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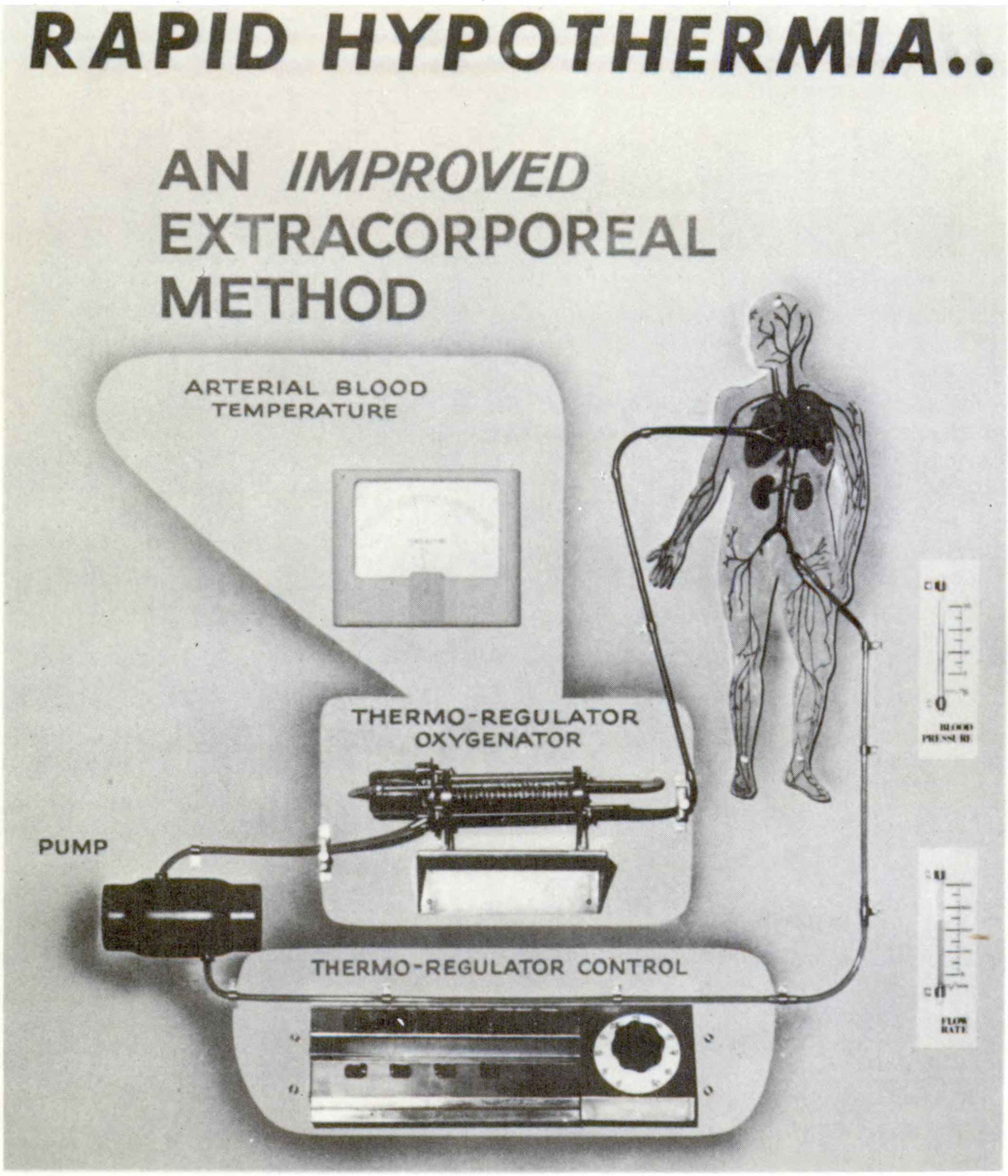

Mock-up of system developed at NRL for controlling the body temperature of a patient during open-heart surgery.

