be a good mechanic, sonar operator, and oceanologist. "Captains of modern submersibles" said Roswell F. Busby, "are a group of exceptionally competent, highly motivated enthusiasts filled with the desire to assist a scientist or engineer. The responsibility laid upon the captain of a submersible is measured on one hand by valuables such as human lives, and on the other hand by the capital investments, which run in the millions of dollars."

It is no accident that the "Association of Submarine Captains" was organized in the USA in 1968 with the goal of raising the dependability and effectiveness of these craft, and broadening the potentials of their use in exploration of the World Ocean. In order to become a member of this association, the individual must have experienced not less than five dives as a craft captain, one of them being to a depth of more than 200 meters.

In our country, hydronauts are still few in number, but construction of submersibles is continuing, and new captains are appearing.

CHAPTER I

THE BIRTH OF THE CRAFT

The Purpose of TINRO-2

A little history.--Can the fish in the ocean be counted?--Craft and trawl.--Craft and fish.

The first self-contained manned submersible craft was designed and built by the Swiss scientist Auguste Piccard in 1948. This was the bathyscaphe FNRS-2, intended for submersion to depths of several thousand meters. Several similar bathyscaphes appeared in the next 10 years.

It is interesting that man's penetration into the ocean with the help of self-contained technical devices began immediately with great depth. The reason for this was that the first dives were made more for the purposes of advertising and prestige than for scientific goals. Later, after visiting this completely new and unusual world, researchers and designers began thinking about the possibilities for putting bathyscaphes to practical use.

Everyone was interested first of all in the oceanic shelf, or the continental shallows, limited to a depth of 200 meters. The principal wealth of the World Ocean is concentrated on the shelf, which occupies an area of 27.5 million square kilometers, or just about 8 percent of the floor of the World Ocean. One of the first to discern the potentials offered by a submersible to exploration of the ocean was Jacques-Ives Cousteau, a pioneer of the ocean deep. (In 1953 Jacques-Ives Cousteau descended to a depth of 1,230 meters in the bathyscaphe FNRS-3.) In his book "The Living Sea," he wrote: "I became more and more convinced that to study the depthsof the ocean, we needed manned submersibles built specially for underwater operations."

Conducting explorations in shallower areas with bathyscaphes is economically disadvantageous and unfeasible owing to their large size, the difficulties of delivering them to the region of operations and of servicing them, and the high cost of their operation. Therefore beginning in about the mid-1960's almost all developed countries began building self-contained submersibles intended to dive to depths of several hundred meters. These were new undersea transportation resources used to convey researchers deep into the ocean, differing fundamentally from bathyscaphes. First, buoyancy is achieved in them basically with a pressure hull, rather than with a float filled with gasoline or other fluid having density lower than the density of sea water, as is done with bathyscaphes. Second, the displacement of these craft is several times less than the displacement of bathyscaphes, and it does not exceed 10-15 tons. The overall dimensions of self-contained craft are also significantly lower, and therefore they may be delivered to the region of explorations aboard a carrier vessel, or even an airplane.

In 1955 the French Administration for Undersea Explorations began planning one of the first of such submersibles, "Denise", named after the wife of the chief designer, Jean Mollard. Jacques-Ives Cousteau's ideas were laid at the basis of the design.

Apressure hull with lenticular shape and intended for a diving depth of 900 meters was manufactured in 1957. An accident occurred during unmanned tests of the hull in the Mediterranean Sea--the cable by which it was lowered broke, and the hull descended down to 990 meters. A new craft was not built until 2 years after this failure, and in 1959 it began to undergo tests at sea, this time successfully.

During the time of its operation, "Denise" made more dives than any other craft of this type (performing numerous oceanographic studies and observing the behavior of deepsea life forms). U.S. scientists leased the craft twice for long periods of time to perform an extensive complex of undersea operations, particularly to conduct geological explorations. Many have been able to see this craft in the fabulous films of Jacques-Ives Cousteau, taken under water.

"Denise" was the starting point for construction of submersibles in many countries of the world.

Since 1960, more than 150 submersibles have been built in the world, with about 90 of them capable of diving to 200 meters. The largest quantity of such craft was built in the USA, the FRG, Japan, and France. They are being used successfully in both integrated and specialized hydrological, oceanological, ichthyological, geological, and archeological studies of the shelf of the World Ocean. Craft intended for technical operations such as cable laying, examination of underwater oil wells, inspection of pipelines, and so on have recently appeared.

At the time of its planning, the TINRO-2 was intended to conduct research on the continental shelf in fisheries oceanography, one of its purposes being to determine the abundance of fish, invertebrates, and crustaceans so as to permit sensible harvesting. The range of tasks that were to be performed by researchers with the help of the craft and which in many ways predetermined the work of the planners had to be clearly formulated, and the required apparatus and equipment had to be chosen.

The traditional methods for determining the abundance of fish from aboard surface vessels usually entail sampling trawl runs, sonar recordings, and bottom dredging. In such research methods the strip of ground surveyed is very limited, and the results are rather approximate and random.

Research conducted with the help of captive submersibles greatly increases the possibility for obtaining dependable information on the distribution of biological forms. But because such craft cannot move independently, undersea researchers are deprived of the possibility for choosing the object and regions of observation.

The self-contained submersible is devoid of these shortcomings. It can be used to survey large areas of ground according to a plan, after which the observation results can be extrapolated to entire fishing regions in which it is impossible to lay a trawl or tow a scoop due to certain features of the bottom.

It was believed that a self-contained submersible could explain the errors observed in sonar fish detectors used by fishing vessels. Prior to the advent of undersea observations, sonar recordings were decoded by analyzing trawl catches. Special decoding albums were published on this basis. We often encounter cases in practice where a fish detector provides distinct recordings but the trawl comes up empty or, on the other hand, where the detector remains silent but the trawl returns full of fish.

A scientist using a submersible can not only estimate the density of fish in a school and obtain an impression of its horizontal and vertical dimensions, but he can also determine their species, size, and age, and consequently make conclusions on the suitability of fishing.

Evaluating the work of a trawl in real conditions was very enticing. The length of modern trawls reaches 200 meters, and their opening is 100-150 meters wide. A trawl is a complex engineering structure that must be planned with a consideration for various factors, for example the speed at which it is to be towed. Movement of a trawl can naturally be studied with scale models in special flow channels or basins, but observations in the field are extremely valuable to designers and fishermen. They are interested in how the trawl opens, how it reaches its required depth, and how the fish enter it.

A free-ranging submersible that is not connected with its carrier vessel in any way could find a moving trawl beneath the water and observe its work only in the event that it is outfitted with modern sonar resources, and mainly if it is able to generate high speed, so as to catch up with the trawl and overtake it. However, the maximum speed of submersibles is 2-3 knots, and their navigational independence is relatively low, and therefore it was decided not to impose this task upon the creators of TINRO-2, all the more so because planners were concurrently working on the craft "Atlant-2", intended specifically to study moving fishing gear. It was felt that the working ability of the TINRO-2 craft near nonmoving fishing gear such as fixed bottom nets, crab nets, and so on could be checked later.

Observations made from a submersible open up great possibilities for ichthyologists, who are interested primarily in changes in fish behavior depending on external conditions and the time of the day. When do fish feed, when do they gather together into shoals and schools, at what time do they rise up in the water and when do they once again descend to the bottom? How does change in sea water parameters such as temperature, salinity, illumination, translucence, and the concentration of different chemical elements affect fish behavior? This is far from a complete list of the questions for which scientists would like to obtain answers.

Of course we can observe fish by placing them in large aquariums, as is still being done today. But this method does not provide conclusive answers, since the fish are in an artificial environment, which cannot but have an effect on behavior. Nor can we obtain exhaustive answers from observations of fish made with SCUBA, since depth and time under water are significantly limited for a SCUBA diver.

Bottom research is of great interest to scientists. The characteristics of seabed topography can be recorded by echo soundings from aboard a surface vessel, and data on bottom deposits are obtained with core samplers and dredges. Direct observations "tied in" with echo recordings and a map of the region can be made from a submersible, as a result of which the shape and dimensions of outcroppings, the structural elements of rock, and so on could be determined precisely. It is only from a submersible that we can observe topographic features of biological origin: various craters, cones, ridges, and depressions--the result of the vital activities of different organisms. Analyzing new information, we can establish the mutual relationship between bottom deposits, topography, currents, and the distribution of living benthic organisms.

Numerous conferences of representatives of fisheries scientific research institutes and of TINRO specialists who were to work with the craft in the future were held in order to determine the range of tasks to be performed with the help of the TINRO-2 craft, and to select the required scientific research equipment. It was only after this that the basic tasks for which the TINRO-2 submersible was intended was formulated.

It was to be used for the following:

Study of the distribution and migration of commercial fishes, crustaceans, and mollusks;

observation of the work of nonmoving fishing gear;

visual observation with the purpose of decoding the readings of fish detectors installed aboard scientific fish detection vessels;

study of the behavior of fish and other biological objects in natural conditions;

observation of accumulations of plankton and the benthos;

performance of integrated hydrological research;

exploration of the floor of the continental shelf.

Visual observations were naturally to become the principal means for acquiring information. However, the tasks listed above also required various equipment, primarily still and motion picture cameras outfitted with high-power underwater floodlights and electronic flash.

It was also decided to install a hydrological complex of instruments aboard the craft to record 8 parameters of the water outside (such complexes for submersibles had not existed in either domestic or foreign practice), and a special portable tape recorder to record underwater observations.

Of course, these were all just general plans. How well suited would the apparatus be to the tasks planned for it? Will it not frighten the fish away? Will the fish allow themselves to be photographed? Much still remained unclear, since the only experience we had was with noiseless hydrostatic vessels or towed craft, which the fish did not hear. Some believed that undersea observers would never manage to see even a single fish, since the craft is a source of noise, light, vibrations, undulations, and an electromagnetic field, which would scare the fish away. Hydrologists predicted the presence of strong underwater currents against which the craft would be helpless. Would the translucence of ocean water be sufficient at great depths, and would the floodlights be able to illuminate the zone of observation well? Questions, questions, questions.... They could be answered only in the course of the craft's operation.

Planning of the Craft

The displacement must be small.--What is to be the shape of the hull?--The crew.--The craft commander will be seated, the underwater observer will be prone.--Eight hours under water--a lot or a little?--The propulsion units.--Storage batteries and independence.--In an emergency.

And so, the purpose of the apparatus became known, and its planning could now be tackled directly.

Before starting our work we examined all similar foreign submersibles, their design, and the unique features of their operation and safety features. (The basic characteristics of some foreign craft used for shelf exaploration are shown in the table below).

Basic Characteristics of Foreign Shelf Craft

Characteristics	"Denise" (France)	"Perry Cabmarine" (USA)						"Star" (USA)			"Nekton" (USA)	"Hakkiye" (Japan)	Craft Permitting Aquanaut Egress		
		PC-3X	PC-3A	PC-3B	PC-5C	PC-9	PC-8B	"Star-1"	"Star-2"	"Star-3"			"Deep Diver" (USA)	"Shelf Diver" (USA)	"Beaver Mark-4" (USA)
Year built	1959	1962	1962	1963	1966	1970	1971	1964	1966	1966	1971	1971	1968	1968	1968
Operating depth, meters	300	90	91	180	366	400	244	60	360	600	305	300	610	244	610
Displacement, tons	3.6	4.79	2.9	3.0	8.3	10.0	5.5	1.3	4.3	10.0	2.1	6.0	8.3	8.5	15.7
Maximum speed, knots	1.0	5.0	4.0	4.5	3.0	--	4.0	1.5	3.0	4.0	3.5	3.5	4.0	3.5	3.0
Power, hp	2.0	5.0	7.0	5.0	5.5	--	5.0	--	3.0	5.5	3.5	3.0	5.5	4.5	1.5
Independent submerged operating time, hr	4.0	4.0	8.0	2.0	2.0	--	2	3.0	3.0	3.0	6.0	2.0	2.0	5.0	4.0
Cruising range, nautical miles	4.0	20.0	17.0	10.0	11.0	--	10.0	3.0	10.0	16.0	7.0	6.0	11.0	18.0	23.0
Crew, persons	2	2	2	2	4	2	2	1	2	2	2	3	1+3	2+2	3+2
Payload, kg	--	337	337	450	450	340	450	190	380	680	135	350	900	1000	900

First of all we had to determine the means for conveying the craft to the region of explorations.

Special vessels were hardly ever built abroad to carry submersibles; instead, old trawlers, coast guard cutters, pontoons, and barges were adapted for this purpose. These included the famous "Calypso", which was a trawler refitted for work with "Denise". There was the vessel "Birch-Tide", refitted by the Americans in 1963-1964 out of a 41-meter freighter for work with the same "Denise".

Foreign carrier vessels are small in size. This can be explained to a certain extent by the fact that research conducted with submersibles basically involves the coastal zone, near ports, which could always be visited to replenish supplies and allow the crew to rest.

It was believed that the regions of operations of our craft would be considerably distant from the base port, and therefore the carrier vessel had to possess good navigational qualities and high cruising independence. We had to reject high-tonnage BMRT class fishing trawlers and vessels like them because their operation requires considerable financial outlays.

After careful analysis we selected the SRTM class vessel with a displacement of 1,000-1,200 tons employing a stern trawling system. A special design office was given the job of planning its refitting as a base for the submersible. One of the principal characteristics of the craft--displacement--was selected in accordance with the dimensions of the carrier vessel. This decision satisfied the desire of the scientists to arrive at a submersible that is small in size, maneuverable, and easy to maintain. Its diving depth was set at 300 meters.

First of all we had to decide what sort of shape to impart to the pressure hull. The hulls of most foreign craft intended for work at depths down to 400-500 meters are cylindrical. Only the hull of the "Denise" has the shape of a flattened sphere, for which reason the craft was given the nickname "Diving Saucer".

Carefully thinking out all possible variants, we decided to design the hull in the form of a cylinder with spherical terminal bulkheads. This was the most appropriate shape for the hull of a craft intended for diving at such depths.

The planners were given a difficult task--they had to make all of the necessary equipment fit in a craft of rigidly limited displacement having a pressure hull of small diameter. Our industry was not producing special small-sized equipment at that time, and its development and manufacture were associated with additional material outlays, high cost of the craft, and longer construction time. Therefore we decided to make do with existing equipment to the extent possible, and develop only that with which the craft simply could not exist, mainly the propulsion units and the water pump.

After selecting the equipment that appeared necessary at first glance and tentatively working out its arrangement within the hull, we established that the displacement of the craft would be twice greater than prescribed. Thus we had to review the list of equipment, and reject some of it. By imparting a spindle shape to the pressure hull--that is, by replacing the cylindrical shells from approximately the middle of the hull to the stern by tapered shells, we arrived at a hull of the needed dimensions.

We decided to make six portholes in the hemispherical forward bulkhead such that an observer lying prone could look through the three lower portholes and a seated observer could look through the three upper ones. The main, forward porthole provided a view forward and downward, which made it possible to see possible underwater obstacles in front of the craft in time, and to concurrently inspect the bottom and its inhabitants well.

As was noted earlier, the crew of TINRO-2 was to consist of two persons--the craft commander and a researcher. The craft commander is responsible for all technical support to the dive, he monitors the operating parameters of all systems and mechanisms, and he performs the operations of separation from the carrier vessel, diving, travel to the place of operations, and return to the vessel. The underwater researcher follows a scientific program, he makes observations, takes photographs, makes motion pictures, controls the craft near the bottom, and records his observations on tape.

Because of the small diameter of the pressure hull (just a little more than 1.5 meters), it was impossible to place the two crewmembers side by side in the bow of the craft. Therefore the craft commander's seat was moved into the center, directly beneath the entrance hatch. In order to permit a view through the coaming of the entrance hatch, it was decided to make another three portholes, one on top and two on the sides. When the craft was surfaced, these portholes were to be above the water and aid the craft commander in coordinating movement of his craft with that of the carrier vessel. Thus there were to be nine portholes in the craft in all.

In order that the workplaces of the underwater researcher and the craft commander could be as large as possible, all equipment and mechanisms that were not needed for direct control of the craft were located in the back of the hull and barricaded off by a soundproof bulkhead, so that noise from this equipment would not bother the crew. As a result two compartments were formed--a manned fore compartment and an unmanned aft compartment.

All craft and monitoring instrument controls were concentrated in the fore manned compartment. Thus under normal operating conditions of the craft, the hydronauts had no need for entering the aft unmanned compartment during its independent navigation. Such a layout prevented distraction of the crew from the principal task of the dive.

A feature distinguishing submersibles from surface vessels is the equality of the weight of the craft and the weight of the water displaced by a fully submerged craft. When this condition is observed, a submersible lowered into the water should rest beneath the water surface and remain in "indifferent" equilibrium--it should not drop deeper, and it should not rise to the surface--that is, it should have zero buoyancy. Further submersion may be achieved either by turning on vertical screw propellers or by taking water aboard into a special tank.

In order to save on storage battery energy, two special weights are used to lower and raise some foreign submersibles. With these weights, the craft has negative buoyancy, and it drops down to the bottom immediately after being lowered into the water. After casting off the first weight the apparatus acquires almost zero buoyancy, and further change in depth occurs as a result of the work of vertical screw propellers. The second weight is cast off to permit surfacing. TINRO-2 uses vertical screw propellers to go up and down.

In order that the entrance hatch and its portholes would extend above the water after the craft surfaces, two ballast tanks were placed on the outer sides of the pressure hull. When they are filled with water, the craft has approximately zero buoyancy, and it is entirely submerged. When they are purged with compressed air, the craft rises to its surface position.

Such was the general design of the TINRO-2 craft, adopted in the earliest stages of its planning.

Now we had to decide how long the submersible could remain under water. This time depended on the capacity of the storage batteries and their number. On one hand the time under water had to be the longest possible. This would permit the crew to survey a large area of the seabed, take more photographs, and acquire more information, while on the other hand excessively long presence of people in a small enclosed space elicits physical and mental tension, leads to fast tiring, reduces attention, and consequently creates a potential for errors in control of the craft. The maximum time a crew can remain in foreign submersibles of this class does not exceed 6-7 hours. This is the figure used as the basis for establishing the length of the work day of hydronauts.

To permit hydronauts to remain for long periods of time under water, special large undersea self-propelled and nonself-propelled laboratories are created, equipped with sleeping places, a galley, and all of the necessary life support systems.

As the operating depth of a submersible increases, the time it needs to reach bottom and to surface, during which the crew does not collect information as a rule, increases. Therefore if the use of deep-diving craft is to be effective, their total time under water must increase as the operating depth is increased.

In addition we had to decide in the planning stage what its independent survival time would be--that is, how long the crew may remain in the craft if for some reason it does not surface or, for example, if it cannot be raised aboard the carrier vessel due to substantial deterioration of the weather. All of the necessary life support resources for the crewmembers must be foreseen in the craft for the event of an emergency. Such resources include emergency storage batteries, since the main batteries may be used as expendable ballast, reserves of oxygen and a carbon dioxide absorber or chemical regenerating agent, and an emergency reserve of water and food.

Several mishaps in which crafts were unable to rise from the bottom for a long period of time have been known in the world practice of operating submersibles. Thus in October 1969 the American submersible "Deep Quest" was working in the Gulf of California at a depth of 130 meters. A cable became wound around the screw propeller, as a result of which the craft could not rise to the surface for 30 hours. It was freed from this "prison" with the help of another submersible, the "Nekton Alpha". The crew survived.

In September 1973 the submersible "Pisces III" belonging to Great Britain was working in the Atlantic Ocean by Ireland's coast. Due to a technical malfunction it sank to a depth of about 450 meters. The craft and its crew were rescued 74 hours later with the help of three other craft, to include the remote-controlled unmanned craft "(Kurv)", which distinguished itself in the raising of the hydrogen bomb off Palmares.

While inspecting a sunken ship off the coast of Florida in 1973, the submersible "Johnson Sea-Link" snagged itself against a guard rail at a depth of 110 meters. After 16 hours, the two aquanauts died of hypothermia in the decompression chamber of the craft. The son of Edwin Link, a famous American submersible designer, died in the disaster. This craft was also rescued by the "Kurv" remote-controlled craft.

The American craft "Aluminaut" once got its nose stuck in mud and was unable to free itself for 22 hours.

One of the important tactical characteristics of a submersible is speed. The maximum speed of TINRO-2, which is intended basically for visual observations requiring slow movement relative to the bottom, was limited to a few knots. This was quite enough for research purposes. Greater speeds require significant outlays of power and fast consumption of the electric energy reserve, which means heavier batteries.

Of course it is dangerous to conduct visual observations near the bottom at such a speed, since in poor visibility the crew may fail to notice an underwater obstacle, and the craft may collide with it. Thus the porthole of the American craft "Ashera" struck a coral reef while working off the coast of Turkey in 1964. Fortunately the porthole did not break, and the craft surfaced uneventfully. However, when such a craft travels at low speed it is hard to control. And, moreover, much time is required to examine even a small area of the bottom.

At that time we were still not experienced enough in the operation of submersibles to be fully certain of what the speed of the craft should be. Therefore we settled on a compromise--the minimum speed was chosen equal to 1.5-2.0 knots. The maximum speed of most foreign craft built prior to this time was about 3.0-4.0 knots while minimum speed did not exceed 1.0-1.5 knots.

After determining the basic tactical characteristics of TINRO-2, such as displacement, diving depth, speed, time of independent operation, and the number of crewmembers, we could begin selecting specific pieces of equipment.

First of all we had to develop the propulsion unit, which includes the electric power sources, electric motors, and reduction gears that place screw propellers into rotation.

About 80 percent of today's submersibles use storage batteries, lead-acid batteries predominantly, as electric power sources. They are located outside the pressure hull, which permits reduction of its volume, and the use of a heavy battery as emergency ballast. Silver-zinc storage batteries are used less frequently, which can be explained by their high cost and lower number of charging-discharging cycles.

After a power unit consisting of hydrogen-oxygen fuel cells successfully passed the test aboard the American submersible "Star-I", a number of foreign companies began developing similar energy sources. However, such sources cannot be used aboard submersibles such as TINRO-2 intended for biological research, since during their operation they release nitrogen, oxygen, and other chemical elements that may make undesirable changes in the environment and influence the behavior of marine organisms.

It was decided to outfit TINRO-2 with submersible lead-acid storage batteries, and to locate them beneath the pressure hull in several containers, one of which was to be used as emergency expendable ballast if the craft was unable to surface conventionally.

In contrast to submarines, which change their depth through hydrodynamic forces arising on the boat's hydroplanes as it travels, most submersibles submerge and surface in response to pressure created by vertical or swiveling screw propellers.

Combined vertical and horizontal propellers are usually installed aboard submersibles; submersible electric motors that rotate horizontally are located on the sides. Sometimes water jets with swiveling nozzles are installed.

The plans of TINRO-2 called for electric motors. But where were they to be located? We analyzed the different layouts and concluded that it would be best to install them in the pressure hull. Of course, at depths greater than 1,000 meters significant power losses occur in the shaft stuffing box--

seals through which the propeller shaft passes. Owing to this we had to significantly increase the total power of the electric motor. Moreover this complicates the design of the thrust bearing, which experiences a load produced by the force of the propeller and hydrostatic pressure. However, TINRO-2 submerges only down to 400 meters, and therefore the layout finally selected for the craft's propulsion unit consisted of electric motors intended for horizontal and vertical movement of the craft, located inside the pressure hull. Such placement of the propulsion unit was to reduce the noise level created by the craft beneath the water, which would be beneficial to scientific biological research.

During the planning, we examined many variants for reversing and adjusting the rotation frequency of the horizontal and vertical screw propellers. Aboard foreign craft this is often done by changing the frequency of alternating current produced by the electric motors. Static converters are used to convert direct current into alternating current. We decided to employ mechanical adjustment in our craft. Installing direct current electric motors and varying the rotation frequency by changing voltage, or installing electric motors with several stator windings to permit stepped rotation frequency adjustment were unacceptable, because this could limit the craft's maneuverability.

The optimum variant was smooth adjustment of the frequency of propeller rotation from zero to maximum in both directions with the help of stepless friction reverse-adjusters, or variators. This is the variant we used in the craft.

In order that the nonrotating vertical propellers of the craft would develop maximum thrust when submerging and surfacing, special design measures were implemented to make the rate at which the craft surfaced and submerged the same.

Much attention was turned in the planning of the submersible to insuring the water-tightness of openings in the pressure hull. Such openings include portholes, cable inlets, and passages for various shafts. Portholes usually have a self-sealing design--that is, when outside pressure increases as depth increases, their lateral tapered surface presses harder against the opening in the craft's hull. Cable inlets may be sealed according to the same principle. The only difficulty lies with insuring a tight fit between the opening and the lateral surface of the porthole or cable inlet.

In order to insure the water-tightness of the passage for the screw propeller shaft through the pressure hull of TINRO-2, the planners suggested an original system which not only dependably sealed the shaft but also permitted constant surveillance of the condition of the seals. This system significantly facilitated preparation of the craft for submerging, and raised the navigational safety.

The screw propeller was installed on a hydraulically-driven swivel mount to permit control of the craft's heading.