Rapid Hypothermia—An Improved Extracorporeal Method

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Early surgical operations were, at best, traumatic events, performed only as a last desperate effort to save lives but more often than not resulting in immediate death. A few patients, however, survived their bloody and painful ordeals, and these limited successes inspired the imaginative minds of surgeons all over the world in their search for ever-better and safer surgical techniques. With the introduction of anesthetics and other advances in medical sciences, surgical operations, over the years, have become increasingly safer and more frequent. In particular, the invention of the artificial heart-lung (oxygenator) provided unlimited possibilities in open-heart operations by solving the problem of two opposing requirements: that of the patient for continued blood flow into the aorta and that of the surgeon for a relatively bloodless field within the heart which would permit recognition and repair by direct vision and without hurry. Just recently NRL scientists made a significant contribution to medical science through the development of a device which, when used in conjunction with an oxygenator, will control the temperature of the patient's body and thus ensure an even greater chance of his survival.

Fundamental studies of heat-transfer processes and propulsion systems for military applications have been under investigation by scientists at NRL for several years. As a result of knowledge gained in this field, they were able to apply certain well-known electrical and thermomechanical energy-conversion techniques to the problems of blood cooling (hypothermia) and pumping, which they pursued at the request of, and in conjunction with, the U. S. Naval Medical Institute, Bethesda, Maryland. The object was a device that would provide increased control of blood-temperature change but minimize or eliminate any turbulence, considered the deleterious factor in blood damage. The first goal has been achieved. NRL scientists have developed a heat exchanger which can be used in existing oxygenators to either heat or cool the blood quickly and without damage. Presented here are some of the problems encountered in the development of such a system and how they were dealt with. Research aimed at satisfying the criteria for blood pumping is still being conducted.

TEMPERATURE CONTROL

The control of blood temperatures plays a significant role in heart surgery. The patient's probability of survival is considerably increased if his temperature is kept below the normal value of 98.6°F during the operation. This probability will be even greater if temperature reduction is accomplished quickly. Earlier devices for this purpose, such as heat exchangers in which the blood is forced through tubing immersed in a coolant, have achieved a sufficient rate of heat transfer but at the expense of additional apparatus and a greater risk of blood damage. Other devices, such as intragastric coolers which circulate hot or cold water in a balloon within the patient's stomach, may not damage the blood, but they fail to cool or heat the blood quickly enough. Moreover, there is no known device capable of cooling and oxygenating the blood simultaneously.

When an artificial lung or heart is used and blood is circulated outside the body (extracorporeal), an excellent opportunity is presented for reducing body temperature, providing a sufficient degree of cooling can be obtained without damaging the blood. The system developed at NRL (see inside front cover) consists of two parts: the heat exchanger (Figure 1), which fits inside the rotating-disc oxygenator, and the control unit (Figure 2), which supplies regulated cold and warm water.

The combined heat exchanger and artificial lung is shown in Figure 3. It comprises a horizontal cylinder having an inlet for the entrance

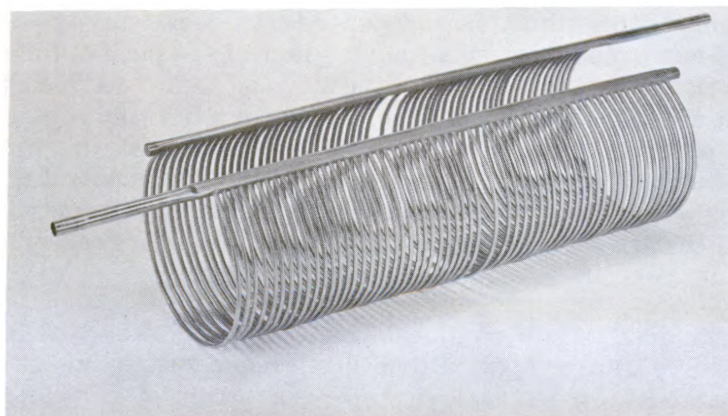

Figure 1--Heat-exchanger unit, for use in a rotating-disc oxygenator. Adjustments in size to fit different oxygenators can be made by the removal or addition tubing.

of blood in the lower portion of one end and an outlet for discharge at the other. The level of blood in the cylinder is determined by the point at which there is observed the least amount of foaming, and this level is maintained throughout the operation. The curved portions of heat-exchanger tubing, spaced equidistant from each rotating disc and passing through the blood, cool (or heat) the blood as it circulates, while oxygen introduced through holes in a pipe located above the discs oxygenates the blood at the same time.