The craft can move near the bottom effectively, with minimum outlays of electric energy, only in the event that it is precisely balanced--that is, if it is weightless in water. The buoyancy of the craft constantly changes due to change in compression experienced by the pressure hull depending on diving depth, and due to change in the density, salinity, and temperature of the surrounding water. Special compensating tanks were made to permit attainment of zero buoyancy. As diving depth increases, the craft becomes heavier due to compression of the hull, and in order to maintain its zero buoyancy, some quantity of water must be pumped overboard from the compensating tanks. However, this increases the density of the sea water and reduces its temperature, which makes the craft lighter. Sometimes the effects of these two forces balance themselves out almost completely, and the need for altering the buoyancy of the craft disappears.

It was decided to join the compensating tanks with the trimming tanks, and to locate them in the bow and stern of the pressure hull.

A special piston pump is used to take in and pump out sea water. It can also be used to pump water from the bow trimming tank into the stern tank and back in order to level the craft or adjust its trim.

In some foreign submersibles, the hydraulic system is located outside the pressure hull together with the pump, and its pressure is balanced relative to external pressure. The trimming-compensating system is also sometimes designed according to this principle. This produces a certain payoff in the weight of these systems aboard craft diving deeper than 1,000 meters. This payoff does not occur for craft diving a few hundred meters. Therefore these systems and the pumps were located inside the pressure hull of TINRO-2, and there was an electric motor to drive the system.

A special system was included to control movement of the craft in several modes, from manual to automatic. A system for stabilizing the depth of the craft while in motion and while hovering motionlessly in the same place was also foreseen.

When traveling near the bottom, the craft commander, whose view of the bottom is poor, surrenders control to the underwater observer. A small remote console is intended for this purpose. It bears the main craft motion control levers. One of them is used to change the depth and heading of the craft, and another is used to control traveling speed and direction (forward and reverse). The remote console is engaged by the craft commander from the main console, and the commander can immediately transfer control back to himself at any time, for example if some sort of complex situation arises.

The traveling mode control systems are redundant. Thus if automatic control fails for some reason and the craft "strays" from its required heading, the commander can switch to manual remote control using a single control lever. If this system turns out to be inoperable as well, he can switch to emergency mode. In this case the motion parameters of the craft are changed with tumbler switches, and the actuating mechanisms operate in "on-off" mode.

Manual mechanical control of all actuating mechanisms is foreseen for the most extreme case.

In order that the craft could move at a constant distance from the bottom and stop at some particular point when necessary, the craft is outfitted with an anchor-guide rope. This is a heavy metallic weight that is lowered from the craft on a thin anchor cable by a special winch located inside the craft's outer hull. The anchor-guide rope keeps the craft above the bottom if a certain quantity of water is taken into the compensating tanks. When the craft travels with a lowered anchor-guide rope, its trajectory follows all of the rises and falls of the bottom. If the anchor gets snagged against something and cannot be hauled back into the craft, the cable could be severed by a special pneumatic cutter.

The anchor-guide rope is located in the stern of TINRO-2, so that silt stirred up by it while the craft is moving would not hinder observation through the portholes. There is a device to determine the moment at which the anchor touches the bottom; when the cable sags, the device turns off the electric motor driving the winch.

Special attention was turned in the planning of the craft to navigation safety. Several backup systems for servicing the craft are foreseen for this purpose.

Ordinarily, TINRO-2 surfaces with the help of vertical screw propellers. If for some reason the vertical screw propellers fail to turn on, the craft can be raised by pumping a certain quantity of water out of the compensating-trimming tanks with the pump. If the electric power supply is completely exhausted, meaning that the vertical screw propellers cannot be engaged and the pump could not be started to remove the water, the ballast tanks could be purged by high-pressure air. The air reserve in the craft is sufficient to create relatively high positive buoyancy following the purging of the ballast tanks, even when the operating depth is great. As the craft surfaces, owing to reduction of outside pressure the air, the volume of which must constantly increase, displaces an ever-increasing quantity of water from the ballast tanks, as a result of which the craft's rate of ascent grows.

In the extreme case the craft will surface if emergency ballast, consisting of the anchor-guide rope and a storage battery, is cast off by the action of compressed air. Air necessary for this purpose is stored in special tanks, and it is not used to purge the ballast tanks.

If the craft snags itself against something on the bottom at a depth of 400 meters, all of the methods would have to be used together to surface the craft, and the positive buoyancy that may be imparted to the craft in real conditions would for practical purposes be always sufficient to permit its disengagement and surfacing. The smaller the depth at which the craft gets stuck, the greater is this force, since a larger volume of water could be released from the ballast tanks.

Special firefighting systems are foreseen. Several cases of fire have been known to occur worldwide in the operation of submersibles. Thus cable insulation caught fire as a result of a short circuit in a Japanese submersible in 1974. And although the craft reached the surface quickly, since it was not very deep, the crew of two persons could not be rescued. Personal resources for protecting the respiratory organs of the crewmembers were apparently not foreseen aboard this craft.

TINRO-2 has an air-foam firefighting system. Foam produced by injecting compressed air into a foaming agent is nontoxic, and it possesses dielectric properties, and therefore it can be used to extinguish burning electric equipment carrying a voltage.

In order to keep the crew from being suffocated by smoke and toxic gases, SCUBA outfits are situated near each crewmember. The air reserve of each of these outfits is sufficient to permit breathing at atmospheric pressure for 1 hour. This is enough time to organize the firefighting strategy and surface the craft.

All possible emergency situations were foreseen during the planning of TINRO-2, to include one where the carrier vessel is unable to raise the craft aboard for some reason, for example due to dramatic deterioration of the weather, failure of mechanisms in the lowering and lifting device, a mishap aboard the vessel itself, and so on. Sometimes the craft must be towed in such complex situations. Therefore a towing device was foreseen. A towing cable is delivered to the carrier vessel by a line-throwing gun mounted outside the craft's pressure hull. The maximum sea state and wind force at which the craft could be towed had to be determined in the tests.

In order that the underwater researcher could see the bottom well at any depth, and take still and motion pictures when necessary, high-power underwater floodlights and electronic flash had to be mounted on the craft, after first determining their locations. Were the floodlights to be located above the portholes, and were their light aimed directly downward, the bottom would appear even and smooth as a table to the observer. The images picked up by photographic film would also be distorted with such illumination. Overhead illumination permits good examination of benthic life forms, while lateral illumination permits orientation relative to submerged obstacles, but it makes observation of undersea life forms difficult. Moreover when the craft moves near the bottom it raises a large quantity of suspended particles, increasing the water's turbidity; therefore it would be best to locate the floodlights below the portholes, as close as possible to the ocean floor--something like the location of fog lights on automobiles.

After weighing all of these contradictory requirements we arrived at a compromise. Two floodlights with a broad beam were located in the forward-protruding upper part of the outer hull in such a way that they would illuminate the space before the portholes; the electronic flash and a narrow-beam long-range floodlight were aimed forward at a slight downward tilt to permit visual determination of obstacles in front of the craft. Two other floodlights were located on the sides at the bow of the craft in such a way that they would provide good illumination to the area observed from the side portholes. When desired, these floodlights could also be rotated forward to illuminatethe forward zone of observation.

Floodlights and sometimes other suspended items of equipment are situated on telescopic or rotating rods aboard some foreign craft. This method has certain advantages, since the floodlight or another instrument can be moved as close as possible to the object of observation.

Change in the craft's trim resulting from rotation or extension of such a rod is compensated by pumping water into the trimming tanks. When the craft ascends and descends, either the rods fold against its sides and the floodlights and instruments enter special recesses in the outer hull, or the rods are drawn into the side of the craft by a hydraulic system.

The plan was to install approximately this sort of rodsaboard the TINRO-2 craft.

During the craft's planning, however, the designers constantly sought better variants for locating the equipment. All instruments and devices mounted outside the pressure hull were scrutinized primarily from the standpoint of the safety of the craft's movement near the bottom. Therefore we rejected the rotating rods, since they offered a serious hazard to movement of the craft near the bottom. The electronic flash was installed in the bottom front of the outer hull. All electronic flashbulbs were turned on by a single console, and they were synchronized for photography. A wide-format "Salyut" still camera and a "Konvas-avtomat" movie camera were installed to permit filming through the portholes; it was decided to check the operation of these cameras during the tests.

Construction of the Craft

Development of the engineering plan.--Everyone wants to work on the model.--The plan is approved.--Construction of the craft can begin.--The submersibles shop.--The pressure hull is ready.--The craft's color must be "coordinated" with the fish.

The rough plan of TINRO-2 was finished.

Development of the engineering plan began. No fundamental changes were made in the layout of the craft in this stage. Its basic characteristics also remained as before, except for diving depth, which we were able to increase somewhat by implementing a number of design measures while maintaining the same weight of the craft.

The main purpose of the engineering plan was to permit selection of the best variants and their detailed development.

Thus for example the rough plan suggested three designs for the onboard ballast tanks, differing mainly in the material employed. They could be manufactured from aluminum or fiber glass. Fiber glass was recognized to be the best: Its weight was lower than that of metal. Structures made from fiber glass are easily repaired with fiber glass fabric and epoxy resin. Outer hull parts such as containers for submersible storage batteries, fins, and the keel and deck parts of the craft or the entire outer hull are made from fiber glass in foreign submersibles. Naturally we did not know how the fiber glass would react to the conditions in which the craft was to be operated at sea. We were especially troubled by the ballast tanks, which jutted out considerably and could easily be damaged when mooring the craft to a vessel. Will the fiber glass withstand such loads? This had to be checked out specially in laboratory tests. The results were good, and the final decision to use fiber glass was made.

It was decided in the engineering plan stage to additionally outfit the craft with a special bathometer--an instrument for taking sterile samples of seawater and performing subsequent microbiological analysis. The bathometer was different from all existing types: Water entered the 1-liter cylinder very slowly, in the course of 2 minutes, owing to which all biological forms present did not experience hydraulic shock during the sampling procedure, and thus they survived. In all, the bathometer could take four water samples stored in four 1-liter cylinders at any depth of the craft. The bathometer was situated above the craft's pressure hull in its central section, and its control console was situated next to the underwater observer. After surfacing of the craft and its return aboard the carrier vessel, the cylinders were removed from the bathometer, and the seawater was analyzed.

One of the main tasks of engineering planning was to create a wooden life-sized model with which to arrive at a sensible distribution of all mechanisms, equipment, controls, and monitoring instruments inside the pressure hull, and to select the most convenient places for the work of the craft commander and the underwater observer.

The locations of mechanisms, control consoles, and even of pipelines and electric circuits was modeled. They all had to be in places accessible for maintenance and repair, and at the same time they could not hinder the work of the crew. Despite the fact that it took a great deal of time to develop the blueprints for its construction and to build the model, the benefit it provided was found to be great. It was used to practice the craft commander's sequence of actions when submerging, when surfacing, and in other situations, which came in handy during the first dives.

I recall with pleasure those restless times--there was a great deal of work, it was unusually diverse, and it was very interesting. Mechanics and electricians came to lay simulated cable systems using ropes of varying diameter. The spherical fore bulkhead of the craft's pressure hull became Valentin Pavlenko's workplace. He and other specialists had to locate several large blocks of the hydrological complex which had no intention of fitting within the places allocated to them. The upshot was that the manufacturer of the complex had to change its configuration and reduce the dimensions of the blocks.

Sometimes five or six people crowded themselves together into the model of the craft, which was designed for two hydronauts. There was no room to turn, but the presence of all was required whenever any sort of difficult problems associated with repositioning an entire system of equipment had to be solved.

Our collective gave its all to the work, and the time soon came when we could say that the model was finished.

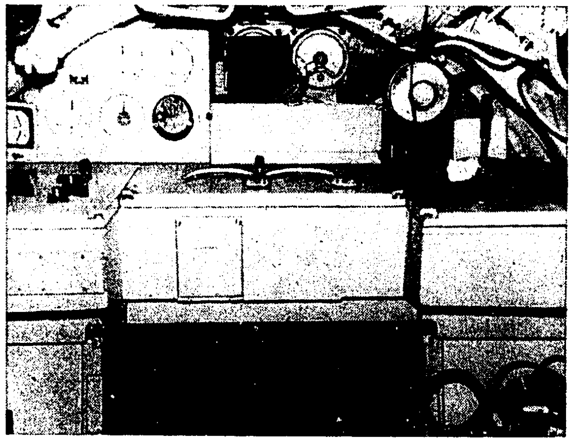
It was already clear by then that the pressure hull was brimming full with equipment, but despite this, the craft was simple to control.

Later, during its operation, it was revealed that the main console of the motion control system, which was situated across the long axis of the craft in front of the commander, was convenient to operate, but it made it difficult for the underwater researcher to reach the bow of the craft. In order to get there, he had to bend himself completely over and crawl beneath the control console through a space approximately equivalent to that between the pedestals of a small writing table. It was true, however, that following a certain amount of training this maneuver became rather swift even for people leaning toward the heavy side!

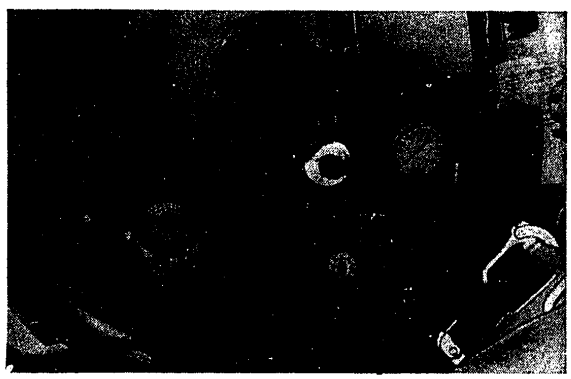
No matter how we tried to persuade the manufacturer of the control console to reduce its dimensions or alter its layout in such a way that a passage would be left in the middle of the craft, our requests were left unsatisfied. We had to leave everything as it was.

A special commission examined the results of the work, after which the general layout of the submersible was approved.

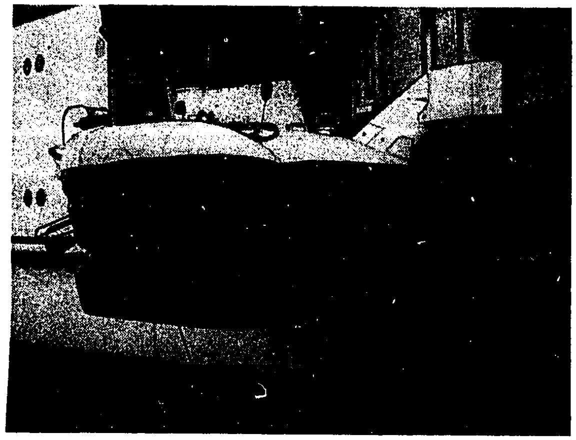
The engineering plan was completed almost simultaneously.



Craft Commander's Console



Underwater Observer's Workplace



General View of Craft

Now began the next stage--producing the blueprints for the craft's construction.

And so, our job was to create a craft with the following characteristics:

Weight, kg	10.500
Overall dimensions, meters	7.4×2.5×2.9
Diving depth, meters	400
Crew, persons	2

This period, which consisted of endless coordination conferences and meetings, often held in different cities, seemed like one long day to me. The trips made my work more varied, but the farther I traveled, the less they saw of me at home, which brought on the justified reproaches of my wife. Of course we did not yet know then that this was only the beginning of such a confusing and intense life. And imagine how many documents we had to read and edit during this period, and how many different instruction manuals had to be written!

The finished drawings of the hull and the equipment layout were submitted to the plant. At this time another plant was creating the propulsion complex, a third was manufacturing the hydraulic system, a fourth was making the compensating pumps, and so on.

Interdepartmental equipment acceptance commissions began their work. I. N. Sakhalov, an experienced specialist who had judged upon the merits of mechanisms for "Sever-1", "Sever-2", and TINRO-2--was the permanent chairman of the mechanical equipment acceptance commissions. He was very serious about his responsibilities, he knew his work down to the brass tacks, and for the most part the equipment he certified for operation did not let us down.

Manufacture of the main equipment proceeded routinely, without surprises, and everything went on schedule. But things did not go all that well with production of the scientific research equipment. The hydrological instrument complex elicited special concern. It followed an original conception. All sensors are located in a capsule. The display block is situated in the craft's manned compartment right in front of the underwater researchers, owing to which they could maintain a constant impression of the chemical composition and properties of the surrounding environment.

Similar foreign hydrological complexes used aboard submersibles, independently, or from aboard a surface vessel, usually measure sea water parameters such as temperature, salinity, and pH (a hydrogen index describing the acidity or alkalinity of water). The parameters to be measured by the complex we were designing were to be much greater in number. The measurement results had to be tape-recorded, and time readings had to be indicated. After surfacing, the tape recording was to be interpreted using another special tape recorder installed aboard the carrier vessel. Signals are fed from this tape recorder to a recorder that plots dependencies between all of the measured parameters and time or diving depth. All parameters are simultaneously recorded for subsequent computer analysis.

Naturally development of such a complex was associated with considerable difficulty. Moreover, during the work the weight and overall dimensions of this complex tripled in comparison with the initially adopted figures. And this happened even in spite of brutal rejection of everything other than that which was most necessary. "Nothing extra, only that with which we cannot do without," constantly drummed Valentin Pavlenko, who was saddled with all of the problems of the scientific equipment.

Other specialists said the same thing as well. But from their point of view other instruments were the most necessary, ones without which existence of the craft would be "entirely unimaginable"! It was very difficult to please both them and the others. The designers had to perpetually invent, alter and re-invent something or other in order to satisfy all desires.

To expand the research capabilities of the craft, a navigation system was developed concurrently with the hydrological instrument complex. In addition to a gyrocompass, it included an automatic course plotter which, receiving speed data from an electromagnetic log, had to constantly draw the course traveled by the craft on a plotting board. It was decided to use miniaturized equipment to create this system. It had never been used before this in our submersibles. We were interested in evaluating the work of this equipment under water in the presence of intense, irregular rocking and high humidity. One could be persuaded of the merits of the course plotter from its model, which worked fabulously in the laboratory.

When it came to choosing the necessary scientific research equipment, installing a "Biozvuk" sonar instrument was suggested. Using hydrophones mounted outside the craft, a researcher could record sounds emitted by fishes and other dwellers of the sea. This instrument consists of a wide-band tape recorder and an acoustic analyzer for subsequent interpretation of the obtained recordings.

However, this proposal was made too late, and a place for the instrument had not been foreseen. Thus we had to limit ourselves to introducing a cable for a hydrophone into the pressure hull, and foreseeing a power outlet for a tape recorder on the electric distribution panel. We decided to install the instrument itself after the submersible was placed into operation, when conditions favorable for doing so would appear.

The hydroacoustic equipment consists of an undersea acoustic communication station, such as one used by divers to communicate with each other, echo sounders, and a sonar set. A ready-made sonar set with appropriate overall dimensions and consumed power did not exist at that time.

At first we suggested using an ordinary fish-detecting echo sounder as the sonar set for determining presence of obstacles in front of the craft and recording fish accumulations. The vibrators were located in the bow of the outer hull, and the instrument's recorder was placed on a console in front of the craft commander. The echo sounder's effective range was sufficient for TINRO-2. We did not have any experience in using a fish-detecting echo sounder for these purposes at that time, and we were unable to say what sort of sonar display method was better--using a recorder or a cathode-ray tube.

Many specialists advised using underwater television, but by this time the craft was literally "stuffed" with instruments, and it was impossible to put anything else into it; moreover we did not have the right kind of ready-made television apparatus. Later we tried using an industrially produced television device.

At the time that the blueprints for TINRO-2 were nearing their completion, the "Sever-2" deep-diving submersible was taking its first steps in the Black Sea. A group of specialists participated in its tests, which showed how difficult it was to assimilate a new submersible.

The blueprints were finally completed, and the plant began construction of TINRO-2, which started with assembly of the pressure hull.

First of all high-precision cylindrical and tapered rings and the fore hemisphere were manufactured out of sheets of superior ship-building steel that had passed the most rigid inspections. Any deviation from proper shape beyond that permissible could lead to disintegration of the craft's hull in response to a load, even one lower than the rated load.

Then the ship assemblers and welders were given a very important task--assembling the hull of the craft out of the individual sections. The life of the hydronauts depended on the quality of their work.

After assembly and welding of the pressure hull was completed, the quality of the welded seams was checked with the greatest care using X-ray techniques; correspondence of all of its geometric dimensions with the specifications of the plan was also checked. All seams were perfect, and wherever minor deviations were discovered, reinforcements taking the form of stiffeners were installed. But there were very few such places, and the pressure hull was accepted for further work.

The pressure hull had to undergo tests in a high-pressure chamber after the steel parts of the outer hull were welded on and before the equipment was installed. Using the results of this test, plant builders and designers had to make a final evaluation of the quality of the pressure hull and the correctness of its design--in a word, they had to pass on the first major stage in the submersible's creation.

A special team of workers scrupulously prepared the hull for the test; they sealed all openings in the skin intended for the portholes, propulsion units, external fittings, and cables. The entrance hatch was already installed by this time, such that its tightness could also be tested. A special water sensing unit with a cable leading outside to a display was installed inside the hull, at its lowest point. If water appeared anywhere in the hull during the test, the sensor would immediately make this known, and the test would be halted.

The pressure hull of TINRO-2 was drawn into the pressure chamber on rails by winches. The hull was secured with metallic lashings so that it would not rise up after the chamber was filled with water. Special sensors that were to show stresses in different places on the skin in response to rising pressure were glued to the hull. The day everyone awaited with agitation finally arrived.

> The craft's pressure hull has been examined attentively for the last time. Everyone is leaving the chamber, and the hatch is closing. The noisy rush of water into it could be heard. Finally the chamber is filled--the examination has begun.
>
> The pointers of the control pressure gauges slowly crawl upward. For the first time the hull experiences the action of tons of water pressure, which it will have to endure in the future many times while working in the ocean.

> The pressure rises in stages of 10 atmospheres. The pressure is held constant for a certain time at each stage. The hull behaves excellently. Pressure is now 40 atmospheres. Now a load equal to 400 tons is acting upon every square meter of the skin. This is the load the craft will experience at working depth. The pressure is increased even higher, up to the maximum permitted by the design. The pressure cannot be increased further--the hull may disintegrate. We record the readings of all the instruments after a long period of time at this pressure. The stresses experienced by the skin of the hull are in keeping with the estimates. The signaling device indicating presence of water in the hull is silent. The difficult exam has been passed successfully! All congratulate one another. Now the pressure begins to decrease.

These first serious tests did not end until the morning of the following day. Everyone waited impatiently for the moment when the water would be drained from the chamber and the hull of the craft could be inspected. The hatch into the chamber was opened, and I was one of the first to get into the hull. No changes of any sort had occurred, and it was completely dry inside the hull. It was hard to believe that such a thin shell could withstand the tremendous water pressure.

Construction of the towed "Atlant-2" craft went on simultaneously with that of TINRO-2. This spectacle made a strong impression, and it was very pleasant to realize that our dreams were beginning to come true. The "Atlant-2" had an especially effective look about it. Installation of its equipment was finished, and the workers had started trimming and painting it. Basin trials were soon to begin. I was somewhat envious of the engineer who was to be the first tester of "Atlant-2", and I impatiently awaited the moment when TINRO-2 would achieve the same degree of readiness.

After the hull was drawn out of the chamber, experienced installers began installing the equipment and laying the numerous pipelines and cable runs.

All of the internal equipment had to be of a size allowing its introduction into the craft through the entrance hatch. Therefore whenever we received mechanisms and devices, they were all passed through a special plywood ring of the same diameter.

Every day the number of instruments increased, and looking at the boxes of equipment arranged next to the craft, it seemed as if it would be impossible to place all of this equipment inside.

We began installing the propulsion complex first. Before this, we tested it on a plant stand on which real operating conditions were simulated to the extent possible. The friction variators, which had never been used before at sea, were checked out especially carefully. On the whole they suited our needs completely.

The external pressure compensating system intended to relieve pressure on shaft stuffing boxes, and all of the other equipment of the propulsion complexes worked very well, and immediately after their acceptance the propulsion complexes were installed in the craft.

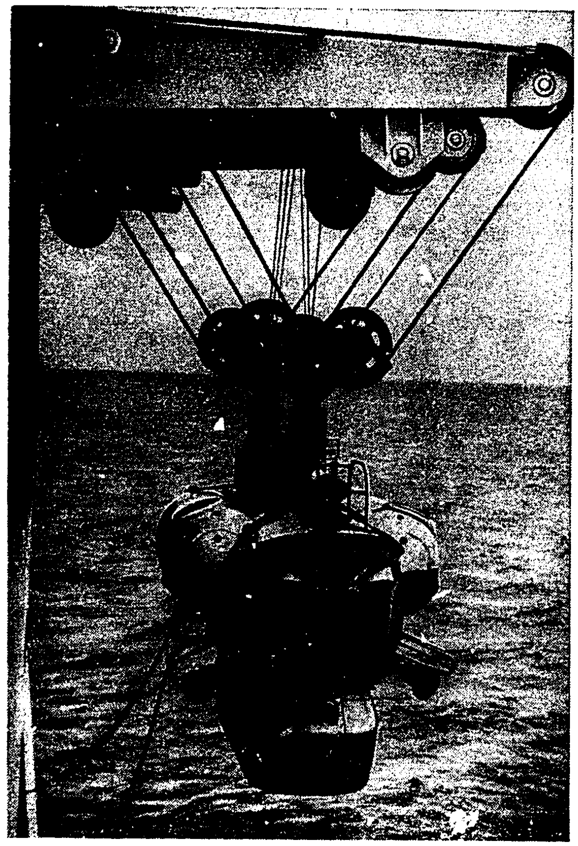
I always carried a very high opinion of the plant fitter-assemblers, but what I was able to witness during installation of the horizontal propulsion unit in the stern of the craft was beyond all praise. It would be hard to describe the sharpness displayed by the assemblers and the number of ingenious devices they employed. The complex, which consisted of an electric motor, a variator, a compensating pump, and a common frame, weighed a rather great deal, but there was only enough room, and just barely, for two persons in the stern of the craft, and moreover our main, most experienced assembler was of extremely substantial dimensions. One can imagine how difficult this work was!

When the control system was finally delivered and we saw it in its assembled form, with all of its blocks, consoles, information panels, and other parts, we thought that it would never fit in the craft, that it would not get through the entrance hatch, and if by some miracle it did, it would be impossible to turn it around in the craft. However, everything calmly assumed its place. Of course the main control console had to be designed to permit its lowering on special screws, so as to permit access to the blocks for their repair.

By spring, assembly of most of the craft's systems and mechanisms was finally finished. The craft began to take on its intended appearance. As before, all delays involved the scientific research equipment. Because the hydrological complex was still undergoing laboratory tests at this time, it was decided to fill its place with items of identical weight and overall dimensions. A capsule simulating the external sensor block and recalling in its appearance some sort of mysterious gun was mounted outside on the bow of the craft.

It took a lot of hard work to procure underwater floodlights suitable for our craft. We had to make the rounds of a large number of enterprises, but in the end they were found and installed. After this the appearance of TINRO-2 transformed completely. The portholes and greenish floodlights made it resemble a mysterious goggle-eyed fish. The similarity was emphasized by the tilted aft fins, which imparted a certain streamlined quality to its countenance.

After installation of two electronic flash units with the poetic name "Biryuza" and the "Modul'" bathometer, the craft's assembly was practically completed.



Hoisting Device

Engine Compartment

Now it had to be painted. In order that the craft would be easily noticed on a seawater background, it was desirable to paint it as bright as possible, which elicited arguments from the ichthyologists. They felt that such a finish could influence fish behavior, and since the main purpose of the craft was to observe fish, the craft had to be painted subdued, dull tones. In the end, the sides were painted traditional battleship gray while the deck was painted white, and a bright red strip that was readily distinguishable from the air was painted along the top.

What was most difficult still lay ahead--testing TINRO-2.

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CHAPTER II

THE CRAFT IS READY TO DIVE!

A Dive...Ashore

Testing of the craft in a high-pressure chamber.--The first launching.--"Freshwater" dives.--Aboard the "Ikhtiandr".--The craft goes south.

Before starting tests involving the craft's submersion, we still had to persuade ourselves once again of its complete watertightness, this time after all of the assembly jobs were completed, the cable inlets were sealed, and the portholes were installed. The craft was once again placed in the chamber, once again the water sensor was mounted inside the hull, and polyethylene bags were glued to the inside of the portholes so as to determine from the leakage which one of them was poorly sealed. The same sort of bags were glued to the cable inlets. After the craft was kept under pressure for a time, it became obvious that it was absolutely watertight, and that further tests could begin.

Now we had to think about the crew for the submersible. An extensive training program followed by examinations was developed for the future hydronauts. A special commission issued a document entitling the bearer to independent control of the craft to those who passed the tests.

Candidate hydronauts traveled to Leningrad for training at the very beginning of summer. Among them was Boris Ishtuganov, with whom I subsequently sailed a great deal, both on and beneath the water. Valentin Deryabin was also included in the program. Being an electrician, he placed all of the craft's electric and electronic equipment under his observation and control.

The triumphant moment of the first launching of TINRO-2 was approaching, but we were still totally unsure as to what vessel would be used as a base for the craft's running and state trials. A special carrier vessel for TINRO-2 had not been built yet. The "Odissey"--the carrier vessel of the submersible "Sever-2"--was on a cruise, and therefore, after weighing all of the pros and cons, we decided to step up construction of a second "Odissey" class vessel and outfit it for work with TINRO-2.

The amount of work that had to be done was not great, the vessel was soon launched, and it was christened the beautiful "Ikhtiandr".

The chief designer and I toured all of the vessel's compartments intended for work with the craft, and we established that minimum alterations would be needed, mainly in the hangar itself. It so happened that construction of the carrier vessel would be finished while we were conducting basin trials of the craft. This suited us.

Before launching the craft we had to test out its life support system. For this purpose a plant laboratory assistant and I had to sit in the craft for 12 hours, having taken the necessary reserve of food with us. Every 30 minutes she and I measured the gas composition of the air, temperature, and humidity. Our "sitting" provided us with the parameters for optimum operating conditions for the regeneration system, which functioned fabulously; the concentration of carbon dioxide and oxygen in the craft's atmosphere was normal. We also established from these tests that in an emergency, the craft's time of survival would be as long as foreseen by the plan.

The long stay in the sealed craft was especially interesting and useful to me, because I was able to evaluate my sensations, and also because I was able to once again practice, in a relaxed situation, all of the craft control operations, and "play out" possible emergency situations.

The long-awaited moment of the craft's first launching finally came. The craft was rolled out of the shop, and a representative of the plant--the mechanic in charge--and I took our places in it and closed the entrance hatch.

> I raised the pressure in the craft compartments by releasing compressed air from special tanks. In the course of several minutes we check the tightness of the seals and the air pressure within the hull. The pressure is not falling; this means that we can equalize it with atmospheric pressure and begin submerging the craft. I report this to the test leader. I can see the launching begin through the portholes. Two railroad cranes smoothly separate the craft from its keelblocks, and we hang suspended above the water. We are slowly lowered, I hear a light splash, and suddenly instead of the transparent air to which I am accustomed, turbid brownish water suddenly covers the portholes.

The main goal of the first dive was to "equalize" the craft--that is, to check its buoyancy under water. It had to be zero. This could be achieved by changing the weight of solid ballast stowed on the craft.

After the craft began rocking evenly on the water surface, the hold of the cranes was relaxed, but two thick cables still joined it to the crane booms. Having persuaded myself that everything was in order, I reported this to the command post and received permission to begin the dive.

> A little apprehensively, I open the vent valves of the ballast tanks. No one knows how the first dive will go. The craft slowly begins to disappear into the water. The water reaches the upper portholes and covers them over. A report from shore tells us that only the cover of the entrance hatch is still above water. The craft stops dropping--apparently the ballast tanks are completely filled with water. The craft's equalizing tanks are empty. I decide to fill them with water until such time that the craft would submerge completely. I open the valves, and water fills the aft tank. The aft trim increases, and the craft swiftly drops down, to the bottom. Obviously too much water in the tank. It is not more than 7-8 meters deep at this point, and in very short time we find ourselves on the muddy bottom, which is so soft that we feel not even the slightest jolt as the craft settles. The water is very turbid, and there is nothing for us to see.
>
> Pumping a little water out, I persuade myself that the craft has zero buoyancy. A command to begin surfacing is transmitted from shore. I open the ballast tank purge valve, and compressed air thunderously displaces the water from the tanks. I can hear air bubbles escaping through the flooding ports, and suddenly we find ourselves on the surface.
>
> Our first dive is finished! The cranes pluck the craft from the water and carefully place it on the keelblocks of its transporter. My mate and I crawl out of the hatch and drop down to our waiting friends. Everyone is pleased with the results of the dive. The craft and and its first crew have received their baptism of fire.

After this the dives became a daily occurrence; during them, the craft had to be subjected to what we call careening in order to determine its stability, we had to measure the thrust of the vertical and horizontal propulsion units with special dynamometers, and we had to make sure that all mechanisms operated adequately under water.

I must give all of the craft's creators their due--the mechanisms worked very well.

The electricians were concerned about the submersible storage batteries which, as experience showed, could be the source of a great deal of trouble due to the low resistance of insulation under water. However, owing to their careful maintenance by plant battery specialists, everything went all right with TINRO-2.

The craft's mechanisms and main equipment underwent meticulous inspection in real conditions. The horizontal and vertical propulsion units worked normally. During one of the dives we attached special dynamometers to the craft to measure the thrust created by the screw propellers. These tests showed that the thrust of the propellers met the specifications. This meant that the vertical and horizontal speed of the craft would be close to that planned.

The anchor winch, the electrical equipment, and the navigational and hydro-acoustic equipment also worked well.

However, we could not escape unpleasant surprises. Once during a routine dive sea water began coming in, and my mate, who was on the researcher's mat in the bow got completely soaked before we could figure out what was going on. It turned out that one of the valves had not closed completely. The participants of the tests were oblivious to time; they worked late into the evening, and sometimes even at night. This was a restless but interesting time.

The writing of the basic instructions, without which even a well trained crew was not entitled to operate a perfectly operating craft, was nearing completion. The safety rules applicable to hoisting the craft from aboard the carrier vessel and to independent navigation, and the rules of its operation had to be written out in precise and dry language. The instructions had to describe, in the proper sequence, all of the actions to be taken by the craft commander, the underwater researcher, and the maintenance personnel from the moment of the craft's preparation for a dive to the moment the underwater operations end and the craft is serviced after being returned to the hangar; all possible emergency situations had to be considered in detail, and ways to respond to them had to be recommended. It took a very long time to write up all of these documents, and it required the participation of experts. Because no one had any experience at that time in operating submersibles, it was decided to put the finishing touches on these documents after the first trials and experimental operation of the craft. We were not sure how many people there should be in the craft maintenance group, what their specialties should be, the number of replacement crews that should be aboard the vessel to insure uninterrupted work, and so on. All of this also had to be determined during experimental operation, which could begin only after the craft finished its plant and state trials.

The training of hydronaut candidates also came to an end, and an examination commission was appointed under the chairmanship of the chief of the undersea technology division. This commission included the chief designer and a large number of leading specialists involved in the planning and construction of submersibles. I had to find the time to both take the examination and assume my place among the commission members. The examinations were taken not only by crew members but also by the builders of the craft, the delivery mechanic--in a word, by all who might have to take part in dives during the craft's running trials. All hydronaut candidates passed the examination and were certified for independent control of TINRO-2.

In the meantime the craft's basin trials were completed, and we began preparing TINRO-2 for its departure for the Black Sea.

Construction of the "Ikhtiandr" was also coming to an end, and I was once again compelled to fly south to participate in its running trials. The ship's crew, headed by the captain-director, also traveled there from Kaliningrad.

In one of the last days of May 1973, late in the evening, the snow-white "Ikhtiandr" eased away from the walls of the plant. For practical purposes there were two crews aboard the vessel--plant personnel and the official crew; add to this the members of the acceptance commission. However, the plans called for a sea cruise in just 2 or 3 days, and therefore all quickly adapted themselves to the inconveniences, and a good working atmosphere was established aboard. We were on the Black Sea by morning, and we began the running trials.

I liked the "Ikhtiandr". The vessel was refitted out of an ordinary BMRT with a displacement of 3,870 tons.

The ship's crew consisted of 80 persons, including 11 scientists. The chief or assistant captain for scientific affairs was in charge of the cruise. The craft maintenance group initially included, besides the two craft crewmembers, an electrician, a mechanic, and a radio navigator.

There were nine scientific laboratories, a decompression chamber with all of the necessary equipment, a diving station, an air tank filling station, several deepwater hydrological winches, and an undersea television station aboard the vessel. Comfortable two- and four-man cabins and a cozy wardroom and mess hall equipped with television sets were reserved for members of the crew and the scientists. All of the crew quarters and service compartments were outfitted with air conditioning systems. Only the presence of the huge hangar for the submersible made our vessel different from others. The hangar was on the main deck, and it took up about a quarter of the vessel's length. At this place the left side was cut out and replaced by sliding doors, which moved on special guides. Despite their great weight, the doors opened easily with the help of electric drives.

The opening of the doors recalled a scene from a science fiction novel. There were rubber gaskets and clamps along the entire parameter of the doors, pressing them reliably against the coaming of the cut-out side when the ship traveled, so that water would not enter the hangar.

The hangar contained keelblocks for the craft and tracks upon which a lift truck conveyed the storage batteries. In order that the lift truck and its storage battery container would not roll about when the ship rocked, there was a cable drive outfitted with small winches that could be used to pull it quite safely from one position to another.

There was a compartment for storage battery repair and charging forward of the hangar. Also located there was a highly productive device used to obtain distilled water for the batteries.

The tracks led from the hangar to the stern, to a compartment in which the craft's main batteries underwent charging and maintenance.

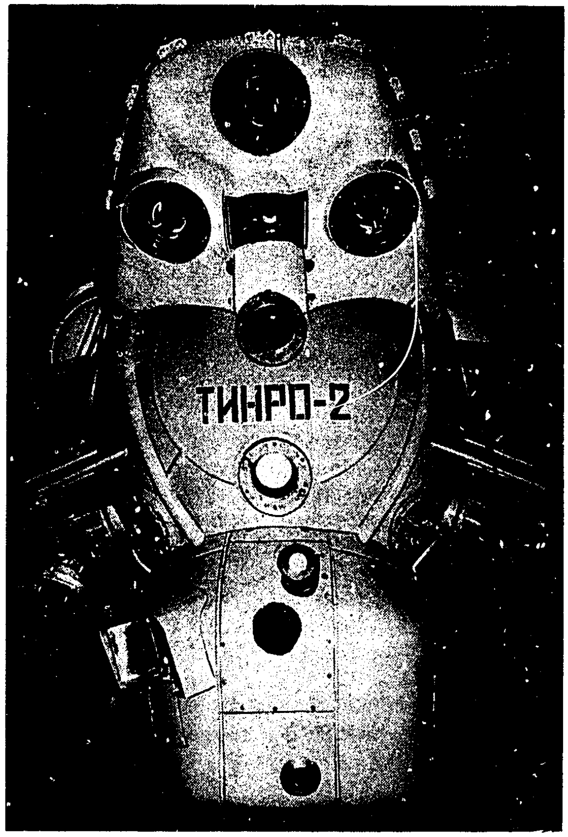
The charging unit itself was on the lower deck, and two outfits of batteries, charging cables, and a gas analyzer, used to check the hydrogen concentration in the air, were stored on racks. The compartment was hermetically sealed, and it was outfitted with a ventilation system.

The mechanical and fitting shops as well as repair shops for the radio-engineering, navigation, and sonar equipment of TINRO-2 were situated on the same deck. A separator used to clean hydraulic system oil and a portable chemical laboratory for its analysis were installed in one of the compartments.

Vast compartments on the deck below were reserved for storage of the needed spare parts, supplies, and special tools. In a word, everything was close at hand.

A powerful hoisting device was used to launch the submersible. It was built in the form of a bridge that was extended out after the doors of the hangar were opened. Cylindrical catches that locked onto the craft's hoisting rods were lowered on thick cables from the bridge. In order that the catches would not swing about when the ship rocked, and in order that they could be guided precisely to the craft's hoisting rods, prior to lowering the catches special guide cables were attached to the rods. These cables were tightened, and then the hoisting catches were lowered down them. The guide cables were wound on high-speed hydraulic winches which maintained constant tension when the craft was in the water by the side of the ship and attached to the guide cables. This guaranteed that the hoisting catches would be lowered precisely to raise the craft aboard.

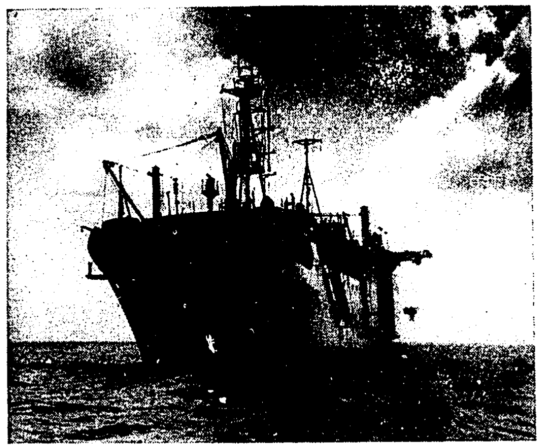
When the craft was suspended beyond the side of the ship--the bridge protruded several meters beyond the side at full extension--unavoidably the ship listed considerably. To compensate for this, special tanks were mounted on the sides in the central part of the vessel. Water was pumped from one side to the other by a high-delivery pump as the bridge and craft were extended outward.



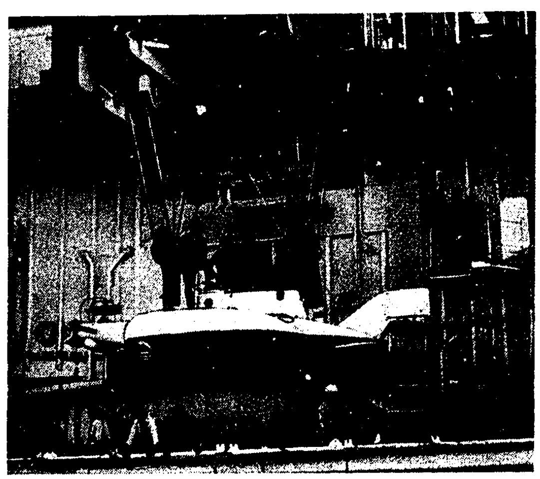
TINRO-2 From the Front

One mechanic controlled the lowering and raising of the craft and pumping of the water from a special console in a glass-enclosed cabin beneath the roof of the hangar.

An electric compressor was used to fill the craft's tanks with compressed air. The air pipelines led directly into the hangar, where they were joined to the craft's high-pressure pneumatic system by a removable pipe.



Scientific Research Vessel "Ikhtiandr" on the Ocean



The Craft in the Hangar of Its Carrier Vessel "Ikhtiandr"

All of the craft's maintenance compartments, the hangar, and the hoisting device control cabin communicated with one another as well as with the fore and aft bridges by telephone and loudspeaker systems.

Communication was maintained with the submerged craft via a special hydroacoustic station installed in the forward wheelhouse.

The vessel possessed trawling equipment, and therefore the crew also contained a trawl-master and a fish processing technician. Of course the trawl deck of the "Ikhtiandr" was somewhat smaller than on fishing vessels, which hindered the work of the trawling team, but it was still possible to catch and process fish.

The "Ikhtiandr" was also adapted for various hydrological operations--mainly recording hydrological sections, taking measurements of the direction and speed of underwater currents at different depths, investigating the bottom with various dredges and bottom scoops, and collecting plankton with a (Dzhedi) net.

Owing to presence of three hydrological winches all of these operations could be performed almost simultaneously, and consequently a sufficiently detailed impression of the region of exploration could be attained quickly.

Two sonar sets, one of which was to be used for hydroacoustic tracking of the submersible, and echo sounders made it possible to search for fish at a significant depth.

The gyrocompass, two radar sets, a radio rangefinder, and modern navigational equipment could be used to determine the vessel's location with sufficient accuracy.

It was universally recognized that the vessel was fabulously adapted for a broad complex of scientific projects during a cruise of many months in any region of the World Ocean.

The "Ikhtiandr" passed all of its tests well. The main engine, the auxiliary mechanisms, the winches, the radio-engineering and hydroacoustic equipment, and the lifeboats were all tested in action. The ship's acceptance certificate was signed.

The weather was calm during the trials, and we were unable to evaluate the ship's behavior in wavy seas. Everyone who had a relationship to the forthcoming trials of the submersible was very interested in how the ship would behave itself in wavy seas, and how this would affect operations with the submersible.

Still untested at sea were the devices necessary for operation of the craft. Before leaving the plant, the hoisting device was tested out with a special load in order to insure its normal operation.

After completing its running trials successfully, the "Ikhtiandr" returned to port. The delivery team left the ship. TINRO-2's meeting with the "Ikhtiandr" was next. The place of this meeting was Sevastopol'. It was to this place that the craft had to be conveyed by rail. However, because it was somewhat oversized, special permission had to be obtained from the railroad service before it could be loaded onto a flatcar. Finally all of the formalities were observed, the craft was loaded on the flatcar, it was covered over with a tarpaulin, and it began to resemble some sort of mysterious contraption. A freight car in which all of the spare parts were stowed was hitched to the flatcar. The plant group escorting the craft was situated in this car as well.

The craft's terrestrial period of life was coming to an end.

The Craft Meets the Vessel

TINRO-2 is loaded aboard the "Ikhtiandr".--Lowering and raising of the craft is practiced.--Preparations for sea trials.

The craft was to be delivered aboard the vessel at the start of August, and so we had to fly to Sevastopol' from Leningrad.

The "Ikhtiandr" reached Sevastopol' 2 days before TINRO-2. During this time we managed to make the preparations for its arrival. The plant delivery team came to Sevastopol' even earlier than the vessel, so as to acquaint itself with the local conditions and determine the region of operations and the order of setting out to sea. The agent responsible for delivery and I inspected the harbor's moorings and our future base, and we located and leased a floating crane with which to unload the craft from the rail flatcar.

The flatcar carrying the craft and the freight car carrying the supplies were conveyed right to the seashore on a siding. The transloading operations were performed in several stages. First the craft was transferred by the floating crane to its pontoon, upon which it conveyed it to the other side of the harbor where the "Ikhtiandr" was moored; then the craft was lowered to the mooring in front of the open doors of the hangar, and it was only after this that the craft was raised by the ship's hoisting device and placed in the hangar.

The long-awaited meeting of the craft and ship occurred. From this moment on, they became a single whole, and even when the craft left for independent navigation, it maintained invisible but sufficiently firm communication with the ship.

TINRO-2 is Loaded Aboard the "Ikhtiandr"

The work of putting the craft in its place went on for almost the entire day, everyone was tired, and so it was decided to postpone practicing the hoisting operations until the next day.

Morning of the following day began sunny and calm--we could not have wished for better weather for the practice launching.

I took my place in the craft, checked its tightness, and began waiting for its first launching at sea. Through the portholes I could see the guide cables tightening, and the main cargo catches dropping slowly along them, and I felt the sensation of the craft separating from the keelblocks. Then it was carefully raised to an elevation of about 1 meter, and after a few seconds it was rocking on the water surface.

I crawled down to the underwater observer's place and looked through the side portholes--now greenish sea water was before my eyes. Despite the fact that the water in the harbor was rather turbid, I could see the side of the "Ikhtiandr" well. It was still clean, free of growths, and lower down somewhere I could vaguely distinguish the bilge keels.

I had to inspect the cable inlets and stuffing boxes, and check the watertightness of the craft. Everything was in order, and the bumpy railroad trip did not have any effect upon the craft. I reported this to the ship and then began waiting for the craft to be raised, when suddenly I heard a totally incomprehensible noise. "Where could it be coming from?" I thought with alarm. "All of the mechanisms are turned off."

Meanwhile the noise alternately grew louder and softer, but I could not understand what was going on. No noise of any sort was heard aboard the ship, but after my report they also became concerned and started raising the craft very quickly out of the water. It was not until I was aboard the ship that it was all cleared up. It turned out that before raising the craft, it was sprayed with water from a manual fire pump in order to wash off the dirt, and I was not informed of this. What I heard, therefore, was the noise of the stream of water forcefully striking the hull.

The most difficult operation was not the launching and raising of the craft, but its placement on the keelblocks in the hangar. This operation had to be performed very precisely, with a tolerance not exceeding 10 mm, which even on the still water of the enclosed harbor was not always successful with the first try. Therefore we immediately got together with the efficiency experts, and on the spot we adapted one of the hangar winches with which to draw the craft to the necessary level.

We performed the craft launching and raising operations three times, and when we were persuaded that the mechanic understood his job well, we decided to perform them out on the open sea as soon as possible.

These first launchings demonstrated that the "Ikhtiandr" could not have been suited better to our craft, even though it had been planned for another. We were pleased most of all by the fact that the distance between the hoisting rods matched the span of the hoisting device, and therefore the latter did not need alteration. The tracks in the hangar used to convey battery containers to TINRO-2 also suited our needs. We noted with satisfaction that at maximum extension of the bridge beyond the side with the craft suspended, the ship's list did not exceed a few degrees, and therefore we did not even need to use the counterflooding tanks.

Plant representatives and designers arrived by this time to participate in the first operational sea cruise. The testing party grew extremely large by the time we were ready to set out to sea, but there was enough room aboard the "Ikhtiandr" for everyone, and comfortably as well.

Divers that were to assist in underwater operations, and provide help when necessary, also arrived. Some of them had participated as aquanauts in an experiment with the "Chernomor", an underwater house. The group was headed by Anatoliy Viktorovich--a very experienced diver, oceanologist, and operator. He intended to film our work and the craft's first steps. Getting a little ahead of myself, let me say that such a film was made. Cuts from it were shown on Central Television during a program devoted to the ocean trips of TINRO-2. Unfortunately the transparency of water in the Black Sea is rather low, and film taken at the bottom was not very effective.

I thought out the plans for all of the sea cruises and concrete dives of the craft together with the assistant chief designer and builder of the craft, who was now called the delivery official. A rather well-enclosed inlet offering good visibility and having a solid, even bottom that dropped away gently to a depth of 70-80 meters was chosen as the main region of the trials. This depth suited us completely for most of the items of the testing program. Deep dives were to be made in the vicinity of Alushta or Yalta, where such craft had been tested before.