As a heat-transfer unit, the new device has several advantages over any used previously. For example, desired cooling or restoration of temperature can be accomplished in about 10 minutes, a considerable improvement over the 90-minute period required in the ice-packing techniques, so that body chilling prior to surgery is not required. Furthermore, temperature control acts on the entire blood flow instead of on only partial flow, as in other methods, thereby resulting in an even distribution of temperature throughout the body.

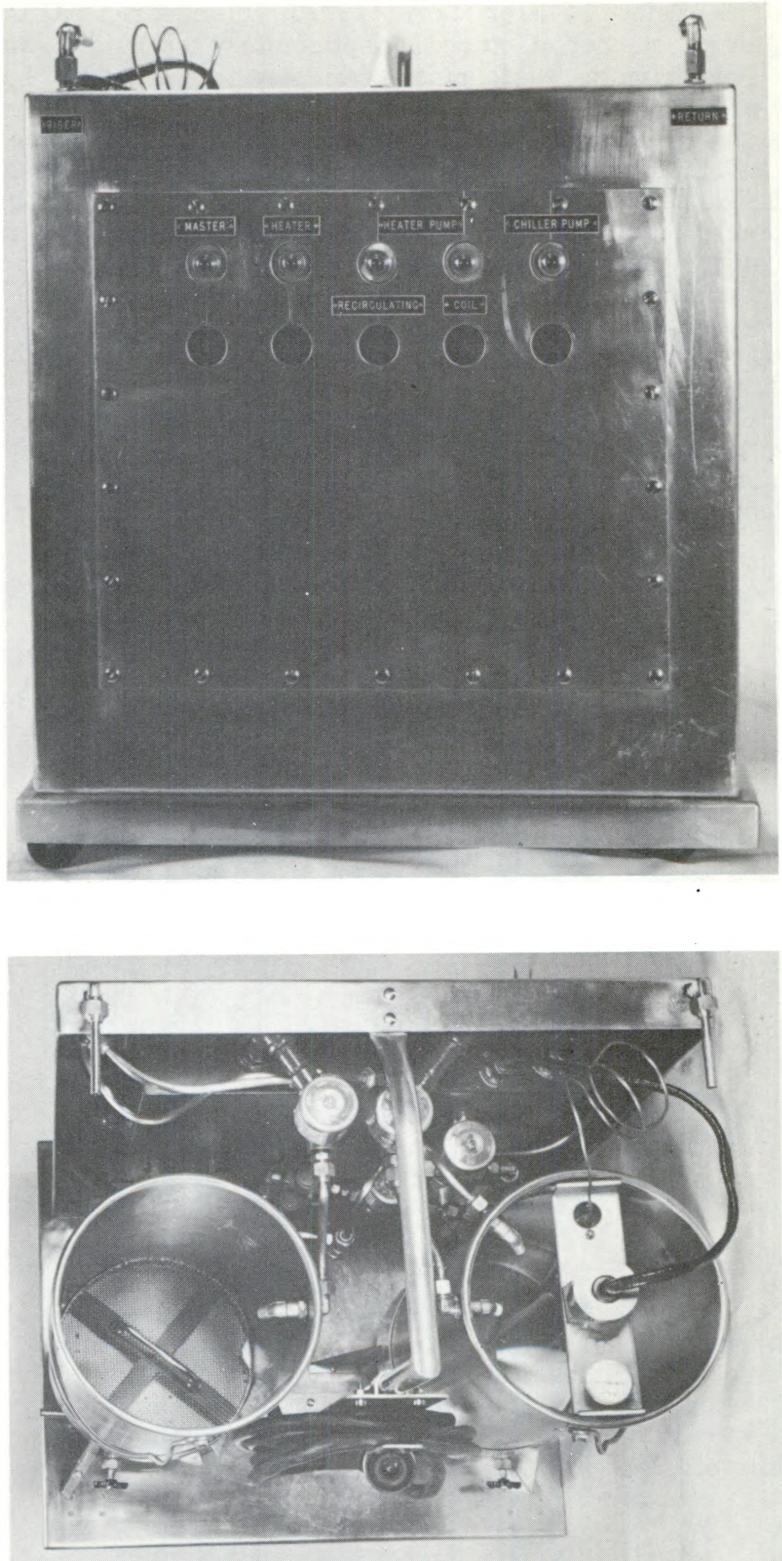

Figure 2--Prototype model of control unit. The bottom view was taken from above, looking down into the two temperature-control tanks.