We decided to test the navigational qualities of the craft in different weather conditions at the first convenient opportunity, or during transfers from one region to another.

We ended up having to schedule out the forthcoming work in detail, literally down to the minute, and coordinate our actions with the participants of the trials and the ship captain.

Finally all preparations were finished. The tanks were filled with good Sevastopol' drinking water, and fuel was taken on. We were now ready for the sea!

The Craft Takes Its Exam

The "Ikhtiandr" sets out to sea.--Problems with the hoisting device.--The first dive at sea.--The craft on tow.--Fire.--200 Meters deep.--The state commission comes aboard.--Speed determination.--TINRO-2's test mile.--400 Meters deep.--Return to port.

There were a large number of formalities, which no one had ever been able to foresee, before a ship such as the "Ikhtiandr" could set out to sea. Port quarantine authorities demanded a mandatory medical inspection of all "guests" aboard the "Ikhtiandr" and immunizations against cholera and tetanus. At another time the ship's documents were found to be not entirely in order. Later it was revealed that not all of the life rafts were secured as required. Then someone said that there was no soap aboard the ship, and the most impatient passengers were ready to run ashore to buy some. This was finally getting to be a joke, but we were no longer amazed by anything, and we were ready to do whatever we had to do in order to get out of port as quickly as possible.

The delivery official, an extremely effusive person, hurried our captain on, but Viktor Aleksandrovich, a highly experienced captain, related philosophically to the swift passage of time and calmly surmounted each obstacle as it came up.

In the end, all of the necessary signatures and medical certificates were obtained, everyone knew where to run and what to grab in the event of a water or fire alarm, and we were given the go-ahead to leave the bay.

On Monday at 2200 hours Moscow time the "Ikhtiandr" separated from its moorings with TINRO-2 aboard. Everyone's spirits were high. The weather was calm. But the superstitious shook their heads apprehensively--we were setting sail on a Monday.

In the morning we reached the vicinity of Yalta, and because the sea state did not exceed 3 points, we decided to launch the craft.

At 1600 hours everything was ready for this operation. The ship was rocking slightly on the waves, its heel did not exceed 5° to port, and it appeared to us that it would be very easy to lower and raise the craft.

This time the plant's delivery mechanic was in the craft, and I observed the launching from the hangar.

Today, when it takes just a few minutes to lower or raise the craft, I find it funny to recall the way things went in those first days. It all happened about like this.

Soft fenders were lowered a few minutes before launching from the hangar, so as not to damage the craft against the side of the ship. Five men were stationed along the open doors of the hangar with poles with which to push the craft away from the ship. At the same time three divers and three sailors manned a 70-man rescue motorboat. The boat moved away from the side of the ship and positioned itself opposite the hangar. Then the craft was launched from the hangar. When it touched water, two divers in diving suits jumped overboard from the motorboat in response to a command, swam to the craft, climbed up it, and removed the catches manually. Then the craft conveyed them on its deck to the side of the ship, after which the divers, once again in response to a command, jumped overboard and swam to the motorboat, which took them back to the ship. The craft was raised in the reverse sequence. An interesting sight it was!

The very first launch was especially memorable to me, because I had to observe it from the sidelines. Each participant of the forthcoming launch theoretically knew his place and the order of action. But the well-ordered theoretical succession was disturbed almost immediately, possibly due to heavier seas, and possibly due to the generally shared anxiety. Whatever the case, when the time came for the launching to start, everyone began bustling about, and the delivery official tried to be in all places at once. The craft, which was occupied this time by the delivery mechanic, barely touched the water when it started bucking about like a wild horse. The divers jumped overboard from the motorboat, not without some reservations, and removed the catches. After this the craft became completely uncontrollable, and it turned its bow toward the side of the "Ikhtiandr" as if readying itself to ram the ship. At the most inappropriate moment the hoisting device jammed. The guide cables on the drums of the high-speed winches tangled themselves into a knot beyond the wildest imaginings, which took several people to untangle with difficulty. The divers scurried back and forth between the craft and the motorboat. In the end, the craft was locked on and raised into the hangar. Everyone sighed with relief. The operation took two and a half hours! As soon as the mechanic got out of the craft he announced that he would not sail the craft at a sea state greater than 2 points, since the rocking was too severe. But at this time TINRO-2 was on the leeward side of the boat, and it was protected from the waves. How would things be when the craft finds itself on open water?

The sea subsided somewhat toward evening, and we decided to subject the craft to its first real dive on the following day.

I was awakened around five in the morning by the sound of wind on the portholes. It was just beginning to grow light. The sea state was 4 points. It was still too early to get up, and so I went back to sleep. After breakfast the entire delivery team convened on the trawl deck to discuss matters of immediate importance. The delivery official said that in his opinion the weather was good, and that he was preparing the craft for the dive. We did not begin to argue with him, even though heavy leaden clouds began to stretch over the sky and the sea started to resemble our native Baltic. By 1200 hours the sea state was already up to 5 points. The ship began rolling heavily from side to side, and for some reason about a third of the delivery team abstained from lunch. It was impossible to launch the craft at this time. The delivery official gloomily agreed with this as well.

Meanwhile life aboard ship returned to normal. The ward-room was opened. A specific place was assigned to each person within it. All required supplies were issued.

In anticipation of better weather, the "Ikhtiandr" came closer to shore and anchored itself within eyesight of Yalta. The part of the crew that was off duty tried its luck at fishing, and the buckets began filling with haddock rather quickly. Someone managed to catch a pair of huge spiny dogfish, or Black Sea sharks.

Meanwhile we analyzed the reasons why the hoisting device worked so poorly.

The morning of the following day bore absolutely no resemblance to the previous morning. The sky was clear, and the sea was barely undulating. Everything bespoke success. We quickly prepared the craft for the dive, but as before, the hoisting device would not work. The ship mechanics could not fix it. Even Yasha, the best plant fitter-mechanic called in by the delivery official, was unable to help us. A pumping unit had broken down, and we did not have a spare pump. It was a pity to see how distraught the mechanics were. After a short conference we decided to return to Sevastopol'. Remembering all of the difficulties associated with our departure from Sevastopol', we did not like returning there at all, but there was nothing we could do.

So ended our first sea cruise, which lasted exactly 3 days. And of course, the fact that the ship sailed on a Monday was responsible for everything.

At an hour past midnight the "Ikhtiandr" dropped anchor at the roadstead of its familiar bay. The vessel was positioned with its stern to Pier No 8, and very soon we received a full taste of all the "joys" of such an anchorage. As soon as the winds came up, the "Ikhtiandr" received instructions to leave for the roadstead, and those on leave who returned too late could not get aboard ship: Communication with them was cut off when the sea state climbed above 2 points. The "castaways" were forced to sit on shore without documents and money, and wear away the night on stools in the port dispatcher's office. The situation was even worse for those who were on the roadstead at the end of their tour of duty. Not only could they not make it on time to their airplanes or trains, but they could not even make it to shore.

We remained in this predicament for a little more than a week. During this time we brought in an installed a new pump in the hydraulic system.

Finally, on 13 (!) September the "Ikhtiandr" once again set out to sea. The hoisting device was readied for work, but during preparations for the craft's dive we discovered that the pressure compensator's piston was sitting a little too deep. It turned out that the bushing of the vertical propulsion complex on the left side had broken. It was a good thing that plant specialists were able to find a suitable stainless steel rod and machine a new bushing in the ship's workshop. This work took up another day.

Soon the craft's long-awaited dive at sea--its first independent dive--began. We were in a convenient inlet. This time the crew of the craft consisted of three persons: the plant delivery mechanic, the assistant chief designer, and I.

I took my place at the control console, my comrades crawled to the bow of the craft, and both of them situated themselves in the researcher's place. A passionate desire to participate in the first dive compensated for all of the inconveniences.

The craft was lowered to the water, the divers released the catches, and we began rocking violently. The craft was towed away from the ship's side by the rescue motorboat. Through the portholes I had a fabulous view of the towing cable being attached and the motorboat dragging us away from the ship. At a distance of 100 meters from the ship, the divers unhitched the craft from the towing cable and returned to the motorboat. We were left on our own. The rocking increased noticeably--heel attained 18-20°.

As we had predicted, the rocking was considerable due to the craft's great equilibrium.

Before beginning our dive we made several runs on the surface at different speeds--we had to see how obediently the craft responded to the helm. I was pleased by its controllability: It was easy to maintain a given heading. The automatic control system also worked fabulously well. We decided to check out all of the craft's other traveling modes later. I radioed for permission to begin the dive, and it was with a sense of pleasure that I heard the calm voice of our delivery official in the earphones: "Permission for the dive granted."

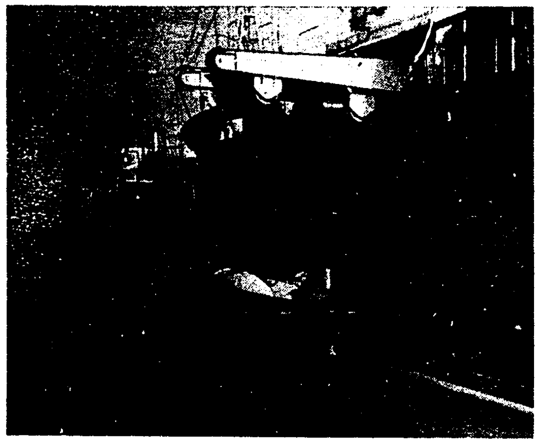
I opened the ballast tank vent valves and began watching how the craft slowly started submerging. Because the crew consisted of three persons, the amount of solid ballast aboard had to be reduced somewhat, and so we did not know how the craft would proceed under water--quickly or, on the other hand, slowly.

When the ballast tanks were completely filled, I set the vertical screw propellers for diving, but the craft's position did not change. Thus we had to take water into the compensating tanks, periodically checking the craft's capability for submerging. It was not until 20 minutes after the vertical screw propellers were turned on that the craft finally went below the water. I glanced into the portholes--the water surface was above us. The instruments showed a depth of 10 meters. We stopped and inspected the compartments. Everything was in order, and I reported this to the ship by our underwater communication system. Now we could calmly evaluate our sensations. At this depth, the water was of a greenish color, and rather translucent. Before our eyes, little jellyfish floated by and some sort of white balls and threads stood motionlessly. We noted happily that the intense rocking had ceased, and only gentle rolling remained.

We decided to descend to 30 meters. As the craft moved, I glanced into the portholes--granted, it was falling upside-down, but it was snowing! At least it looked that way from so large a quantity of white particles of detritus around us.

Two minutes later the craft stabilized itself at a depth of 30 meters. We once again inspected the compartments and reported the situation to the ship. I set the course at 60° and turned on the gyropilot. TINRO-2 held its course precisely. Then I switched to manual control and once again persuaded myself that the craft was very responsive.

This was a twilight kingdom at this depth, and the water was greenish in color. After 30 minutes we were ordered to surface. I turned on the screw propellers, and at a depth of 5 meters, after persuading myself that the vessel was not directly above the craft, I purged the ballast tanks with compressed air--the craft rose to the surface evenly, without heel or trim. The surface shimmered silver above the craft, and an instant



The Craft is Lowered to the Water

later we could see through the portholes that the motorboat had positioned itself 1 cable from the ship. We were put in tow, and moments later we were at the hangar. We could hear the catches locking on, and then the craft being raised above the water and set upon the keelblocks with a gentle bump. We exchanged our impressions, and we congratulated one another on our first baptism at sea. The hatch finally opened, and I could see the smiling face of Yasha, who was subsequently always the first to meet us when we returned to the ship, and track us in our independent dives. Making our way to the transfer bridge, we were met by embraces from our friends. We were congratulated with the first successful dive, and we congratulated the creators of TINRO-2 with the great success.

Only two and a half hours had passed from the moment the entrance hatch was secured to the moment it was reopened, and we did not spend more than an hour beneath the water, but there were impressions enough to satisfy us for a long time to come. We devoted the evening of that day to telling the story and analyzing our observations.

The work of the echo sounders was irregular. Our acoustical engineers went right to work to find the causes of this problem and repair the apparatus. We had consumed hardly any of the storage battery capacity, and so it did not have to be recharged.

From this moment on we settled into our work routine. The time the craft remained under water, and consequently the time I worked as craft commander increased to 6-7 hours. The battery discharged completely after such a lengthy dive. We did not have a standby battery outfit aboard the ship, and therefore it had to be recharged on the following day. This took about 20 hours, during which we did not dive.

Gradually all of the craft's characteristics were checked out. Serious malfunctions were not discovered, and the inevitable minor problems were cleared up by plant specialists on the spot.

During one of the dives we had to check the effective range of the radio communication resources and echo sounders. The weather was good in the morning, but by the time we selected the place for the dive, set out the buoys at different depths to check the echo sounders, and had the divers mark the route the craft was to take, the weather began to deteriorate. By the moment of launching the sea state was already up to 4 points. We had to postpone our planned operations, and instead we decided to have the ship tow the craft in the disturbed sea and determine its maximum safety parameters. We had to work out the towing mode for the event of poor weather, when it would be impossible to raise the submersible aboard ship.

I took my place in the craft and piloted it away from the ship by myself. Despite the roughness of the sea (the waves attained a height of 2 meters), the craft moved away from the vessel well. I turned about and began performing various maneuvers while on the surface: I varied my heading in relation to the orientation of the waves, and I determined the minimum RPM of the main propeller at which the craft stably maintained its prescribed heading. After this I tabulated the results, which due to the intense rocking was harder to do than to control the craft, and I reported by radio: "Ready for towing." Something incomprehensible followed. I was to use a pneumatic line gun to "shoot out" the towing cable attached to the craft. This cable was supposed to be caught up and joined to the ship's towing cable. But the divers, who had not been briefed clearly, began climbing aboard the craft. There was no way I could fire the gun. I was forced to immediately stop the engines so that none of the divers would drift into the propellers. As a result the craft found itself at the mercy of the elements. The craft was careening 32°, and the period of oscillations was about 5 seconds. Barely able to hold onto the deck of the craft, the divers unhitched the totally wrong cables. They could not hear me, and so I radioed my advice to the ship, from which an attempt was made to communicate the information to the divers. Aboard the motorboat, which was dangerously close to the craft, no one had the slightest notion of what was going on. At the last moment radio communication failed, and there was nothing left for me to do but coldly watch the events unfold. After several attempts the divers managed to bind the craft, motorboat, and ship tightly together, and a stiff wind caused the entire interconnected unit to drift slowly toward shore. I learned later that the engines could not be started aboard the ship, and that it was unable to travel farther from shore.

The captain gave the order to cut the towing cable so that the craft could move independently with the motorboat to the middle of the familiar inlet, but the motorboat was mistakenly severed from the craft, and so the craft continued to drift together with the ship. Everything turned out all right in the end, but the participants of this "adventure" were very tired. We decided to meticulously coordinate forthcoming operations and to brief all participants in the future. We decided to repeat the towing operation on the following day, taking all of the mistakes into account.

Fresh winds were still at hand, but we started the trials anyway. The launching of the craft and its separation proceeded fabulously. I shut the motors off 1,000 meters from the hangar and ejected the towing cable with a thunder. It was immediately caught up and spliced to the ship's towing cable, and in a few minutes the craft was following behind it obediently. Communication was good, and I asked that the towing speed be increased gradually. At a speed of 4 knots the craft suddenly began submerging; trim attained 20° at the bow, and the craft heeled to starboard about 5° due to the main propeller, which was shut off. Any further increase in speed was undesirable. Thus we determined the maximum possible towing speed--3.5 knots. At this speed the bow of the craft submerges, but the commander's portholes remain on the surface. At higher speed the portholes disappear beneath the water as well, with only the towing cable visible through them amidst the beautiful greenish water.

Now we had to make just two more trips at sea, and the state commission would accept the craft.

Valentin Deryabin was my mate in one of the last dives. We had to make the final inspections and adjustments of all electronic equipment. TINRO-2 separated from the vessel uneventfully, and the dive began. I noticed that the craft had no intention of breaking away from the surface. In order to submerge, we had to take in additional water into the balancing tanks. The craft began descending, but at a depth of 20 meters, rather than stopping as was intended, it began dropping further rather quickly, and we settled on the bottom at a depth of 25 meters. We were unable to rise with the help of the screw propellers, and so we had to pump water out. The craft began surfacing. At a depth of 15 meters we stopped in order to inspect the craft and clarify the cause of its strange behavior. I additionally set the anchor, and in order to increase its holding force I began taking on sea water into the aft tank. Suddenly water began gushing into the craft from the trimming tank vent valve. I did not know that this tank was already filled. We had to close the valve and rise to the surface in order to equalize the craft's position. Then we began submerging once again.

At a depth of about 5 meters Valentin and I simultaneously smelled something burning. I opened the door in the bulkhead--the aft compartment was full of smoke. I immediately turned on the emergency ballast tank purging system, and the craft shot to the surface like a bullet. We turned off all power consumers right away. It seemed as if the burning stopped, but there was much smoke in the craft. I reported the situation to the ship and requested permission to open the entrance hatch. The sea state was a little more than 2 points, and therefore water rarely swept over the hatch. Valentin and I took turns breathing the fresh air and diving back into the craft. Whenever a large wave appeared, we had to close the hatch. The smoke cleared, and I saw that the magnetic starter of the vertical propulsion complexes and the cables leading to it were burnt. But the danger was already past, and there was no need to use our firefighting system. We also decided not to use the breathing masks because the craft was being aired out well through the hatch.

The motorboat approached us, took the craft on tow, and delivered it to the side of the ship. Black from soot, we crawled out of the craft and went to wash up.

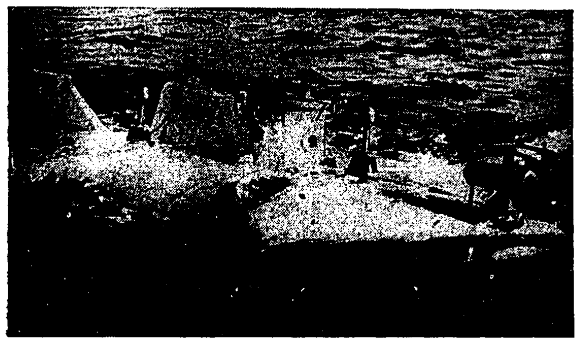
After careful analysis of the causes of the fire, it was established that the starboard vertical propeller had jammed, and this caused ignition of the starter, the thermal safety device of which failed to operate. It was a good thing that there was a spare starter aboard the ship. It took only a day to make the repairs, and so we did not have to return to Sevastopol'.

Next day Valentin and I once again attempted a dive in order to finish what we started so unsuccessfully the last time. Everything went excellently.

The final thing to do was to dive to 200 meters. This was the first time we ever descended to this depth.

Having found a place for the dive with a good even bottom 210 meters deep, as usual we began waiting for appropriate weather. This time we were in luck, and we were able to attempt the dive a day later The delivery mechanic was my mate. We stopped every 50 meters in order to carefully inspect the compartments. Illumination changed very abruptly as we went deeper. It became practically dark at 70-80 meters. We turned on the floodlights to see the already-familiar "snow". We made two more stops--100 and 150 meters. Everything in the craft was in order. At a depth of 200 meters there was an impenetrable gloom beyond the portholes; the bottom could not be seen, though according to the echo sounder it was but 15 meters away. We checked TINRO-2's "weight". As a result of the hull's compression the volume of the craft decreased, and it became somewhat heavier, but it obediently remained at its assigned depth. Now we had to check the operability of all systems and mechanisms. We took turns switching on the electric instruments, changing the craft's heading, and changing its speed. We dropped the anchor. It settled to the bottom, and the winch switched off automatically. We checked the work of the floodlights and electronic flash. Everything was normal. We took four samples of water in the bathometer. It now appeared that we could return. We ascended with halts every 50 meters as well.

Finally we reached the surface. Everything had operated stably, the craft was obedient, and after being raised into the hangar we congratulated each other with successful completion of the plant trials--a complex stage in the life of the craft. That same evening we dispatched a radio message summoning members of the state commission, and the "Ikhtiandr" returned to Sevastopol' with TINRO-2 aboard.



The Craft Approaches the Side of the "Ikhtiandr"

A few days later the state commission convened aboard the "Ikhtiandr".

In addition to the usual tests, which were essentially a repetition of the plant trials, the program of the state trials included determination of the craft's maximum speeds in the horizontal and vertical planes, and a dive to 400 meters.

At its first meeting the state commission wrote up a clear schedule for the operations, set up in such a way as to complete them in minimum time. It was far into autumn, and we could not wait around for the weather to suit our needs. All of the commission members were interested in the speediest end to the trials and certification of the craft for operation.

Following the craft's several dives during the plant trials, the commission members were clearly aware of the most difficult aspects of organizing operation of the craft and its carrier vessel. Despite stable underwater communication, determining the range of the craft during its independent navigation continued to be difficult; however, as the ship's crew and the crew of the craft accumulated experience, even this operation became easy, since all of the necessary equipment was available for this purpose.

Mooring of the craft to the ship was a sufficiently difficult operation, one which became especially complex in heavy seas. The ship's side fenders were adapted to the "Sever-2" craft, and they were poorly suited to TINRO-2. Therefore temporary fenders were made aboard ship out of automobile tires. These fenders served their purpose well.

These issues associated with joint work of the craft and vessel were discussed at meetings of the commission, and after common agreement was reached, the "Ikhtiandr" set out to sea for the final trials.

We began to think about how to measure the craft's horizontal speed when it was beneath the water. Special measured miles with leading marks readily distinguishable from the surface of the sea are usually set up for surface vessels in these cases. The length of the measured sections in the regions in which we were sailing was about 2 nautical miles. TINRO-2 would have had to travel this distance three times. The power capacity of the batteries would not have been enough to propel the craft at full speed for such a distance. Therefore we decided to set up a measured mile along the side of our ship. Two direction-finders were secured to the bow and stern, a bright-red floating buoy was attached to the craft by a long buoy rope, and the vessel's position was fixed with fore and aft anchors. After the craft submerged, it was set precisely on the ship's course, and it traveled the measured section three times at a depth of 30 meters, maintaining a constant heading. The distance between the direction-finders was known, and observers recorded the position of the red buoy towed by the craft, the resistance of the former and the buoy rope having been determined earlier. The craft's maximum speed was a little less than expected. The speed turned out to be less than that planned apparently because additional power not foreseen by the plan had to be picked off from the main motor, and because it was very difficult to precisely calculate water resistance for such a poorly streamlined body with a large number of protruding parts.

The craft's vertical speed was measured with a depth gauge during its submersion to 100 meters and resurfacing. The resulting measurements were precisely as planned.

Then the craft's behavior at low and moderate speeds was checked out once again--everything was normal.

The main examination was still to come--a dive to 400 meters. It was decided to perform it not far from Yalta, where the depth attained 460-470 meters. Of course we were unable to find an even section of bottom, and therefore we had to dive into a gigantic pit in the bottom at a depth of about 400 meters. The plant team prepared the craft especially carefully.

The dive, in which the builder of the craft and I took part by tradition, began after lunch. The weather was favorable, and the craft was operating faultlessly. However the craft did descend suspiciously quickly. "What is the matter?" I shared my doubts with my mate, and he admitted that he had taken a very heavy toolbag aboard with him, containing, among other things, very large wrenches. That was why we descended so quickly--the craft was heavier.

We attained the prescribed depth in about an hour, since as usual we made stops along the way to inspect the equipment in the craft.

When the depth gauge reached its long-awaited mark, I called the builder over to my console so that he could persuade himself of this personally. We stabilized the craft at this depth, and in the course of an hour we checked out the work of all mechanisms and the condition of the portholes, cable inlets, and stuffing boxes, and we performed various maneuvers. I reported completion of all items in the program via the communcation system, which operated stably, and I was given permission to ascend. Once again we made stops at different depths in order to check and recheck the operability of the mechanisms.

And finally we leapt onto the surface! It is difficult to describe the way we felt at that moment. We had a sense of joy, and we were walking on air! Our friends, who greeted us aboard ship, also experienced the same feelings.

And so the craft would now await interesting and entirely new work, and it was ready for it.

CHAPTER III

THE 'BLACK' BLACK SEA

The Craft Under Water

Preparations for the trip.--The composition of the expedition.--More troubles.--We become divers.--We dive with aqualungs.--New crews.--Ichthyologist under water.--An encounter with fish.--The boundary of light--the boundary of life.--Everyone wants to reach the bottom.--Journey with a geologist over an undersea slope.--The Black Sea trip ends.

Life aboard the "Ikhtiandr" came to a temporary standstill after the trials. While decisions were being made as to where and how TINRO-2 would begin its experimental work, the "Ikhtiandr" was based in Sevastopol.

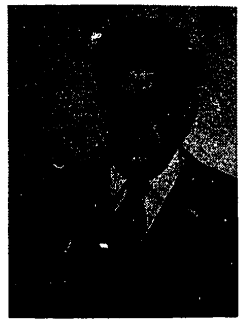
In January 1974 a decision was made to transfer the "Ikhtiandr" together with its submersible to a new ship owner. The latter became the Administration of the Scientific Research Fleet in Kerch'. Soon the name of a new port of registry was painted on the side of the "Ikhtiandr".

At the end of January the ship moved to Kerch'. While the numerous documents involved in the ship's transfer were being filled out, the "Ikhtiandr" underwent preparations for a trip with TINRO-2 into the Black Sea.