Another advantage is that the method of heating or cooling is entirely safe and can be precisely controlled. Blood will not tolerate...

temperatures below 34°F or above 113°F. This restriction automatically rejects a number of otherwise satisfactory means of heating and cooling. For example, if a thermoelectric device such as refrigeration system were used, malfunction of the controls could result in freezing (or boiling) of the blood before corrective measures could be taken. Techniques employed in the NRL system eliminate any such possibility. During the initial cooling phase, water introduced into the tubing flows from a tank filled with crushed ice, so that it automatically comes out at the right temperature. To keep the patient at a constant temperature during the operation, or to warm him rapidly afterward, water is supplied from another tank equipped with thermostatic controls. Because of the large volume of water in the tank as compared with the capacity of the heater, failure of the thermostat would result in no more than the allowable change of 1°F in water temperature, and hence in body temperature, before it could be detected. The control unit is interlocked with automatic valves and relays, so that all the operator has to do is set the desired temperature on the thermostat and push the proper button.

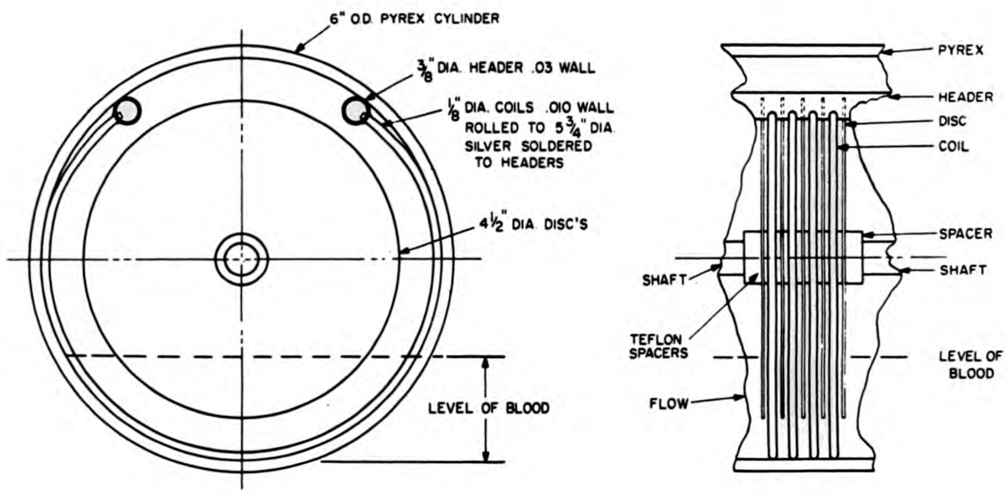

Figure 3--Schematic views of NRL's combined heat-exchanger and artificial lung. Side view, at right, shows spacing of rotating discs and heat-transfer tubing. End view is shown at left.

DAMAGE CONTROL

Although the pump which circulates the blood will itself inflict a certain amount of damage, in earlier systems most of the damage occured in the oxygenator. For this reason it was necessary to consider a number of factors which, if ignored, would contribute significantly to blood damage.

Velocity

According to authorities at the U. S. Naval Medical Institute, blood velocity must be kept below about 2 ft/sec, in order to prevent injury by foaming to the easily damaged organic cells. This is at least an order of magnitude less than the velocity used in the design of commercial heat exchangers. In the NRL device, rotation of the discs serves to greatly increase the rate of flow of the blood pool without disturbing the rate of flow through the body of the patient and without disturbing the consistency of the blood by foaming.

Surface Contact

Any contact with nonorganic surfaces damages the blood. Therefore, the use of fins and similar methods of increasing the surface area available for heat transfer was ruled out. By the combination of heat-transfer tubes and rotating discs, an improved conduction-type heat transfer is obtained between the heat-exchanger element and the blood, although very little surface area has been added.

Turbulence

Any turbulence or flow discontinuity which might cause foaming or bubble formation must be eliminated, since the body cannot tolerate such a condition. This is of particular concern when the blood is warmed rapidly, since the solubility of gases is reduced as the temperature goes up. This problem no longer exists, because the heating phase and oxygenation take place simultaneously.