Representatives of the administration, mainly Konstantin Vasil'yevich Kostitsyn, followed the course of the preparations very attentively from the first days, and they helped form the crew for the ship.

It was decided to include well-known scientist-biologists and ichthyologists among the detachment of underwater researchers.

Before being transferred to the Administration of the Scientific Research Fleet, the TINRO-2 had to be demonstrated in action. I moved to Kerch' at the beginning of February in order to perform a test dive. Several plant specialists and I began preparing the craft for work after its almost



K. V. Kostitsyn

4-month period of inactivity. Boris Ishtuganov, who could not bear to part with the craft, also took an active part in these preparations. During this period we helped train the craft's new crew.

The "Ikhtiandr" set out to sea on 20 February. The Black Sea could not be called calm during this time, and it was a very long time before we could find a place for the check dive. Finally on 23 February, after the sea calmed down somewhat, the craft made its dive. In addition to me, Boris Ishtuganov took part in it for the first time. The total depth at the place of the dive was only about 20 meters, such that we had to descend very attentively so as not to hit bottom.

The new master of the craft was pleased with its work, and therefore following our return to Kerch' the exact schedule for the forthcoming trip was immediately written out.

It was decided to conduct the first experimental trip of TINRO-2 without leaving our territorial waters on the Black Sea. This was an absolutely correct decision: Any new submersible must first be operated near native shores before setting out for the depths of the World Ocean.

The program for the trip was developed by the VNIRO laboratory and Giprorybflot's undersea technology division. A large part of it consisted of technical and organizational tasks, as well as scientific research. The work of the hydrological complex and the navigational system of TINRO-2 had to be checked out for the first time in the field.

The administration asked me to take part in the trip (as the submersible's captain-mentor) in order to render assistance during the Black Sea trip. Those who participated in the first trials of TINRO-2 were also to participate in this trip together with me. The craft was manned by its official crew, which included both Boris Ishtuganov and Valentin Deryabin. M. P. Aronov was approved as the trip's scientific director.

The trip was scheduled to begin in the first days of March, there was very little time left, and K. V. Kostitsyn hurried the preparations of the "Ikhtiandr" along at every dispatcher's conference.

The ship's crew was already fully manned.

A special Undersea Research Service was created. Later all submersibles, both built and planned, were to be placed at the disposal of this service. In the first days of March the "Ikhtiandr" once again set out to sea with TINRO-2 aboard. Operations were to be conducted in the vicinity of the inlet already familiar to us, and off the Caucasian coast. The vessel was given permission to occasionally visit ports to correct possible malfunctions or for other purposes.

Whenever problems arose that we could not correct through our own efforts, we had to return to Kerch'. The number of dives was not planned, since the intensity at which the operations could be conducted was still not clear.

Initially the craft maintenance group consisted of just three persons: a mechanic, an electrician, and a radio-navigator. Later a battery specialist was also officially added to the group specifically to charge the storage batteries.

Because the new ship's crew had never participated in the launchings of the craft and had no idea what they involved, on arriving in the inlet we immediately decided to practice the launching and raising operations and the interactions of the craft and vessel. Our new captain very much lived by the book, and he was a highly precise individual; this time, therefore, everyone had to completely learn all of the instructions, manuals, and regulations. This helped the crew to assimilate the necessary operations quickly. Concurrently with studying the documents, all of the ship's services began a competition to improve the methods of work with the submersible. Many efficiency proposals were submitted, and a decision was made to check them out and introduce the best during experimental operation.

We spent the first 3 days in the selected inlet practicing the raising and launching of the craft. The captain's senior assistant and I wrote out the responsibilities of each crewmember in different situations, including emergencies. Each had to know what he was to do in a given situation or when general quarters was sounded. Such was the demand of our captain, and we did not begin work until everyone learned his "lesson".

After the thousand-and-first (!) launching and raising operation, the decision to make the first real dive was made. But, as the saying goes, the first pancake came out a mess. A loud crack resounded during testing of the emergency storage battery container release mechanism--one of the four drive rods broke. We did not feel it possible to repair it in the facilities available aboard ship, and we did not have any spare rods. Thus we had to return to port and wait until a new, improved tie rod would be delivered from the plant. The break occurred, we found out, due to absence of lubricant in the bearing units. The defects were eliminated, the new rod was put in its place, and we once again set out to sea.

We began work after leaving the port the second time. The craft was controlled by Boris Ishtuganov during the first dive, so that he could acquire the practical habits. During the trials we never came close to the bottom, and this perhaps was a shortcoming of the program, since for practical purposes the craft should be operated right at the bottom.

Boris sat at the control console. In this instance I was in the observer's place. The bottom became distinctly visible at a depth of 40 meters. Boris turned the controls over to me, and now I guided the craft as close to the bottom as possible. It is very difficult to determine distance beneath the water--everything seems much closer than it is in fact. Thus I was certain that the bottom of the craft was literally scraping the bottom, but when I wanted to settle the craft down near some small rock outcroppings, I found that I was still almost a whole meter above the bottom. Underwater visibility at this depth did not exceed 7-10 meters. The bottom was sandy, and all that could be seen were small rocky ridges here and there. The water had a pleasantly greenish hue; the closer the craft came to the bottom, the lighter the latter became--reflection of light from the sandy bottom was having its effect.

I should state that controlling the submersible at the bottom is an incomparable pleasure. Oleg Nikolayevich Kiselev, one of our first scientists who made 100 dives aboard the hydrostat "Sever-1", compares moving over the bottom in a hydrostat with flight in a balloon. I would compare cruising in an independent submersible with the slow flight of an airplane--one completely ceases to hear the noise of the propulsion complexes, or to feel the discomfort of one's posture. The underwater scenes are breathtaking--so unusual and attractive they are.

Nor is there anything comparable with the pleasure of controlling the craft beneath the water. The slightest turn of the control stick is enough to make the craft obediently descend or surface. Even at a speed less than 1 knot--that is, 15-20 meters per minute, the craft maneuvers easily. When the bottom is even, one can travel literally 10 cm above it for a rather long time, even with the vertical screw propellers turned off.

On "approaching" the bottom we rose to 5 meters above it and released the anchor. After the propulsion complexes came to a halt the craft began drifting slowly with the current. In order to stop this drifting we had to take a small amount of water into the compensating tanks. The craft stopped motionless and turned its stern in the direction of the current, which drew it a little closer toward the bottom. It was very pleasant to be in the underwater silence. I looked around. Small haddock occasionally floated by the portholes, and flounders or skates could be seen buried in the sand in two places.

Having discovered nothing interesting, we decided to roam about with the guide rope out. Boris turned on the propulsion complexes, and the craft proceeded forward slowly. In about 10 minutes I turned left and very soon saw before me a straight trench 5-6 cm deep with flared edges, trailing off into the distance. It was only after I retraced my steps that I realized that this was the track left by the anchor-guide rope. "We will be able to mark out the region of operations in this way," I noted. "It would take a long time for silt to fill in such a trench."

> After this Boris and I decide to settle the craft on the bottom, the appearance of which seemed sufficiently firm to us. Boris takes in the anchor, and we gradually begin dropping to the floor. A gentle bump followed, and a small turbid cloud rises up about the craft--we are on the bottom. It is so close and so well visible that I get the urge to touch it with my hand. I call Boris down to me, so that he also could take in the pleasant sight. The two of us crowd together on the researcher's mat and survey the almost lifeless picture of the Black Sea's floor. It is quiet in the craft, and the gyrocompass is barely audible.

We were under water for almost 5 hours when we were reminded from above that it was time to go back up. Those who remained topside were impatient to learn what we had seen.

> Boris equalizes the craft's "weight" and turns on the vertical motors. The craft climbs slowly upward. The bottom is no longer visible, and the water is becoming noticeably lighter. At a depth of 10 meters we make a check halt, and an instant later we are on the surface.
>
> We wait for the motorboat to approach the craft, set the tow cables, and lead us to the hangar. The captain prohibited us from approaching the "Ikhtiandr" and separating from it on our own with the hope of avoiding collisions. As always, the divers are the first to meet us. They work very quickly, dexterously, almost automatically.

V. Deryabin also took part in subsequent training dives. In my opinion Boris Ishtuganov was ready for independent work under water.

Then began the scientific operations, in which scientist-researchers took part. They all underwent a special training course. They all acquainted themselves with the fundamentals of the craft's layout and the means of its control, they learned what to do in the event of an emergency, and they studied the methods of underwater photography. They all became certified specialists after a special examination and their first successful dive. They were issued certificates permitting them to work in TINRO-2 as underwater researchers.

The first underwater researchers were colleagues of the VNIRO laboratory. They began practicing approaching the bottom and maneuvering near it from the very first dives. Gradually we progressed to bottoms with more-complex relief having submerged boulders and steep slopes. After a while I was fully persuaded that they all had a good sense of the craft's capabilities and could begin doing their principal work. Many of the first underwater researchers were experienced scuba divers, and therefore it should not take them much time at all to accustom themselves to work under water. The first underwater researchers were my mates in the very numerous subsequent dives, and we became used to working together, understanding ourselves well both above and beneath the water.

My mate for the first dive performed for scientific purposes was Marlen Aronov. The craft was anchored at a depth of several dozen meters. The underwater researcher began his work. Visibility attained 10 meters, and it increased significantly when the floodlights were turned on. Impressions were visible everywhere on the bottom. They were obviously impressions made by skates, which like to bury themselves in the sand. We observed accumulations of jellyfish, and red and white tunicates. Groups of whiting floated by the craft's portholes.

While Marlen was occupied with the diving program I tested the craft's buoyancy, which had shifted for some reason from zero to positive. The quantity of water in the compensating tanks had to be increased. However, after a certain time the craft began slowly surfacing once again. Air had apparently entered the ballast tanks. Just in case, we asked the vessel to stay farther away from us and, bleeding air from the ballast tanks, we rose to the surface.

After correcting this problem we began regular dives for scientific purposes, in which all of the underwater researchers and hydronauts took part.

The thirteenth (!) dive was interesting. It occurred at the apex of the Yazyk Depression. For the first time the craft had to work in a region having a complex, rough topography containing a wealth of cliffs, steep slopes, and narrow troughs, and it proved itself well.

At a depth of 7 meters a school of tiny fish passed by the craft at great speed, and we were unable to examine them. On approaching the bottom we noted (glossy) and whiting. We counted 20-25 fish every 80-100 meters. The fish were not scared of the craft, they came close to the portholes, and we could even observe large fish attacking smaller ones. Large Black Sea turbot came into sight from time to time. Sometimes only the outlines of fish buried in silt were evident. One turbot had not had enough time to bury itself completely, and its jaws, tail, and fins stuck out of the silt, such that the craft almost snagged against it. The craft went almost directly over another turbot, but the fish did not produce even a tremor. Deep burrows from which small gobies swam out were encountered on rare occasion. Whiting was encountered throughout almost the entire water column, down to 2-3 meters from the bottom.

During this dive the crew became persuaded that the Black Sea is in fact black. As we descended, visibility became worse and worse, and it began to get completely dark at 70-80 meters. The closer the bottom was, the fewer fish there were. Below 130 meters the fish disappeared. It is approximately at this depth that the boundary of all life passes in the Black Sea; below this is the hydrogen sulfide zone. First extensive black spots are observed on the bottom, and then gradually the entire bottom becomes dark.

Biologist Valeriy Pavlovich Petrov obtained interesting results during the Black Sea trip. He observed the distribution of (fazeoliny), jellyfish, and other benthic organisms. The data he obtained made it possible to reach a conclusion as to the craft's suitability for conducting benthic research over significant areas of the seabed.

Work with TINRO-2 excited everyone, even those who were not direct participants of the dives. Ideas on improving the launching and raising processes and the communication and direction finding systems literally poured in from all directions. The captain suggested moving the hydroacoustic communication post from the vessel's forward wheelhouse into the shift chief's deckhouse, which was practically unused, and which contained back-ups for all of the ship's main navigational instruments, including echo sounders and a sonar set. It was decided to permanently install the radio station for underwater communication with the craft there as well. Prior to this one of the radio operators had to run about along the side of the vessel with the set on his back, which was naturally not very convenient. Surprising though it was, radio communication with the craft was sufficiently good, even when it was in the closed hangar and the radio set's antenna was raised on a mast. The radio operators could not explain this phenomenon, and we, without attempting explanation, simply capitalized on this phenomenon. The chief of the ship's radio service took on the job of outfitting the new compartment, and by the next dive both the radio operator and the sonar operator were in their new place. We enjoyed the benefits of this innovation right away. The control post now maintained telephone communication with the craft and the workshop, and loudspeaker communication with the wheelhouses, the central control posts, and the cabin of the hoisting device.

Love for the TINRO also had an effect on our personal life at sea. Thus one of the ship's dogs was named Tinra (we had to change the ending as an allowance for her sex); later she lived in my home in Leningrad, and when it came time to register her at the veterinary hospital the physician could in no way understand where such a strange name had come from.

S. P. Girs With the Dog Tinra

In the intervals between dives all of the hydronauts learned diving. We noticed that people in marine specialties, especially pressure-suit and scuba divers, assimilate control of the submersible more quickly and feel more confident under water. Therefore we decided that all hydronauts making dives in the craft should obtain diver's qualifications. An experienced diving specialist conducted our training, and very soon we were able to swim with an aqualung and sit in a decompression chamber. Our trip occurred in summer, and we selected the hottest days for our SCUBA dives, such that this training was not only useful, but also pleasant.

In accordance with the plans, in the middle of our trip we received an order to go to Sevastopol' and take a group of fitters and instrument repairmen aboard together with a hydrological complex that was to be installed aboard TINRO. It took several days to assemble the equipment. Another day had to be spent on a medical inspection of all new arrivals.

Immediately after we set out to sea, the "underwater researcher school" once again opened its doors aboard the "Ikhtiandr" for the new arrivals.

During this time we carefully wrote up the plan for the dives. The work facing us was to be rather complex. We had to check the correctness of the readings of some sensors in the hydrological complex using another complex of instruments lowered into the water on a cable. The craft was to remain not far from it throughout the entire time.

On 15 June TINRO-2 made its twenty-second dive in the Black Sea. The main task of this dive was to adjust the log in the hydrological complex. Once again we had to deploy our improvised measured mile, and anchor the vessel to two barrels at the inlet's roadstead. A sailor was planted on the stern barrel to take in the cable, but for some reason this maneuver was rejected, and our sailor was forced to linger alone for about an hour before he was finally removed from the rocking barrel.

It turned out that there was a very strong underwater current in the place of operations which almost caused TINRO-2 to collide with a bank of sorts right away. It was a good thing that the sharp decrease in the depth readings of the echo sounder was noticed in time. There was no longer enough time to seek another place for the measurements, and therefore the work had to be continued. It was not until six and a half hours later that we finally determined the craft's speed.

In the next dive we had to compare the sensors of the two complexes. B. Ishtuganov went as the craft commander, and a physicist served as the underwater observer. Boris had to work hard during this dive because the craft had to be kept close to the control complex all the while, and lengthy halts had to be made at different depths to make the measurements. At first Boris constantly kept stumbling upon the ship's anchor chain, but he could not find the cable from which the control complex was suspended. There was no way that we could help him, but in the end Boris himself piloted the craft to the sensor block, and the measurements were made successfully at 15 and 30 meters. But at 45 meters the complex suddenly strayed once again out of TINRO-2's zone of visibility, perhaps due to worsening of visibility beneath the water--evening was already coming on. The craft had to be set at anchor in order to keep from straying too far from the complex, and the work had to continue without the complex in sight.

During these trials the craft was accompanied by divers, who performed prescribed operations with the sensors of the complex at certain moments. Unusual communication was maintained between the divers and the crew of the craft: They wrote all of their messages out with pencil on pieces of laminated plastic and pressed them to the porthole.

Almost everyone aboard ship was involved in these operations. Naturally this required good organization, coordination, and mutual understanding among the experiment's participants. At first we had to devise a unique form of scenarios for the future actions beforehand. If especially complex operations were to be conducted, on the previous day we convened in the ward-room and "played out" these operations. Later, everyone learned to understand each other intuitively.

While on the Black Sea trip we made a few evening and night dives during which the ichthyologists observed the behavior of marine inhabitants with great interest. It was found that working in darkness was much simpler than in the presence of light. We turned on the bright light in the uppermost part of the craft, making the craft well visible for a distance of more than a nautical mile when traveling on the surface and, as the craft surfaced, from a depth of 15-20 meters. Subsequent tests of the hydrological complex were conducted only in darkness, since in this case the movement of the craft could be corrected from aboard the vessel. We also tried out different direction finding methods in the dark, because we had to know the position of TINRO-2.

We still did not know what the final results of the tests run on the hydrological complex were--the numerous tape recordings had to be processed and the obtained data analyzed; nevertheless it was time to begin tests on the navigational complex.

Once again new faces appeared aboard the vessel--the designers of the navigational system. Once again apparatus had to be installed--a course plotter, a gyrocompass, and electronic blocks. Once again we had to adjust their operation. The instruments were placed in the aft compartment, and the course plotter was fitted to telescopic runners beneath the commander's chair. As we had anticipated, transportation did not do the delicate instruments any good, and it took some time to adjust them. Finally the complex began working as it should on a bench in one of our workshops, marking the ship's course on a plotting board.

This complex was assembled entirely out of blocks and components used aboard airplanes of the Civil Air Fleet. During the first dive, the resistance of insulation on the complex' electric circuits dropped to zero, and it broke down. This occurred due to the high humidity in the craft, which attained 90-95 percent. All of the rest of the equipment was designed for use at sea, and therefore it was oblivious to high humidity, and even ocean spray. The failure of this complex was a let-down to us, since we had been counting on it so much, but it had to be sent back for modifications.

After this the "Ikhtiandr" made its way to our inlet in order to evaluate the possibilities the craft offered for working near fixed seines.

Early in the morning on the following day, divers put out a seine about 30 meters long and approximately 2 meters high in water 35 meters deep. Weights touching bottom were attached to its lower edge, and floating buoys supported it from above.

The dive was made in daylight. TINRO-2 sailed over to the area in which the seine was set up and began its dive, but the seine was not to be found, even though visibility beneath the water was 7-10 meters. I changed my heading several times and made circles, but no signs of the seine were to be noticed. At this moment the gyrocompass began working poorly for some reason; we turned it off and abandoned our attempts at orienting ourselves under water. We had to surface. I did not want to resubmerge right at the seine, since we had to determine the range from which it would be noticeable from the craft, and at which the craft could safely maneuver. We were compelled to ask one of the divers to don his gear and guide TINRO-2 to the seine by swimming ahead of it. We were following right at the heels of the diver when suddenly he swam abruptly upward--the seine, billowing forth like a sail, was before us. It seemed from the craft that the ends of the seine were folded inward. The current made it vibrate slightly. We began maneuvering near it. First the craft traveled along the seine, and we could easily see that it reached the bottom in some places and rose above it in others. Further on, the craft came extremely close to the seine, which suddenly began undulating--the craft stopped. It became obvious that the craft was tangled in the seine. We shifted from forward to reverse, but the seine kept a firm hold on the craft. We could not see exactly what the craft had snagged from the portholes, and thus we were unable to attempt any sort of purposeful actions. After floundering about a little while longer, we asked the divers to help us extricate ourselves from this trap. Of course, we could have surfaced on our own, together with the seine. At this depth the craft could create a lifting force of more than a ton, and together with all the weights, the seine did not weigh even half that. However, we did not want to resort to extreme measures, because the divers were ready to come to our aid at the first signal. It turned out that the swiveling floodlight on the starboard side and the tail fin were completely entangled in the seine. After we were "dissected out" we spent a little more time working at the bottom.

This dive taught us to be maximally attentive when working with a seine. In general, a seine should be approached such that the current would be forcing the craft away from it. In this case maneuvers would be easier to perform, and the probability of becoming entangled would be lower.

After we were raised aboard the "Ikhtiandr" following the dive, we were showered by questions: "What did you see? Did you get scared? How did you feel when you found yourself caught in the seine like fish?" Incidentally, every crew fortunate enough to take TINRO-2 under water was greeted on its return in the same way.

In the middle of July, participants of dives aboard TINRO-2 included an ichthyologist, a biologist, a sonar specialist, a diver, a physicist, a geologist, an oceanologist, a ship-building engineer, and even a mathematician! They all said that the dive brought them more pleasure than they had ever experienced before, despite the extensive work program. But no one felt fear before descending beneath the water. In a word, there was the total absence of a psychological barrier.

All researchers and seamen aboard the "Ikhtiandr" wanted to see the underwater world with their own eyes, but Marlen Aronov permitted only scientists and the builders of the instrument complexes to dive.

Among the underwater researchers, Marlen himself made the most dives. It was literally impossible to drag him out of TINRO-2. An experienced SCUBA diver with a remarkable knowledge of the Black Sea's undersea world, he always found something new and unusual during each dive.

He, and incidentally all other participants of underwater expeditions, shared their impressions in the crew's mess hall before the mandatory film showing. These stories elicited considerable interest. The upshot was that following their return to Kerch', five members of the ship's crew went to the Undersea Research Service requesting enrollment in the hydronaut training group. This atmosphere of universal interest promoted successful work.

The trip was nearing its end. It was decided to finish it off with a 400-meter dive on the continental slope, which was of interest to the geologists. Therefore a geologist took part in the dive with me. One of our tasks was to check out the work of the hydrological complex's sensors at such a great depth.

The dive was made on 30 June in the latter half of the day. It was hot, and the temperature in the craft climbed to 28°. We began with 80 meters of water beneath the keel of the craft. After some time we saw the slope of the shelf and turned toward the direction of increasing depth. One hour into the dive we reached 120 meters. The slope descended at a 30-35° angle. Its steepness gradually increased, and so we had to decrease the craft's horizontal speed and increase its vertical speed. The craft's stern was oriented toward the bottom, and therefore the lower end of the vertical stabilizer sometimes snagged against the ground, causing a trim of 10-15° at the bow. At such time the craft had to be moved quickly away from the slope. Whenever the craft touched the shelf, black streams of silt drained downward from it and disappeared into the depths.

The geologist adjusted himself well to the craft and immersed himself in his work. He was perpetually recording something on tape and photographing something else, and he forgot about the time. I had to hurry him on, so that we could reach 400 meters by 1800 hours. At this depth the temperature in the craft dropped to 16°. We discovered a small, almost horizontal platform on the slope, as if prepared specially for us, and we lowered TINRO-2 onto it. We took a few photographs of the slope, and made ready to surface.

In order to get a proper look at the bottom as we ascended, we had to turn the bow of the craft toward the slope. Before us was a gray, gloomy, totally lifeless sloped wall. At 180 meters we discovered outcroppings of layered white rock; higher up, bright yellow and black spots and hollows oriented downslope were encountered on the surface. And it was not until a depth of about 100 meters that we saw our old familiar whiting.

We rose to the surface uneventfully.

The operational trip of the submersible TINRO-2 ended successfully. The captain's first mate congratulated the entire ship's crew on this event. Now we had to process the results of the observations and write up a detailed report on TINRO-2's work.

The Trip's Principal Results

What did we learn?--The craft passed its test--it could now begin work.--All of the craft's mechanisms and systems are functioning normally.

We returned to Kerch' and parted company for our own homes, but there was no time to rest. The results had to be summarized.

The first operational trip of the independent submersible TINRO-2 lasted 135 days, 90 of which were spent at sea; the rest of the time was spent standing in Kerch' and Sevastopol' waiting for mechanisms of the craft to be repaired, the crew to be manned, supplies to be obtained, and the hydrological and navigational complexes to be installed. During its cruises TINRO-2 made 29 dives in the Black Sea at different depths and for different purposes.

Twenty-nine dives. Is this a little or a lot?

Twenty-nine times the ship's crew launched the craft, and it raised it back aboard as many times. During this time the crewmembers worked out all of their actions well, and they learned to understand one another intuitively. On days that the craft dived, the ship's services worked so efficiently that for all appearances they were being driven by some sort of single mechanism. And although the trip chief and I wrote up detailed programs for each dive, we did this more to avoid misunderstandings than to work out our actions.

Preparations of the craft began two and a half hours before the dive: All systems and mechanisms were checked out with a checklist that was presented to the hydronaut for final inspection. Following his report, I noted the craft's readiness for the dive in a special log kept in the wheelhouse. The rest of the ship service chiefs also signed off this log. This order was established by the safety division, and it was always followed religiously.

Just before the dive the hydrologist measured currents at different depths, and the water density and temperature, while the ship's surgeon checked the health of the crew, and it was only after this that the dive could begin.

The time required to prepare the craft decreased from one dive to the next, but it never did get lower than two or two and a half hours. Because the maintenance group was so small and there was little space in the craft, it was impossible to perform all of the operations more quickly.

The craft was fully suited to its purpose, it was dependable, and it was simple to control and maintain. However, we did decide to enlarge the maintenance group by including a few more fitters and electricians, so that the craft could be inspected more quickly after its ascent, and discovered problems could be corrected. This usually took about an hour and a half.

After the dive was completed and the craft was placed in the hangar, the hydronauts usually described the work of the mechanisms to the maintenance group.

When the weather was good, the intensity of the dives was rather high; therefore on days when several dives were made in succession, everyone became very tired.

One of the most successful aspects of the trip was developing the joint actions of the vessel and craft. Despite absence of dependable fenders, the craft was never damaged during the trip during the launching and raising operations. And yet several times the craft had to be raised in the presence of a sea state of 4 points.

A good system for locating the craft under water was set up. In addition to a noise emitter, an additional device was installed aboard TINRO-2 in the event of an emergency; using it, the ship's sonar could locate the craft with high accuracy during times of hydroacoustic communications.

Locating the craft after it surfaced initially produced difficulties. Some sort of special, complex stations were suggested for this purpose, but a very simple solution was found instead. A sonobuoy was placed in the craft, in the pressure hull, and the antenna of the radio set was used as the transmitting antenna. The first test of the system showed that the craft could be located by the ship's direction finder at a range of 5-6 nautical miles. This was entirely suited to our needs, but the device was never used subsequently, since with good underwater communication and direction finding, the ship and surfaced craft were never more than 500-600 meters apart. At night-time the craft was easily noticed by its bright anchor light.

Work was hardest in June. In 30 days we made 14 dives, mainly for scientific purposes.

What pleased us the most was that fish were not scared by the craft.

All underwater observers--biologists, geologists, hydrologists--admitted that the portholes were conveniently located.

The bottom and marine life forms could be observed through the forward lower porthole, while the upper portholes could be used to survey the water column, slopes, canyons, and so on.

The three lower portholes could also be used, though of course in this case the observer had to stand on his knees. In new craft, the diameter of the forward lower porthole should be enlarged. This would improve the view and increase safety when moving near the bottom.

The observer's prone position was recognized to be convenient, especially when working near the bottom, but it was decided to alter the headrest, since it was difficult to hold the head up for so long: The neck muscles tire, and headaches develop.

The arrangement of the outboard floodlights was well conceived. The central floodlight, which was directed forward and produced a narrow beam of light, assisted movement in the presence of complex, rough relief, and it permitted prompt detection of an obstacle. Stationary floodlights with wide beams directed downward were used when working at the bottom. An area of about 4-5 m^2 was lit up when they were turned on with the craft lying on the bottom. As the craft ascended, this area increased. The light from these floodlights was sufficiently bright, and it permitted good examination of the details of bottom and benthos. The side rotating floodlights could be turned on to increase the contrast of objects in the zone of observation. Flashbulbs installed above the craft and on its sides permitted photography; however, we could not obtain contrasting images. Moreover even when the main porthole was used for photography, the photographic field was not fully illuminated.

In twenty-nine dives the craft commanders--V. Deryabin, B. Ishtuganov, and I--acquired the habits of control and learned how to maneuver the craft near the bottom. The only thing we could not do was determine the true distance between the craft's bottom and the seabed. It would be desirable for TINRO-2 to have a flexible rod for this purpose, the tip of which, being level with the bottom, should be visible from the main porthole.

The underwater researchers acquired the necessary habits of controlling TINRO-2 quickly, in just 1-2 hours of navigation under water. Of course, the first time I transferred control of the craft to a new hydronaut I was somewhat anxious. How would the biological specialist manage with his new responsibilities? But the realities surpassed all expectations. All observers accustomed themselves very quickly to the single craft control stick, and they were able to perform all maneuvers near the bottom.

I recall in this connection the American writer (G. Soul's) description of the first dive aboard the "Star-II" craft. Literally immediately after control was surrendered to him, he was able to chase a large crab scurrying along the bottom. Earlier, this had seemed unlikely to me. But now that I have acquired my own experience, I can assure the reader that it is very easily to control a submersible. Of course I am referring only to moving the craft around under water; special training is required to submerge the craft, to impart zero buoyancy to it, to change the craft's weight during navigation, to surface, and to perform other similar operations.

All were sorry that there was only room for two people in the craft. Many of the dives required observation by several specialists. As an example there were cases when an ichthyologist would see interesting geological formations and no fish, and a geologist diving on the following day would see masses of fish but could not find that same plot of ground. Sometimes it is useful for two specialists of the same profile to dive together, so that they could exchange opinions on phenomena that are difficult to understand by a single person. Moreover the amount of work the underwater researcher had to do was so great that sometimes two people could barely complete it with difficulty. A third member of the crew could be given a large number of functions, such as taking still and motion pictures or controlling the craft near the bottom, which would increase navigation safety.

In 29 dives we were able to clearly determine the best working speed of TINRO-2. It would be suitable to conduct research at a speed of 0.7-1.0 knots. At a greater speed, it is difficult for observers to determine fish species. In any case we never traveled at maximum speed beneath the water. This does not mean that it should be limited to 1 knot. The speed reserve should always be present in the event that obstacles must be surmounted, or if the craft is to be maneuvered on the surface when approaching the carrier vessel and separating from it.

The power of the vertical screw propellers was insufficient, which was felt especially when submerging and when surmounting underwater obstacles. In general, it is better in this case to place the craft in reverse, rise in the water, and then detour it. These propellers were fabulous in stabilizing the depth of the craft. The automatic motion control system also operated well.

Touching down on the bottom turned out to be the most difficult operation for all. But even this operation all of the hydronauts assimilated in the end. The craft began to touch bottom very gently, without noticeable bumps. The craft's negative buoyancy, which was equal to 10-15 kg, was fully sufficient to keep it on the bottom. TINRO-2 never got stuck in mud, though of course we never touched bottom when the thickness of the silt deposit was greater than 10-15 cm; furthermore we never stood in one place for more than 45 minutes.

We wrote out all of these conclusions and submitted our report to the Administration of the Scientific Research Fleet. Our work was given a good evaluation. The principal conclusion was that the craft fully suited its purpose, that it operated well, and that it was suitable to organize another trip, this time in the ocean. Everyone was interested in the possibilities for using the craft for underwater biological research. Our work elicited a considerable amount of interest.

In the end, we decided to make our next trip on the "Ikhtiandr" with TINRO-2 aboard in the Atlantic Ocean that same year.

Twenty-nine dives taught us a great deal, but this was still only the beginning.

CHAPTER IV

Six Months in the Ocean

Preparations

A training cruise on the Black Sea.--Eleven dives.--Fabricated emergencies.--Raising the craft with the ship's cranes.--TINRO-2 fails to surface.

Before setting off for the ocean, the administration management decided to conduct a short two-week cruise on the Black Sea to practice interaction between the craft and the vessel one last time, and in particular to test new methods for determining the bearing and location of TINRO-2. Moreover hydronaut candidates who had completed their theoretical training had to prove themselves in practice, and new members of the "Ikhtiandr" crew had to learn all of the operations involving the launching and raising of the craft.

In general, much attention was devoted to selecting the crew, since unusual and difficult work was ahead. Lev Vasil'yevich Medvedev was appointed captain. This choice was no accident: Lev Vasil'yevich was an experienced seaman who had served for a long time as a ship captain.

Marlen Aronov was once again appointed chief of this training cruise, and I was appointed captain-mentor of TINRO-2. Once again we had to go to Leningrad, this time for 6 months.

We set out to sea, and immediately we went to the inlet with which we were familiar. The weather was very good, and we began work on the next day. We had to test a captive floating buoy with a buoy rope that was 1.5-2 times longer than the craft's maximum diving depth as a means for indicating the location of TINRO-2. A similar method was used successfully by the Americans to determine the location of "Star-II". The buoy rope was a thin capron cord which was hooked to TINRO-2's vertical stabilizer by a carabine. A breakaway having a breaking strength of 40-50 kg connected the carabine to the cord, permitting the craft to separate from the buoy rope in the event that it snagged itself beneath the water. An intermediate float was tied to the buoy rope 10 meters away from the craft; this float drew the rope upward and prevented it from winding itself around the screw propeller. A bright orange Japanese capron float with a diameter of about 400 meters served as the floating buoy. It was well noticeable from the ship even in heavy seas at a range of up to 5-6 cables. At night, when a lamp powered by a battery operating off of sea water was turned on, the buoy was visible for a range of 1.5 nautical miles.

L. V. Medvedev, Captain-Director of the Ship "Ikhtiandr", in the Wheelhouse

The "Ikhtiandr" anchored in an area with water up to 40 meters deep, and we prepared TINRO-2 for diving. Nikolay Surov, a hydronaut candidate, was to make the dive. The divers were led by an experienced specialist who had also undergone training as a hydronaut and was now awaiting his underwater test.

After submerging, I crawled over to the observer's place, and from then on the craft was controlled by Kolya on his own. He passed his examination.

Installation of the Hydroacoustic Beacon

The buoy turned out to be an excellent means for detecting the craft's position, and its buoy rope never wound itself around the propeller. During this dive, hydroacoustic communication with the vessel was very good, since the duty navigator, who oriented the ship relative to the buoy, never let the craft get far away from it.

The position of the buoy could also be used to accurately determine the location of the craft when it was on the bottom.

During subsequent dives we tested several types of hydroacoustic beacons mounted on the craft. They all differed in design, but they were tuned to a frequency corresponding to that of the ship's sonar set. We finally chose a beacon consisting of a small sphere, which contained its own power supply. Before the craft made its dive, this sphere was secured to the tail fin, and the beacon emitted acoustic pulses at short intervals. Whenever we entered into communication with the ship, we could hear the beacon's signals well, ones highly reminiscent of the signals produced by the first cosmic satellite.

We measured the inertial characteristics of the craft once again. We found that it took 10 seconds for the craft to come to a full stop after being placed into reverse when traveling at a speed of 1 knot; during this time, the craft travels about 3 meters. This is quite enough room to stop the craft before an obstacle detected even at a distance of 5-10 meters.

A dive in which TINRO-2 was "confronted" by an emergency situation fabricated by us was the most interesting part of the cruise: According to the scenario, for some reason the craft was unable to rise from the bottom and surface, and we had to find it and raise it up.

Taking water into the tanks, TINRO-2 settled to the bottom at a depth of 40 meters. Divers approached the floating buoy and dropped down to the craft along the buoy rope. A capron cable--a "bridle" which the divers secured to the craft's hoisting rods--was secured to the buoy rope beforehand. The capron cable was wound around the ship's cargo winch, and the craft was raised relatively easily to the surface. After this it was carefully placed back on the bottom, and the divers removed all of their fastenings. Now TINRO-2 had to surface on its own, but something unforeseen happened at this moment. While the craft was lying on the bottom, a strong underwater current filled its lower recesses with sand, and it became significantly heavier. The vertical screw propellers were unable to break the craft away from the bottom, even after water taken aboard to impart negative buoyancy to the craft was pumped out. All of the water was pumped out of the compensating tanks, but even this did not help: It was only after partial purging of the ballast tanks that the craft began to surface.

This unforeseen emergency situation did not cause us any concern, since we had just previously raised the craft with the help of cargo cranes and were prepared to repeat the maneuver at any time. We wanted to check out the craft's capabilities, and even this incident was a good lesson for the crew. All of the methods for surfacing the craft in this situation were not tested out. We could also have completely purged the ballast tanks, severed the anchor, and discarded the storage battery.

After placing the craft in the hangar and checking it out, we found out that all of the storage batteries were covered with fine shell sand weighing 200 kg. A most curious goby was discovered between a battery and the hull; "guilty of no wrongdoings," it was released back to the sea.

In all we made 11 dives during the cruise, which lasted 14 days. Seven future craft hydronauts took part in it, and only two of them were unable to fully master the craft in view of a number of objective and inobjective causes.

IZVESTIYA reporter V. Belov, who requested a chance "behind the wheel of the underwater machine," participated in one of the dives, and he easily completed his assignment. This demonstrates once again how easy it is to control the craft.

At the conclusion of the training cruise a dive was made to the rated depth. Prior to this, I was the only one who had ever descended to such a depth as a hydronaut; this time it was Boris Ishtuganov's turn. A diver was appointed the second member of the crew. I was naturally concerned for them, since this was the first time they were to go to such a depth; I was even more agitated than had I been in the craft myself.

The dive began after lunch, and it lasted until darkness. Judging from the calm reports to the ship, everything was going excellently. Everyone aboard the "Ikhtiandr" came on deck to see TINRO-2 surface. The radio operator, who climbed a mast, was the first to see the yellow spot 30 meters below the water. And so it was that the successful return of the hydronauts from the deep was announced by radio.

This dive, which lasted almost 8 hours, once again confirmed the need for using a buoy as a means for recognizing the craft.

We returned to Kerch', where we were awaited by the official qualifying commission, which following a hard exam awarded class III hydronaut qualifications to all who passed the exam, underwent diver training, and clocked the required number of hours aboard the craft; I, who had clocked more than 100 hours under water by this time, was awarded the class II hydronaut category. We all received special certificates, and from this moment on we officially started to be called hydronauts.

We began preparations for an ocean trip intended to last 175 days. We had to stow everything necessary for a 6-month cruise for the ship and craft.

Each day less and less free space was left aboard the "Ikhtiandr". Boxes containing spare parts, instruments, and storage batteries, and cans containing all sorts of oils and lubricants stood everywhere.

The time of our preparations for the ocean trip coincided with a remarkable event in the history of Kerch'--presentation of the Gold Star of a hero city. Delegations from the hero cities of Leningrad, Odessa, Novorossiysk, and Brest visited us aboard ship during these triumphant holidays; members of these delegations inspected TINRO-2 with interest, and they wished us successful work in the ocean.

The program of the trip and the composition of the scientific group were approved in Moscow. The latter included VNIRO colleagues who had already been working together with us in the same program for about 10 years now, and administration colleagues who had never participated yet in ocean cruises aboard conventional vessels.

Representation of the shore-based Undersea Research Service for the trip consisted of its chief, whose main task was to accumulate experience in operating the craft and analyze its research possibilities.

The maintenance group of TINRO-2 now consisted of five persons: mechanic-repairman Sasha Vinogradov, who had already sailed aboard the "Ikhtiandr", electrician Aleksandr Khalizov, who replaced N. Surov when he became a hydronaut, radio navigator Oleg Donets, battery specialist V. Sonin, and fitter V. Kuzovlev.

L. V. Medvedev was appointed captain of the "Ikhtiandr", G. Gordeyev was appointed executive officer, G. Tret'yakov was appointed chief mechanic, and V. Loshchenov was designated first mate. They had all sailed aboard the "Ikhtiandr" for a long time, and they knew each other well.

Preparations for the cruise and an inspection of the ship were completed by the second half of October.

On 22 October the crew and members of the scientific group were assembled. The ship recalled a disturbed beehive. Many relatives appeared for the send-off. More bundles of various sorts and jars containing homemade jam and sauces appeared in the cabins, which already seemed overstuffed. But the moment of parting was at hand. All were excited--both those who were sending us off, and those of us who were being sent off. This was the first time I was to leave for such a long trip, and of course I was concerned about leaving my family for so long a time.

The Cruise Begins

Departure from Kerch'.--Test dives.--New underwater observers.--Amphoras on the bottom.--Bosporus.

On 23 October at 1200 hours a command resounded from the captain on the ship's broadcasting system: "All visitors leave the ship. All hands prepare to cast off!"

The "Ikhtiandr" moved away from the wall and went into the Kerch' Strait through the fishing port's narrow inlet.

Spectators were standing right at the water. The ocean cruise began.

We sailed from Kerch' to Yalta to fill our tanks with good fresh water. Kerch' water was so saline that it was difficult to rinse the storage batteries and raise the resistance of insulation to the necessary limit.

We arrived at Yalta in the morning of the following day. The vessel moored at the passenger pier to take on water. The crew was given a possibility to stroll on *terra firma* for the last time. We were not allowed to leave Yalta because the crewmembers were missing some sort of medical certificates. Thus everyone had to go to the medical unit. But the certificates were finally obtained, and examination was made, and the "Ikhtiandr" assumed a heading toward Bosporus.

Owing to the training trip on the Black Sea, we were able to begin our dives right away on the ocean cruise. We planned to make one or two dives in the western, little-studied part of the Black Sea, so that our scientists could compare their observations with ones made in well-studied regions at the shores of the Krimea and Caucasus.

On 27 October the weather was calm and sunny. There were 130 meters of water beneath the keel. Conditions were right to launch the craft.

Boris Ishtuganov and Nikolay Surov took part in the first dive on that day. Nikolay had to make a checkout dive and demonstrate that he had not forgotten how to control the craft after a month of idleness in Kerch'. Everything went well, and the craft was raised back aboard ship. After a few hours TINRO-2 was once again launched, this time with scientific purposes. This time Surov played the role of craft commander, and his mate was Marlen. However, they did not see anything interesting. They encountered the now-boring whiting and jellyfish. The bottom was firm, and it contained shell fragments.

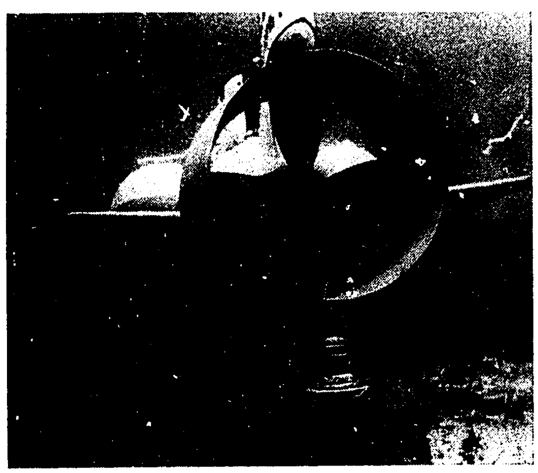
The third dive was made on that day as well. Once again N. Surov was appointed craft commander, and Gennadiy Solyanik went as the underwater observer. He had already performed his checkout dive for the ship commission. Gennadiy was lucky--this day he saw several large unbroken ancient amphoras. Apparently an olden ship had sunk in this place, but nothing of it remained to be seen. The crew of TINRO-2 wanted to survey this region, but suddenly, literally within 10-15 minutes, the weather deteriorated considerably. The captain ordered the crew to return immediately. Wind speed was already up to 15-18 meters per second at this moment. Rain began to fall before the sea even had a chance to get rough, and visibility became much worse. We had never needed to raise the craft in such complex conditions, and this was already the forty-third dive. I was anxious for our novices, who had to suffer such a turn in the weather in their first dive.

The craft surfaced, but there could be no talk of having it approach the ship on its own in such conditions. We launched a boat, which took the craft on tow, but it could not make any headway against the wind. The situation was becoming very serious. At this moment the captain came to our rescue. He ordered the main engine started, and he oriented the ship in such a way that it approached the craft with the open hangar directly opposite the latter. The divers, who were already on the craft, simply attached straps to it and ascended together with it directly into the hangar. This maneuver was completed quickly and precisely and, I would say, gracefully. Everyone gave a sigh of relief. Yes, with such a captain, none of the weather's whims could be feared!

The weather turned to its worst. All night the ship slowly advanced toward Bosporus, rolling from side to side. Everything in the cabin had to be removed from the table, and in the hangar the craft had to be secured well to its keelblocks. By morning the sea subsided somewhat, but a strong, cold wind continued to blow. The entrance to the strait could be seen through the mist.

After a while we could see small Turkish villages with their ever-present tall white minarets on the right shore of the strait, which was already lit by the sun.

Changing of the Crew



TINRO-2 From the Back

After entering the strait, a Turkish pilot came aboard. Traffic in the strait was very brisk: Vessels of different flags and ferries carrying rail cars and motor vehicles passed along and across the ship's path as an endless stream.

After 2-3 hours we reached Istanbul. The city spread over both shores of the strait, which were joined together by a gigantic suspension bridge about 2 km long. A beautiful quay with brisk motor traffic stretches along the strait, and tall, brightly painted houses line the quay, making the city look very handsome and festive. And above all towered a fortress, which spilled in terraces almost down to the water's edge, and the famous Mosque of St. Sofia, which had been fashioned out of a Christian cathedral.

For the entire time that we were passing through Bosporus, Marlen stood at the bow of our ship with binoculars and cameras of all sorts hanging from his neck.

By evening we passed through the Marmara Sea, on the following day we crossed the Aegean, and on 30 October we reached the Mediterranean.

The Mediterranean Sea

Storm.--In the footsteps of J.-I. Cousteau.--The first dive.--Rough bottom.--Encounter with fish.--Amazing underwater scenes.--To reach the ocean sooner.--Rescue of a Moroccan vessel in the Strait of Gibraltar.

Several dives were planned in the Mediterranean Sea, in the vicinity of the Tunisian plateau. We knew that the water there was amazingly clear and that the bottom was good, and we intended to not only make scientific observations but also photograph TINRO-2 under water with the help of SCUBA divers. However, the Mediterranean weather would not make things easy for us--throughout the entire time we were steaming along the coast of Greece, the sea state was 5-6 points.

The craft was being prepared at full steam in the hangar. New members of the maintenance group acquainted themselves with the craft's layout and learned their responsibilities. Sasha Vinogradov, who had undergone training together with the plant specialists and who had participated in previous cruises aboard the "Ikhtiandr", and Volodya Kuzovlev, his assistant, spent their entire days beside TINRO-2; they checked out its mechanisms, and they installed a backup depth gauge for the underwater observer.

The craft's new electrician, Aleksandr Khalizov, had sailed aboard ships many times prior to this, and he immediately concerned himself with the craft, but he still had no idea as to the volume of work awaiting him.

Battery specialist Vasiliy Pavlovich Sonin, a very serious and sizeable person, worked together with him. Sasha was skinny and tall, while on the other hand Vasiliy Pavlovich was short and fat. Despite the differences in their appearance, character, and age, they came to work together well, and they were literally inseparable. During our passage they restored the outfit of storage batteries that had been expended in previous dives of the craft. Now we possessed two working outfits of batteries.

Radio navigator Oleg Donets was on his second trip aboard the "Ikhtiandr", he underwent training in the group of hydronaut candidates, he prepared himself for training dives aboard TINRO-2, and he prepared all of the craft's electronic systems, constantly making improvements on one thing or another. On his proposal a backup gyrocompass was installed near the underwater observer, making control of the craft near the bottom easier.

Oleg spent a great deal of time charging various storage batteries in the instrument power supply blocks. Whenever Oleg extracted them all from the craft and arranged them on the charging rack, large and small, acid and alkaline, transparent and opaque, it seemed to me that our craft had been built mainly to carry batteries, and that there was nothing in it but batteries. The term "power block" became so permanently entrenched in our vocabulary that even the box of food which the crew of the craft took with it on dives was henceforth referred to only by this name.

A week had passed since our departure from Kerch'. Toward its end, the sea state reached 6-7 points. Intense rocking began, and all work in the hangar had to be stopped. The "Ikhtiandr" had never sailed in such weather before. Everything was creaking, and it was difficult to walk the deck. A lifeboat on deck above my cabin squeaked repulsively whenever the ship rolled hard. It could not be secured any better, and I was forced to sleep beneath this unusual accompaniment.

At night we reached the vicinity of the Tunisian plateau. The weather had not changed, and we decided to go on to Gibraltar without stopping.

In the morning of the following day, there was nothing to recall yesterday's storm. There were 45 meters beneath the keel. We decided to set anchor. We could barely make out the African coast in the haze on the port side. Everyone awaited the first dive in the Mediterranean Sea with impatience. The captain announced on the broadcasting system that the dive was to occur at 1400 hours. The maintenance group began preparing the craft. The trawl was set out for the first time during the trip, even though large accumulations of fish had not been observed with the echo sounder; the size of the catch had to be compared with observations made from the craft. An hour later the trawl was raised almost empty: A couple of dozen 30-centimeter cat sharks and three moderate-sized spiny lobsters, which caused a great stir of excitement among the crew, were taken from it. The cook was also interested in the lobsters, and in short time we were able to taste their meat. We found it to be very flavorful.

Just before the dive Senya Mikhaylov took several hydrological readings. The density of the water was found to be 1.028--that is, much greater than in the Black Sea. In this connection we decided to increase the craft's solid ballast by 100 kg. We used two reserve anchor-guide ropes as the ballast, placing them inside the pressure hull. They fit well between ribs in the hold of the craft; and so they remained there for the entire trip.

The hands of the clock neared 1400 hours. The sun was shining brightly, it was warm, and the sea state did not exceed 2 points. A strong current with a speed of about 1 knot close to the surface of the sea caused us some concern. During the craft's descent the current could carry it far away from the ship, since adjustment of its ballast in the new conditions would require a certain amount of time.

At 1430 hours Marlen Aronov and I were already sitting in the craft. The ship was standing at anchor, and as soon as the divers released the catches the current began sweeping the craft away. A motorboat had to catch up to us and tow us back. I tried submerging the craft on tow, but nothing happened, and it was not until additional water was taken into the compensating tanks that the craft went down. Deeper down, the current was weaker, and we began work.

We saw the bottom from a range of 25 meters. The water was very translucent, it was of an amazingly beautiful turquoise color, and it was so clear that it was difficult to orient ourselves while diving--to determine whether or not the craft had started submerging or not, and its speed. The "snow" helped us with this in the Black Sea.

We were in the traditional region of operations of J.-I. Cousteau, and now the beautiful scenes of the undersea world of the Mediterranean Sea were before us in real life, rather than on a movie screen.

Beneath us was a jumble of huge stony outcroppings. We traveled at a distance of 20 meters from the bottom and looked for the most interesting place in which to settle the craft down. In the end, Marlen approached the bottom. We were traveling forward, precisely detouring the protruding crags, which were sometimes 10 meters high. When I looked through the portholes in the coaming of the hatch, their summits were visible somewhere above the craft, in the haze. At the bottom, Marlen piloted the craft with special care, but despite this, he nevertheless hit the crags several times. Areas with beautiful bright sand could be seen between the rocky outcroppings; we wanted to land the craft in them, but the current carried us away. Thus we had to come in under cover of a large cliff and take on a little more water in the tanks. It was only after this that the craft lowered gently to the bottom. I moved next to Marlen. Now we could look around at our leisure. After the Black Sea, with its even bottom and monotonous, almost lifeless scenes, the picture we saw astounded us. Rocky outcroppings covered with sponges, corals, and bryozoans towered around us. In natural life they seemed boring and gray, but as soon as the floodlights were turned on, red, yellow, and green colors immediately began to dance around. Damselfish and other reef fishes swam by quite close to us. Visibility at the bottom was not less than 20 meters. We spent about an hour on the bottom, enjoying the underwater scenes, after which we surfaced uneventfully.

After TINRO-2 was raised aboard, the "Ikhtiandr" raised anchor and proceeded further west, to Gibraltar.

On the following day the ship reached the next bank, this one with a depth of about 120 meters. Once again TINRO-2 descended into the waters of the Mediterranean Sea. This time there were two Borises aboard--Boris Ishtuganov and Boris Vyskrebentsev. They experienced the same delight with what they saw as I had with Marlen. The amazingly translucent water and the colors of the undersea world were astounding.

TINRO-2 settled down on the very margin of a rocky bench next to a 30-meter cliff, and the floor of this chasm was clearly visible through the translucent water. A school of fish, mainly (antis) and horsemackerel, swam by the craft. In all, Boris Vyskrebentsev counted seven species of fish.

No matter how interesting it was to dive in the Mediterranean Sea, the ocean awaited us, and therefore immediately after the craft was raised aboard, the "Ikhtiandr" went on to meet it.

After each dive everyone convened in the captain's quarters to analyze the work of the ship services and the results of the underwater observations. The scientific group and the hydronauts were invited to these conferences. The benefit of such discussions could not be doubted, and therefore this tradition remained in force aboard the "Ikhtiandr" until the end of the trip.

On 7 November we reached Gibraltar. A triumphant meeting was held aboard the ship, and a holiday banquet was organized. Everyone received congratulatory radio messages from home. The ship's amateur artists put on a good concert. It began immediately after dinner beneath the open sky on the trawl deck, though naturally the weather suddenly changed abruptly (for the umpteenth time!), and intense storm winds began to blow from the ocean.

The "Ikhtiandr" had already passed through the narrowest part of the Strait of Gibraltar and reached the ocean. At this time the radio operators received an S.O.S. from a small Moroccan fishing boat slightly forward of us. Their engine had broken down, and the strong wind threatened to toss the boat onto the rocks. Despite brisk ship traffic in the strait, no one responded to the appeal for help, except us.

The concert had to be interrupted, and the "Ikhtiandr" struck a heading toward the boat in distress. In short time, in pitch dark, among waves increasing in size with every minute, the searchlight revealed a felucca with five fishermen aboard, who had already prepared a towing cable. Our attempts at throwing them a cable were unsuccessful; after several maneuvers of the "Ikhtiandr" we finally managed to place them on tow, and then we tried to determine where to deliver our wards. Their radio set had broken

M. Girs Communicating With the Submersible

The Central Post Aboard the "Ikhtiandr"
for Communicating With the Craft

down, such that all we could do was shout across, competing with the whine of the wind and the noise of the sea. The Moroccans asked us to tow them to Tangier. The "Ikhtiandr" changed its course and steamed for the African coast. By three in the morning the bright lights of the city, familiar to us from the movie "Espionage Networks", appeared, and the ship entered the port's outer roadstead; a tug was already hurrying toward us from shore. As the tug dragged the felucca into the harbor, the "Ikhtiandr" turned about and once again set out for the ocean.

The holiday concert was postponed to the next evening.

The Ocean Above Us

Selection of the place of the first oceanic dive.--Loss of the trawl.--We dive.--Underwater impressions.--The divers become climbers.--Muddy waters.--New Year's dive.--Simulated dive in the hangar.--Hydronauts on a diet.--Sharks beside the craft.--The hydronaut-researcher is a lady.--The last dive.

We were already on the ocean when we woke up in the morning. I had waited for this moment for a long time, and it was somehow strange to realize that the "Ikhtiandr" was not on the Black Sea, but on the Atlantic, and that the coast that we could see from afar was not our familiar Crimea but foreign Portugal.

We were not far from Gettysburg Bank, near which we decided to make our first dive in the ocean. The "Ikhtiandr" sailed several tacks above this bank, and we attentively followed the stylus of the echo sounder: "What will the bottom be like?"

The sounder's recording recalled an old comb with broken teeth: There were almost no even areas, and the minimum depth or, more accurately, the minimum distance from the surface of the water to the summit of the highest crag was 20 meters.

Fourteen little boats fishing for tuna with rods were floating in the vicinity of the bank. Warmed water drained into the ocean out of special pipelines mounted along the sides; this water attracted the fish, and the catch was unusually abundant.

Meanwhile the "Ikhtiandr" continued to survey the bank. Finally we found a more or less even area, and we marked it with a buoy bearing a radar reflector. This work took almost the entire day, and therefore we decided to launch the craft on the next day, and meanwhile to set out the trawl. We began trawling at a depth of 150 meters. In about 45 minutes the ship shuddered slightly--something had snagged against the trawl. We began raising it aboard, but the greater part of it remained on the bottom--we were able to extricate only trawl fragments, both ours and others'.

Apparently more than one fishing vessel had suffered the same fate here.

After this incident we reconsidered the suitability of launching the craft in this place.

To a submersible, one of the most serious hazards is a lost trawl. If a craft enters such a huge open sack, the upper margin of which is held above the bottom by floats, and the lower margin of which is pressed to it by heavy weights, it would be almost impossible for it to get out. Fishing gear or trawls lying on the bottom in disarray are also dangerous to a submersible. I had already mentioned the American submersible "Deep Quest", which snagged its propeller against a cable at a depth of 130 meters and could not get free of it for 30 hours. Its release required the help of a second craft.

Were we to find ourselves in such a situation, we would not be able to count on help from another craft--one was simply not available. TINRO-2 could be "caught" from the bottom with a special small bottom trawl, present aboard the "Ikhtiandr". After discussing the situation, the cruise chief, the captain, and I decided that the risk was not worth it, and that it would be better to find a more-suitable place for the first ocean dive.

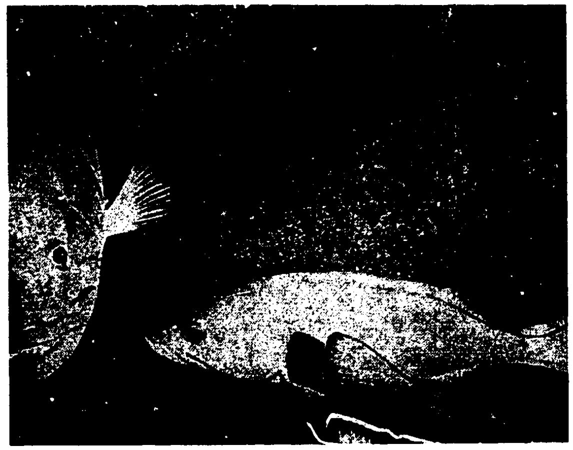
Before leaving Gettysburg Bank we attempted to find the buoy we had set out, but it had disappeared without a trace. Apparently someone else picked it up.

We were also unable to work at Ampere Bank, the next one down the line, because of the weather's deterioration. The "Ikhtiandr" was forced to move farther south, in the direction of the Canary Islands.

We made a stop in the vicinity of (Sen) Bank, where the depth was about 180 meters. The relief of the bank suited us: Some of the slopes were steep, and some were gentle. The water density was almost the same as in the Mediterranean Sea. Everyone awaited the launching of the craft.

As usual, Marlen Aronov and I made the first exploratory dive. After our medical check-up we took our places in the craft. The launching began, and in no time the craft was under water, at the ship's side. The water was so clear that through our portholes we could see not only the side of the ship from stem to stern, but also its bottom. It seemed as if the craft was suspended in thick blue air over a bottomless pit.

The water was clear, without suspended particles, all the way to the bottom, which we could see from a distance of 40 meters. We immediately descended to 200 meters. It was bright around us, almost like on the surface, and we did not even have to turn on the floodlights. The bottom could be seen well through the portholes. It was even, with only a few rocky outcroppings sticking up here and there. We decided to anchor next to one of them and look it over.



200 Meters Deep. Now These Are Fish!

And so, on 12 November 1974 TINRO descended to the floor of the Atlantic Ocean. That for which we waited and prepared for almost 10 years was now reality! It was a noteworthy moment, we congratulated one another on this event, and we started our work.

There were many fish around, and they related rather calmly to the craft. Neither the mechanisms nor the hydroacoustic instruments frightened them. (Bekasy)--very likeable little fish with long skinny noses--were seen most frequently swimming by the portholes. We also encountered mackerel, but in small schools of no interest to fishing. The fish reacted to light. By alternately turning on the floodlights on opposite sides, we could "lead" the fish from side to side.

After a while we raised anchor and decided to approach the slope of the bank. The course TINRO-2 had to take was communicated to us from the ship, and it slowly began moving over the bottom, detouring the rocky outcroppings. A school of five or six small striped pilot fish could be seen through the porthole on the bow; they held a position near the sensor block of the hydrological complex, as if bound to it.

Suddenly the bottom disappeared beneath us, and the craft found itself suspended above a deep chasm. Somewhere down there we could make out the steeply descending slope. We did not have enough time to dive any deeper--we had to surface. At this moment the reduction gear of the left vertical screw propeller jammed (we did not find this out until we were aboard ship once more). Despite all attempts at compelling the craft to surface, it continued to drop slowly into the void. The echo sounder's depth reading was 260 meters. In literally a few minutes the craft's tail fin gently touched bottom and stopped. It became noticeably darker because we had descended to the bottom and because it was already evening on the surface. Once again we checked out the vertical propellers. They would not work. Thus we had to pump water out of the compensating tanks. Only after this did the craft separate from the bottom and begin rising slowly.

While I was busy with the mechanisms Marlen calmly watched through the portholes, absorbed with a large oceanic eel more than 2 meters long, which he even photographed. Finally TINRO-2 leapt up on the surface and was raised uneventfully into the hangar.

The reduction gear broke, mechanics Vinogradov and Kuzovlev found out, due to a disintegrated ball bearing. It was replaced by a new one, and on the next day the craft was ready to dive, but the weather went bad.

The "Ikhtiandr" proceeded further, to (Dasiya) Bank. We wanted to remain in this region for a longer period of time because the bank's relief suited our needs. We had but to wait for better weather.

On the fourth day the winds died down, but the ocean was covered with swells, and the height of the waves attained 3 meters. "Swells are a perpetual phenomenon in the ocean," we decided, and so we began preparing the craft for the dive.

B. Ishtuganov was appointed commander, and B. Vyskrebentsev went as underwater observer. This time TINRO-2 immediately discovered a large accumulation of fish, the largest ones being burbot, attaining a length of 70 cm.

After the craft was placed in the hangar we discovered to our amazement that the storage battery's cowling had been torn off. All that remained of this cowling, which was made from thick fiber glass, were small pieces beneath the fastening bolts. We have never established the cause of its disappearance.

The craft never experienced any other serious problems for the rest of the cruise.

We made a few more dives at Dasiya Bank and "worked in" all underwater observers who had finished their training in our on-the-job study program by this time.

One of the most interesting dives was the one in which N. Surov and G. Solyanik took part. The transparency of the water was the highest of the entire period of observations--the bottom was visible from 65 meters. It was established during our work that when the craft moves at a distance of 15 meters from the bottom, a strip of ground 60 meters wide can be seen well through its portholes--that is, a distance equal to the breadth of a

TINRO-2 Catches a Wave

trawl's opening. Thus we determined the actual navigational conditions under which TINRO-2 could be used to evaluate the effectiveness of a trawl.

On 19 November 1974 TINRO-2 completed its 50th dive since it was put into operation. The craft followed the slope of Dasiya Bank down to 320 meters. Translucence was now customarily good. This time the hydronauts were able to enjoy viewing the even meadows of coral sand and crags with a curious lilac-red color. Huge burbot were often encountered, and for the first time the crew was able to see morays hiding among rocks. A school of mackerel about 40 meters long passed by the craft a small distance away from it. The fish moved very close to each other in six tiers. The bottom, meanwhile, was difficult to see due to the bekasy. A layer of water 4-5 meters thick was "stuffed" by these tiny fish. Just watching the bekasy was an unusual pleasure. The fish swim almost vertically, constantly poking their noses into the bottom, seeking something out of it for their nourishment.

On the day of our 50th dive my wife called me from Leningrad by radio-telephone. The connection was not so hot, and our conversation was mediated by a telephone operator, which resulted in a funny misunderstanding. I told my wife that we had just completed our 50th dive, and the telephone operator told her that I had just turned 50. Taken aback, my wife congratulated me on my birthday! It was in this odd way that the "anniversary" day ended.

The next was not an anniversary dive, but it was memorable. The craft was to be launched in the evening. At that time someone noted several large sharks swimming together alongside the ship. They were impudently swimming near the hangar itself, and we had no idea how these guests would relate to the appearance of a motorboat and divers in the water. Surveying this scene, the divers declared that they did not care for the neighborhood, and that they did not wish to work with the craft in such conditions, especially in the evening and at night. Jumping into the black water boiling with sharks was in fact dangerous. We postponed the dive for safety's sake; anyway, the weather was beginning to turn for the worse.

A change had to be made in the way the divers worked with the craft, and not only due to the appearance of sharks. The problem was that it was simpler and safer to raise the craft aboard the "Ikhtiandr" in heaving seas than it was the lifeboat out of which the divers worked. The boat was wearing out before our eyes because of the jerks and bumps against the ship it experienced while being raised aboard. The captain was concerned about its condition. The little boat was totally unsuited to this purpose, since it could be used only in calm seas.

There were numerous solutions, but the best was felt to be that of having the divers climb down to the craft on storm ladders, a suggestion made by Captain Lev Vasil'yevich Medvedev. Two ladders made from flexible steel cables were lowered from the bridge of the hoisting device to the bow and stern of the craft while it was in the hangar. The divers were to use these ladders to ferry over to the craft after its launching, and release the catches. After this the ladders were to be drawn into the hangar together with the divers.

Everyone impatiently awaited better weather, so as to test the new technique, which recalled an aerialist act on a trapeeze. Finally the weather subsided. The craft was launched into the water. As soon as it touched the water, the divers nimbly climbed the ladders down to the deck of TINRO-2 from the hangar. Quickly releasing the catches, they scrambled back up the ladders, and they were raised into the hangar uneventfully. After this the divers were renamed climbers, since they hardly touched water by this method. The "shark danger" ceased to cause us anxiety.

During its dive, the craft had to pass alongside a rather steep slope of the bank at a depth of up to 400 meters.

This was in itself an unusual working depth.

I was at the command post, and Boris Vyskrebentsev was at the observer's porthole. After a little while I heard his happy voice through the hydroacoustic communication system: "I can see a school of tuna."

About 100 large tuna about a meter in length were escorting the craft at a depth of 45 meters. The boldest approached to within 2 meters, such that

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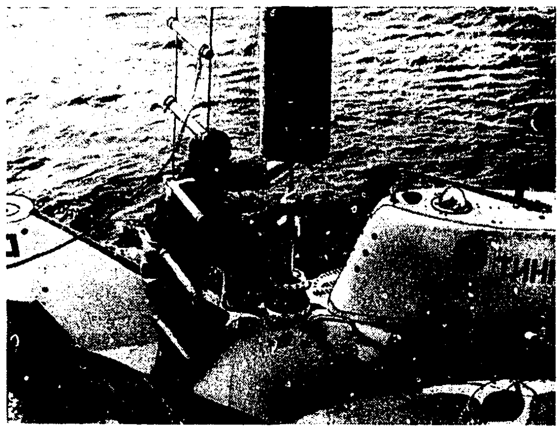


The Catches Are Released

The Craft is Readied for a Dive

they could be examined well, even though this time the water was filled with "snow," just like in the Black Sea.

The slope of the bank at the place of the dive was sandy, and it was broken up by a wavy relief 15-20 cm high recalling a washboard. As the depth increased, the ripples decreased in size, and at about 170 meters they disappeared altogether. Very soon the steepness of the slope increased, and the craft, the tail fin of which was glancing the bottom, began dropping downward. Sometimes large craters of incomprehensible origin, about a meter in diameter, could be seen through the porthole. Beautiful pastel-pink fish swam about them; they were completely round, they varied in size from a large coin to a small dish, and they had large eyes. We named them "nickels".

Rods baited with fish were secured to the craft before the dive, but nothing beneath the water showed any interest in them.

Almost no fish were encountered at 400 meters. On rare occasion we came upon scorpion fish and perch. The 45° slope descended even deeper.

Our research program was completed, and we began raising the craft. As we approached the vessel we decided to test the line gun as a means for mooring the craft, which we had not done since the time of the trials. The executive officer announced on the loudspeaker system that the craft was going to shoot its line gun, and he requested all to leave the port side of the ship and stay away from the portholes. Naturally this command had the reverse effect, and in an instant the entire side of the ship was filled by curiosity-seekers. As soon as the craft was even with the hangar the captain ordered: "Fire." But only a light hissing could be heard, and all fell silent. An agonizing minute passed, but the gun never fired. It turned out that the stemof the air valve had broken off.

The craft approached the hangar on its own, and the "climbers" dexterously saddled it. The entire operation took just a few seconds, and so we finally decided to work without the motorboat in the future.

In the evening, when it began to grow dark, we witnessed a strange natural phenomenon. A huge luminescent cloud of almost circular shape took form before our eyes on the starboard side of the ship, just a little above the horizon. A bright spot with a tail moved randomly in its center. The clouds increased in size, and the spot's tail constantly changed its position. After the first cloud dissipated, a second grew in its place, followed by a third. At one moment they overlapped each other. The clouds were luminescent, and they recalled the moon, but their brightness was significantly weaker than that of the latter. None of the crewmembers had ever seen something like this before, and we were never able to understand what this phenomenon was. Radio reception was not disturbed during this time, and the magnetic compasses behaved normally as well.

Our stay in the vicinity of Dasiya Bank was coming to an end. We had made eight successful dives here, and in the future we were to travel to the Canary Islands, visit Las Palmas, and then move farther south. Marlen Aronov and I had to make the last and ninth dive near the western slope of the bank.

The weather was good, and there were numerous fishing boats beside the "Ikhtiandr", which pulled their trawls literally from beneath our ship. There was practically no place to drop anchor. Despite the most terrifying signals raised aloft on our mast, and radioed appeals, no one wished to move away to the required distance. One Spanish trawler was prepared to drive its stem right into the open hangar of the "Ikhtiandr", so great was the curiosity the sailors displayed for the unusual appearance of our vessel. It was only after we began launching the craft that a small area was vacated around us.

Most of the boats were fishing with pelagic trawls down to 160 meters; therefore the craft immediately descended to 200 meters, in order to avoid an undesirable encounter with someone else's trawl.

Hydroacoustic location of the craft was almost impossible in such conditions. It was very difficult to isolate, from the choir of operating sonar sets, the delicate squeaking of our beacon. We could determine the location of TINRO-2 only from its floating buoy.

We descended almost to the very top of the bank, and then we immediately began traveling downslope. At a depth of 360 meters the bottom was completely smooth and sandy. Except for (bekasy) and horsemackerel, there were almost no fish. Unexpectedly the craft found itself hovering above a deep canyon with steep walls at a depth of 370 meters. We descended to 395 meters to the bottom of a huge pit. There was nowhere to go. Directly before us was a vertical wall, the upper edge of which was visible somewhere above us. The sensation was such that the craft had gotten itself into a submarine grotto. It seemed as if the upper edge of the wall bended inward and hung over TINRO-2. I experienced the same feeling in the Mediterranean Sea during our first dive to the foot of a tall crag. The optical illusion can be explained by the way light propagates in water, and I understood this quite well, but the sensation was so intense that I unwittingly felt like putting the craft in reverse and withdrawing from the "grotto".

The wall was greenish due to the vegetation covering it, which had large, burdock-like leaves. Large red prawns up to 8 cm in length sat among these "burdocks". Perch sometimes floated by leisurely, "glancing" into the craft's portholes with curiosity.

We traveled along the wall to find ourselves above a sandy bottom from which short white tubes with bent-in margins rose like fantastic flowers. When the craft ran over them, the tubes bent gently, and then straightened back out. Tiny eels swam out of some of them. Apparently these were some sort of unusual white sponges that we had not encountered before.

Traveling a little further, TINRO-2 stopped on a short rocky bench above the bottom of the canyon. Sardines swam leisurely in front of the craft. An almost-black perch about a meter long swam slowly from beneath the bench on which we rested. It looked about, swam right to the lower portholes, and suddenly lunged nimbly at the sardines--we never saw them again. The panorama was remarkable!

After the craft was placed in the hangar, the "Ikhtiandr" went south, to the Canary Islands, and on 9 December it dropped anchor in Las Palmas. It was pleasant to rest and stroll on firm ground after 47 days of sailing. Everyone liked the city, but we had to move on.

Still before us was Endeavor Bank, where we decided to work with the first good weather. The minimum depth of the bank was about 300 meters.

N. Surov and B. Vyskrebentsev took part in the first dive on this bank. As it was being launched, the craft was pushed in one direction by the current while the ship was forced in the other by the wind. Communication became unstable, and the crew of TINRO-2 decided to settle to the bottom at 380 meters until the "Ikhtiandr" could get closer to the craft. B. Vyskrebentsev began taking photographs using the electronic flash. Suddenly there was a popping sound--a capacitor in the power supply of the electronic flash failed. Nikolay Surov took on a little water in the compensating tanks to make the craft's position more stable, and he crawled into the bow to disconnect the failed capacitor. By the time he returned to his place the ship was above the craft, and communication was restored. Deciding to move on to a new place, Boris turned on the vertical propellers, but the craft would not move from the bottom.

During the hour that the craft was on the bottom, the light hull was covered by coral sand in the area of the storage battery due to the action of the strong currents.

I had the same experience during the training cruise on the Black Sea. But at that time no one gave it a second thought, since the divers could come to the assistance of the craft at any moment. Here, however, there was cause for concern, since the divers could not descend to a depth of 380 meters. I advised the crew to pump some water out of the compensating tanks, but they were unable to do so because the system had apparently become clogged by sand and silt. Surov dropped anchor and once again turned on the propellers. The craft shuddered slightly, but it had no desire to rise. It became necessary to purge the ballast tanks with a little air, and it was only after this that the craft slowly began rising.

According to our calculations the weight of sand on the craft was about 170 kg! After this, no one ever parked the craft on sand--everyone came to understand what this could lead to.

We made one more dive at Endeavor Bank, during which the craft encountered a large shark about 5 meters long. The span of its tail was about 1 meter.

At the bottom, the hydronauts came across a piece of ground covered by red, yellow, and white corals. Once again we had to lament the absence of a manipulator on the craft.

After this we departed from Endeavor Bank, and we were not at all sorry for it--work in this area was made difficult by the very strong current and the abrupt changes in the water's salinity gradient.

A day later the "Ikhtiandr" was at the shores of the Western Sahara.

The first dive was made at night. Ichthyologist Tolya Pomozov was aboard the craft; because of his great height, he could barely fit in the observer's post, but he immediately forgot all of his discomfort as soon as the craft submerged.

As the craft was being launched, intense sea swells were noted, and the ship was heeling 7°, but we had become accustomed to launching the craft by now, and such a sea state no longer caused anyone anxiety.

The craft submerged in darkness, which permitted the crew to enjoy uncommon planktonic phosphorescence of water disturbed by the craft as it moved beneath the water. Sheaves of blue sparks spread out in the water beyond the portholes, disappearing as soon as the craft stopped. In a bright beam of light these sparks alternately took on the shape of balls, hairs, and rods. At first glance they appeared motionless, but were one to simply look at them more attentively, these balls, hairs, and rods would begin shifting about quickly, fluttering their miniscule rowers, and twisting about. They were all the tiniest living beings.

This time the craft found itself in a dense accumulation of horsemackerel. When the floodlights were turned on, the fish came right to the portholes, through which light passed out of the craft's compartments, and butted them with their noses, as if trying to get inside the hull. TINRO-2 was traveling 5 meters from the bottom, but it could not be seen because of the large number of fish. In response to the lightest tap inside the craft they swam away, but then they returned and accompanied it as it moved along, at times running a little ahead, and falling behind at others.

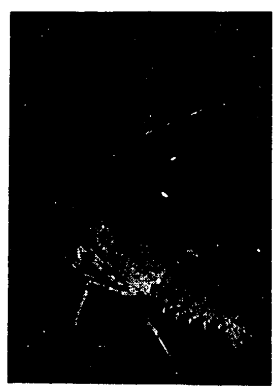
It was much faster and simpler to raise the craft aboard at night. The bright light spot from the craft's lamps was well-visible from the surface while the craft was still 50 meters deep. As it ascended, the spot became more and more bright, assuming a redish turquoise color. The ship approached the surfacing point of TINRO-2 even before it appeared on the surface.

We made all subsequent dives either at night or before dawn. These hours in the life of the undersea world were also of the greatest interest to the ichthyologists.

Night work tired the craft maintenance group and the hydronauts, such that we were not too unhappy the next time the winds came up and the seas became restless--we could subject the mechanisms to preventive maintenance and put our documents in order. A strong wind carried clouds of sand from the Sahara from the shore, which could not be seen. A thin layer of sand covered everything, it rustled beneath the feet, it grated on the teeth, and attempts at removing it were useless.

The poor weather did not keep the vessel from engaging in other pursuits, including fishing. On one day tuna appeared near the ship, and all off-duty crewmembers went topside with improvised rods. In half a day about 2 tons of fish were caught, which significantly enriched our ration.

We decided to make the next series of dives further south, at the point of transition between the shelf and the continental slope. The first pair of hydronauts did not discover anything especially interesting, except for large spiny lobsters.



A Mauritanian Spiny Lobster 50 cm Long.
West African Shelf, Depth 315 Meters

The 31st of December was approaching. The 23d and last dive of the ocean cruise in the passing year began at 1900 hours. Gennadiy Solyanik and I went down. We immediately dropped to 400 meters, turned the bow of the craft toward the steep slope, and began examining it. Spiny lobsters began to be frequent beginning at a depth of 300 meters. They sat beneath rocks with their long whiskers sticking out, or on small open areas of sandy bottom. In the latter case they permitted the craft to approach to a range of 2 meters, after which they moved away from the illuminated zone.

The craft attained an even and smooth shelf, and I noticed that the bottom was marked by straight lines--numerous traces made by bottom trawls, looking like country roads from an airplane. There were many craters and pits. The impression was that some sort of giant elephant had been walking about on the bottom, but these were traces left by the activities of marine animals.

For some reason prawns were sitting around eels that had burrowed into the ground.

At 2100 hours local time the craft rose to the surface of the ocean, at which time we were inundated by a tropical torrent. The thunder could not have been more intense, and the lightning blinded the eyes. At this time Leningrad was celebrating the New Year, and it was difficult to imagine that the city was engulfed in snow and cold.

At 2400 hours local time we also celebrated the New Year. The entire crew convened in the mess hall. Several persons led by Captain F. Reva from the trawler "Kerchenskiy Rabochiy", which was returning home, visited us. We also had a Father Frost, and a Snow Maiden. The executive officer read a poem of his own composition about our odyssey. After a festive banquet, in which only the watch did not participate, a concert began by tradition.

On the first day of the New Year we received new orders for work in the vicinity of Cuba. Before crossing the Atlantic we had to put in at Dakar to replenish our stores. But we had to postpone our departure--we needed to wait for diver V. Kruglov, who was undergoing surgery "to correct a condition of appendicitis" at a floating base not far from the "Ikhtiandr".

During this time we made a few more dives on the shelf, but we did not see anything especially interesting.

A passage across the ocean and testing of the craft in the highly complex conditions offered by a tropical gulf were what we wanted, and they had been planned in the trip's program. A group of physician-physiologists from the Institute of Aquatic Transportation Hygiene flew out of Moscow for Dakar to participate in this work.

While waiting for their arrival we made one more dive at the boundary of the shelf; Boris Vyskrebentsev conducted the underwater observations.

Light was weak under water, and visibility did not exceed 10 meters. Suddenly Boris noted a shapeless mountain--it was a trawl lost by someone.

Boris decided to descend in order to keep from becoming entangled in it, and he found himself in a narrow canyon about 100 meters wide. The echo sounder fixed the bottom at 800 meters. In Boris's words he had never encountered a gloomier place in any of his dives. The black steep walls of the canyon and the total absence of vegetation and living beings all recalled the mythical entrance into Hell. Our hydronaut got out of Lucifer Canyon (the name he gave to the place) as fast as he could, after which the trip along the shelf was continued.

We arrived in Dakar on 13 January. The "Ikhtiandr" stopped at a mooring next to the Italian passenger liner "Galileo Galilei". Approaching the port, this ship had run aground in shallows, and now a "lacerated wound" gaped in its bottom in the vicinity of the fuel tanks.

After a short stopover the "Ikhtiandr" headed across the ocean. The weather was fresh. A 6-7 point northeast wind blew for the entire 12 days of the passage, as if chasing us along. We traveled at an average of 260 nautical miles per day. During these days the hydronauts busied themselves with writing the work programs together with the newly-arrived physicians. During their explorations they had to determine the optimum work-rest schedules for the hydronauts, the length of the work day, and the peculiarities of nutrition during the cruise and while beneath the water. Several years ago similar research was conducted by aquanauts--that is, inhabitants of undersea houses and craft subjected to the immediate effects of sea water, but their recommendations were useless to us, since we were working in entirely different conditions.

The experiments were begun during the passage. At the request of the physicians we had to simulate a dive by the craft inside the hangar. The main goal of this "dive" was to determine the influence of the craft's environmental conditions upon the hydronauts. Air temperature inside the hangar was 24-26°, and it corresponded to that of sea water in an oceanic gulf or in any other tropical region. These same dives were to be used for practical training of hydronaut candidates. It was with a consideration for this that we formed the crews, which were to dive in the waters of the gulf following the simulated dives.

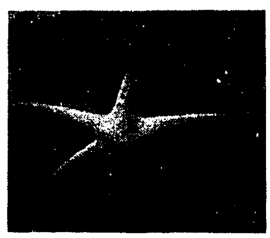
The first "experimentals" were Oleg Donets and I. In a few minutes before our "dive" we were covered from head to foot with all sorts of sensing units, like cosmonauts; wires led from these sensors to special instruments. My friend and I got into the craft, locked the entrance hatch, and began work: We turned on the regeneration system, and then periodically, also as in a real dive, we switched on the craft mechanisms that produced heat and created noise. After every 30 minutes we took air samples in the craft and measured humidity and temperature in different points of the compartment, and we took readings from the sensors attached to our bodies. The length of the "dive" was 5 hours, during which communication was maintained with the ship. By the end of our stay in the craft the temperature increased to 29°, but owing to good ventilation neither I nor Oleg experienced overheating.

The gas composition of the air, the temperature, and the humidity inside the craft were in precise compliance with the norms.

In all we performed 5 simulated dives, one of which lasted 8 hours.

To determine the optimum food rations and to count the calories expended by hydronauts during work under water, 26 types of foods packaged in tubes and small cans had been brought aboard. They included soups, side-dishes, stewed fruit, juices, and jams. During one day of our passage a tasting session was set up aboard ship for these foods. We liked some, and others not so much. All "experimentals" had to eat only this preserved food for 10 days, and I must admit that we awaited this trial without real delight.

Meanwhile the passage was coming to an end. No one was enthralled any more by either the schools of flying fish leaping up from beneath the ship's stem, or the whale sharks.



Starfish With a Span of 35-40 cm Between the Farthest Points of the Rays. West African Shelf, Depth 100 Meters

Bunches of seaweed giving off a strong odor of iodine were retrieved from the Sargasso Sea with homemade nets from the moving ship. In his time, Columbus, on noticing this seaweed pacified his crew by promising them a swift landfall. The goal of our passage was close as well. And in fact, the coast soon unfolded itself before us.

On the 14th day of the passage the medical research was restarted. The "experimental" hydronauts were put on a "cosmic" ration. They could take nothing but fruit juices and water from the common table. Three times a day we ate food squeezed from warmed tubes, and all the while we had to bear with the abundance of witty remarks by others present.

We had to note down on a special form the amount of bread we ate and the quantity of water we drank, and we had to assess the quality and taste of the offered food. We were weighed each day. To me, the food we got was enough for normal work, but some complained about its monotony.

After this experiment it was a long time before we could get rid of the habit of eating anything that comes out of a tube, and every morning, when we brushed our teeth, we had to "restrain" ourselves from eating the toothpaste.

Reaching the vicinity of the Great Bahama Bank, we decided to capitalize on the good weather and make a few dives, mainly to train the hydronaut candidates and to finish off our biomedical research.

A dive revealed that the slope of a bank was rather steep, and that the bottom was peppered by large beautiful bivalves slowly moving in all directions. The water in this region of the ocean was less transparent, but it was very warm from the surface to a depth of 100 meters. Its temperature was 25-26°. After 4 hours in such warm water, the temperature in the compartment climbed to 28-29°, and we were forced to turn on the ventilation in order to permit the work to go on.

After analyzing all of the numerous temperature, humidity, and noise measurements, the Moscow physicians--physiologists and hygienists--concluded that the craft's environment was satisfactory, and that the work done by the hydronauts could be classified as being "moderately hard, coupled with a high level of nervous and emotional tension." The indicators of the functional state of the central nervous system, cardiovascular system, and hearing organs of all hydronauts recovered fully a day following a 5-hour sojourn beneath the water.

Having completed its planned work, the "Ikhtiandr" went to Havana, where the physicians parted company with us--they flew back to Moscow. Before going home, we decided to make a few more dives in a convenient gulf, in order to photograph the craft under water. A suitable bank 25-30 meters deep was quickly found, the ship was anchored, and the divers went off to inspect the bottom--a place to land the craft had to be found. A large box with a transparent bottom was built to permit observation of the situation during the underwater work of the divers. This structure was attached to a pole and lowered to the water from the motorboat. The visibility afforded by this box, which came to be called the "televiewer", was excellent for up to 3 meters in all directions. In the event of danger, the divers were summoned back to the boat by a prearranged tap. The divers carried short clubs to defend themselves from sharks (following the advice J.-I. Cousteau gave in his book), but no one ever had to use them. Sharks never bothered the people, though they did swim rather close to them.

The divers determined the craft's diving location and marked out the route the craft was to take. The sun was directly overhead, and the water was amazingly clear: Corals, sponges, and fishes of all sorts could be seen with remarkable clarity from aboard the "Ikhtiandr". The conditions for launching the craft were right.

This time I went as underwater observer, and novice A. Vinogradov was the craft commander.

We saw many beautiful fish, much more than in the eastern Atlantic. Parrot fish of unimaginable colors and hues chased about in the warm water. We came to like the curious soldier fish, which stood almost motionlessly, as if on watch, near the entrance to its burrow, and it rabidly lunged at every passing fish, even if it was of significantly larger size. In such encounters, the soldier fish deploys its fins in a very warlike manner.

TINRO-2 approached the point where the filming was to begin, not far from which lay the large familiar anchor and chain dropped from the "Ikhtiandr". We began waiting for the SCUBA divers. They soon swam over to the portholes--they were Marlen Aronov and Igor' Danilov, our chief photographer. They began explaining where the craft was to go, but at this moment a huge barracuda unexpectedly floated over and began "posing" before the still and motion picture cameras. The sharks, however, despite all of the effort of our operators, did not wish to be photographed.

After the filming was over the craft headed for the slope. As it approached it, more and more fish were encountered, and large ones occurred more frequently. Then, as had happened in former dives, the bottom suddenly disappeared and the craft found itself above a bottomless blue pit. The echo sounder, which was set out at 200 meters, could not record the depth of the bottom. The bank plunged vertically downward. We returned to the very edge of the slope once again, took several photographs of large schools of fish passing by the portholes, and returned to the vessel.

The second dive in this region was performed by ichthyologist Nadezhda Savchenko, as yet the only woman that had dived aboard TINRO-2. She assimilated the controls very quickly, and she took several good photographs of dense accumulations of fish.

And so the last item of the program was completed, and the "Ikhtiandr" assumed its return heading.

On our way back we entered the famous mysterious Bermuda Triangle or, as it is also called, Devil's Triangle, already for the second time. Naturally we had heard about the disasters that occurred in these gloomy seas, but nothing unusual happened to us. Marlen was sorry that due to poor weather we could not make as many dives in this region as we would have wanted to, but after all, something had to be left for another time.

During our 2-week passage to Dasiya Bank, with which we were already well familiar, the weather was ideal. But a strong wind came up on the day we arrived at Dasiya. Thus we had to wait for it to abate for almost a day

A Soldier Fish Among the Corals. Great Bahama Bank, Depth 10 Meters

before we could make the last dive of the trip--the 48th. Soon enough, it also was behind us. The craft was set in its place in the hangar, and Lev Vasil'yevich Medvedev congratulated the whole crew on completion of the trip's program. The "Ikhtiandr" set its course toward Kerch'.

The Craft Secured by Its Anchor-Guide Rope

TINRO-2 Among Gorgonacean Corals.
Great Bahama Bank, Depth 12 Meters

On that same day Radio "Mayak", which the radio operators picked up entirely by accident, reported that the scientific research vessel "Ikhtiandr" had successfully completed the Soviet Union's first ocean cruise with a submersible aboard.

Trigger-Fish, Great Bahama Bank, Depth 10 Meters

(Серioly) Beside the Submersible, Depth 21 Meters

Before getting home we had to write up a sizeable volume of reports and prepare the craft for an inspection having the purpose of evaluating the condition of its mechanisms and systems after such a difficult trip. It was hard to believe that our work was completed, and that we would not dive again for several months, or that we could relax a little and get on with our paperwork.

On the return trip the vessel stopped at the famous Gibraltar, which left a pleasant impression.

And so we were already on the Mediterranean Sea. Familiar scenes popped in front of our eyes though of course in the reverse sequence. Bosporus, the beautifully lit bridge joining Europe and Asia, and finally our own Black Sea.

A tug was awaiting us in the Kerch' Strait. A welcoming party was aboard, to include Konstantin Vasil'yevich Kostitsyn, who had done so much to make our trip successful and who was informed of all events aboard the "Ikhtiandr". He congratulated all participants of the cruise on its successful completion, and announced that TINRO-2 would be exhibited at the international "Inrybprom-75" exhibition in Leningrad.

And on the pier to which our ship was moored already stood a second TINRO-2, shining with a fresh coat of paint; the two craft were as similar as two peas in a pod. In short time the new craft was to take its place in the hangar of the "Ikhtiandr" and set out for the next trip at sea.

Some Results

Forty-eight dives in the Atlantic Ocean.--The craft is fearless of underwater currents.--Diving parameters may now be computed.--The "Inrybprom-75" exhibition.

TINRO-2 and its designers and testers passed a hard examination which demonstrated that the craft can and must work in the ocean.

The first oceanic trip of the "Ikhtiandr" with the TINRO-2 craft aboard lasted exactly 175 days. The ship spent 90 days in regions intended for operations with the submersible, with only 56 of them offering suitable weather. During this time 48 dives were made, of which eight were for bio-medical research and hydronaut candidate training, and the rest of which were devoted exclusively to scientific research.

About half of the dives were made to a depth of 300-400 meters, and the average duration of each of them was 4 hours 20 minutes.

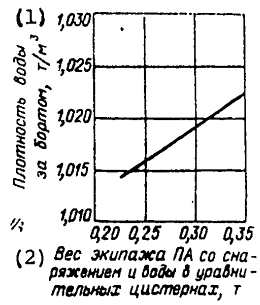
Poor weather made the work of the complex consisting of the carrier vessel and the submersible difficult on the ocean. The perpetual heavy swells caused an especially great deal of trouble, hindering the craft's approach to the vessel and creating the danger of their collision. Owing to numerous

Five Meters From the Surface

Two Craft

ways for protecting both the craft and the ship, no damage ever occurred during the cruise, despite the fact that 11 dives were made in the presence of swells from 1.5 to 3.0 meters high.

Water density in the ocean varied from 1.021 to 1.028 tons per cubic meter. Therefore we had to take water samples prior to each dive in order to determine water density; this permitted us to compute the craft's trim before it was even launched. Knowing the weight of the crew and instruments taken aboard by the observer, this problem could be solved by plotting the dependence of the initial quantity of water in the compensating tanks on the weight of the crew in relation to a particular density of sea water.



Dependence of initial water quantity in compensating tanks on sea water density and crew weight.

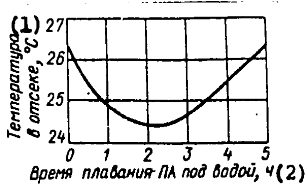
Key:

1. Sea water density, tons/m^3
2. Weight of submersible's crew and its gear, and of water in compensating tanks, tons

Owing to such computations, the time the craft had to spend on the surface before leaving the ship's side was significantly reduced. This was especially important in the presence of a strong surface current, when the ship had to stand at anchor while launching the craft. In these cases the current could sweep the craft far away from the vessel, as a result of which hydroacoustic communication worsens and it becomes more difficult to perform the dive in the prearranged place. Sometimes it is also necessary to launch the craft quickly when the ship's fish detection instruments discover interesting accumulations of fish.

Underwater currents, the velocity of which did not exceed 1.0-1.2 knots, did almost nothing to hinder the work of the craft. When desired, shelter could always be found at the foot of a crag or near some other obstacle; moreover the anchor kept the craft secure. The main engine's power was fully sufficient to surmount such currents.

The rather high temperature of sea water, which did not drop below 14-15° even at a depth of 300-400 meters, despite the fact that it was winter, made the work of the crew somewhat difficult. It was hot in the craft at the very beginning of the dive, and during the dive the temperature increased, rather than decreasing. Thus ventilation had to be turned on.



Change in craft air temperature depending on diving time.

Key:

1. Temperature in compartment, °C
2. Time of submersible's presence under water, hours

TINRO-2 was designed mainly for work at the bottom. Therefore we were interested in determining how much time was spent at the bottom itself. We set up a table showing the average times spent in different stages of the craft's preparation and work:

Operation	Time Spent
Preparing for a dive, including battery installation	3 hours
Launching	5 minutes
Separating from the ship's side	10 minutes
Approaching the ship	25 minutes
Raising the craft and placing it in the hangar	5 minutes
Maintenance after a dive, including battery removal	2 hours
Charging and recharging storage batteries for the next dive	19 hours

We found that the craft's maintenance alone took an average of 24 hours.

Most of the time was required to charge the storage batteries and prepare them for installation aboard the craft; in this case even more time was required for these operations in regions with a hot climate, since the temperature of the electrolyte climbed above the maximum limit, and it had to be cooled. It is best to have two outfits of storage batteries on a cruise; these could be installed aboard the craft alternately.

The maintenance group, which consisted of only 5 persons, tired quickly at a diving intensity calling for 24-hour operation, but as a rule the weather did not remain good for more than a few days, and the work soon had to be interrupted. January and February were the fullest months (11 dives were made in each), 10 dives were made in November and in December, and there were 3 dives in October and in April.

The launching, raising, separation, and approach of the craft took an average of 45 minutes. The time required for the craft's submergence and surfacing depends on the intermediate stops to inspect the compartments and trim the craft. Because we imparted a slight positive buoyancy to the craft when working at the bottom, surfacing was somewhat faster than submerging. If we consider that the craft's rules of operation limit the crew's work day to 5 hours, we can approximately compute how much time is left over for work at the bottom itself.

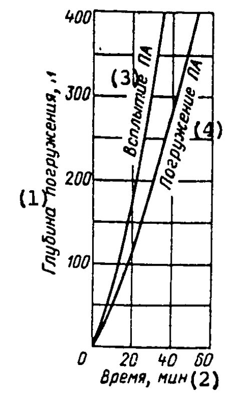
Thus for example if the craft dives to a depth of 100 meters, travels along a sloping bottom to a depth of 400 meters, and after this rises to the surface, there would be about 3 hours 20 minutes left for work on the bottom. In about the same fashion we determined the parameters for each dive, and it was in accordance with this time budget that we wrote out the assignment of the hydronauts.

On the whole the crewmembers were pleased with the illumination inside the craft. And as we accumulated experience, we came upon ideas for improvements, which were made in the craft's equipment during the cruise. Thus Igor' Danilov suggested installing an automatic camera of his own design in the craft. As soon as the craft was raised from its keelblocks the automatic camera turned on, taking photographs of the bottom at particular time intervals with its own electronic flash. The quality of the photographs was good; moreover the automatic camera sometimes recorded things that the underwater researcher missed.

Hydrologist S. Mikhaylov proposed mounting a current meter on the craft to measure its speed and the velocity of currents when standing at anchor or on the bottom. A current measuring instrument, lowered from the ship's side on a cable, had been used for this purpose previously. Removing everything from this instrument except for the current meter itself and the rotation counter, our mechanic secured it to the upper lateral porthole, through which the instrument's readings could be easily seen.

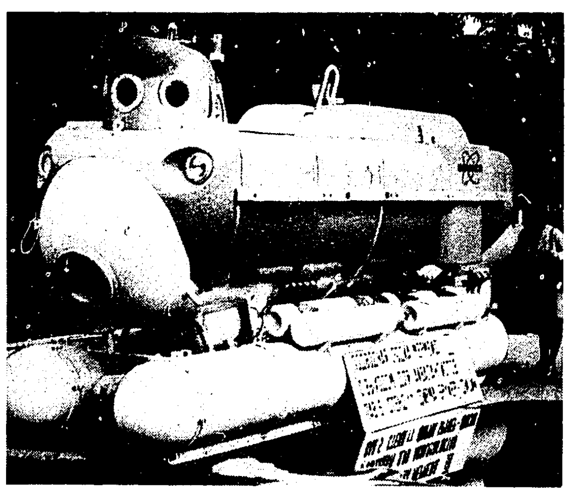
A vertical propeller RPM indicator, installed as proposed by V. Deryabin back during the Black Sea cruise, significantly aided trimming of the craft under water. Now, after stabilizing the craft at the required depth, the commander needed only to glance at the indicator in order to decide whether to take water into the compensating tanks or pump it out. This operation was performed until the vertical propellers stopped, indicating that the craft had attained zero buoyancy.

For practical purposes our TINRO-2 could have gone on its next trip immediately after its ocean cruise, without undergoing repairs, but it had to be shown at the exhibition in Leningrad. This was an apt reward for its successful work in the ocean!



Dependence of craft submerging or surfacing time on diving depth.

Key:
1. Diving depth, meters
2. Time, minutes
3. Surfacing the submersible
4. Submerging the submersible



"Mermaid-3", Built By the Bruker Company, at the "Inrybrom-75" Exhibition

We had to make the craft ready for demonstration prior to the opening of the international "Inrybprom-75" exhibition, which was to be held in August 1975.

In addition to TINRO-2, the "Atlant-2" towed craft was shown at the exhibition. Both craft stood on high pedestals at the entrance to the Soviet pavilion. Behind them was a huge diorama of the undersea world; it was in the pavilion's vestibule, and it seemed as if the craft had just emerged from the water.

In addition to Soviet submersibles, there was a self-contained craft with a diver egress hatch, the "Mermaid-3" built by the West German Bruker Company, and the self-propelled craft "Mark-IV" built by the French (Kazakrus) Company.

Interest in these craft and, incidentally, in the technology of oceanic exploration, was great, and therefore there were many visitors.

Once again I took my place beside TINRO-2, explained its work, and participated in discussions. Several serious discussions concerning achievements in underwater research were held during the time of the exhibition.

Soviet scientists and hydronauts inspected the "Mermaid-3". One of its designers, hydronaut H. Haas, explained its features. We were pleased by the high quality of the craft's trim, and the thought behind its general layout. The craft had undergone tests in freshwater lakes, and following the exhibition it was to work in the vicinity of Malta. A small pontoon that was not adapted to navigation far from shore was used as the carrier vessel, which significantly restricted the craft's region of operations. In turn, representatives of the West German Bruker Company inspected our craft. They were especially pleased by the automatic system controlling movement on a given heading at a particular depth, and the craft's hovering system. The "Mermaid" is outfitted only with manual control.

The exhibition showed once again that development of the World Ocean and of undersea technology is enjoying a great deal of attention from all countries.

POSTSCRIPT

During the writing of this book the "Ikhtiandr" completed another 6-month cruise on the Atlantic with the new TINRO-2 aboard. Once again the captain-director of the ship was Lev Vasil'yevich Medvedev, and I served as the craft's captain-mentor. Boris Vyskrebentsev, who had participated in the last cruise, became scientific director.

The research program for this cruise was very full, and TINRO-2 worked at full capacity, even though the weather conditions were much more complex than before. We can now say that the ocean was indulgent of us during the first trip, and as if to compensate, during the second trip it presented itself in its true menacing grandeur. Days with a sea state below 3-4 points were rare.

The new craft displayed its obstinacy from the very first dives.

Despite these difficulties, we made one and a half times more dives than during the first trip, and scientific results of greater value were obtained.

A dive in the vicinity of West Africa became the most memorable to me. Our captain, a person who had controlled fishing vessels for many years and who could finally see for himself what goes on in the depths of the sea, took part in it. I should say that in his first dive, Lev Vasil'yevich Medvedev not only controlled the craft excellently on the surface and beneath the water, but he also brilliantly maneuvered the craft over to the ship. This once again confirmed our opinion that craft commanders should be people with a background in marine professions. During this dive Lev Vasil'yevich took a few superior underwater photographs of fish accumulations.

On the eve of the May Day celebrations of 1976 the "Ikhtiandr" once again moored itself in the Kerch' fishing port. Once again we had to part from our "Ikhtiandr", our new-found friends, and Kerch', a cozy and friendly city that contributed a brilliant page to the development of undersea research in our country.

Sea Eel and Horsemackerel, Dasiya Bank, Depth 125 Meters

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