BLOOD REQUIREMENTS

A heat exchanger must contain a certain amount of blood for priming purposes before it is connected to the patient. And since the amount of whole blood available from a blood bank often determines the number of operations that can be performed with extracorporeal blood circulation, it is imperative to keep the size of the oxygenator as small as possible and the initial blood requirements low. The NRL system not only requires a comparatively small volume of blood for priming, it also can be adjusted in size so that the amount of blood used in each operation can be either decreased or increased to meet the individual need of the patient, thereby increasing the number of operations that can be performed.

CONCLUSIONS

During the past year the apparatus has been successfully employed at the U. S. Naval Medical Institute in over thirty human operations and in innumerable animal surgeries. The surgeons who have used it have become quite confident of its value. Thus NRL scientists, deviating only slightly from the main line of their military research, have provided the medical profession with a reliable new tool which, when used in conjunction with an artificial heart-lung, makes it safer than ever before to operate under direct vision within the open chambers of the heart.

ACKNOWLEDGMENT

The author is indebted to Mr. Rudolph G. Steiner, who assisted with this work ans who is now with the Goddard Space Flight Center.

Nitrogen Narcosis and Its Effects on Performance

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On May 23, 1939, the Experimental Diving Unit, Navy Yard, Washington, D. C., received word that the submarine SQUALUS was down off Portsmouth, New Hampshire, in 240 feet of water. Within two hours Navy divers were airborne toward the scene of the disaster, and communication was soon established with the SQUALUS. Thirty-three men were alive in the control room and forward compartments; at least one of the aft compartments was flooded; and the fate of 26 men aft of the control room was unknown. Fourteen hours later all 33 crew members in the forward portion of the ship were brought to the surface and confirmation made that all aft compartments were completely flooded.

This rescue was noteworthy in many respects. For one thing, it presented an opportunity for the first open-sea utilization of the newly formulated helium-oxygen breathing medium. From our present point of view, however, the significant fact is that most of the divers were required to operate in 240 feet of water, breathing compressed air, under conditions of extreme cold and almost total darkness. Breathing air at this depth induces a condition which makes coordinated activity almost impossible and can cause lapses of memory and gross disorientation. On several occasions divers lost control of their air supply, which resulted in overinflation of the diving dress and subsequent "blow-ups" in which the divers were literally blown to the surface like a cork released from the bottom. It was extremely dangerous, and in some cases futile, for divers with impaired faculties to work at this depth in a maze of hoses and cables. One diver reported: "I found the after torpedo hatch, then went to the starboard rail and forward about 15 feet. At this time thinking became difficult. I started to tie the descending line to the rail and suddenly realized that I was just waving my arms and not accomplishing anything." This man was describing one aspect of nitrogen narcosis. Although divers at this time were aware of the effect of compressed air and the consequent high partial pressure of nitrogen at these depths, this was a case in which the welfare of 33 men depended upon the extent to which trained personnel could carry out their tasks in spite of impaired performance due to nitrogen narcosis.

In 1943 the French diver Dumas was attempting to set a record for depth during a self-contained dive, i.e., without air-line contact with the surface. A line, knotted every 5 feet was lowered over the side of a boat to a depth of 250 feet. Dumas was to descend parallel to this line, remove his belt, and tie it onto the line at the deepest point of his descent. In the course of his dive Dumas testified: "The damned rope doesn't hang straight. It slants off into the yellow soup. I am anxious about that line, but I really feel wonderful. I have a queer feeling of beatitude. I am drunk and carefree. My ears buzz, and my mouth tastes bitter. The current staggers me as though I had had too many drinks. I lower on down, trying to think about the bottom, but I can't. I am going to sleep, but I can't fall asleep in such dizziness. There is a little light around me. I reach for the next knot and miss it. I reach again and tie my belt on it. I was infuriated to have missed my goal." Dumas' subjective impression was that he had descended slightly over 100 feet. But when the line was brought up his belt was tied off at a little over 210 feet.

Since 1903, when the first report of nitrogen narcosis was published in the Journal of Physiology, various definitions and descriptive accounts have appeared in the literature. Costeau, in his book, The Silent World, describes nitrogen narcosis as "rapture of the depths." He says, "The first stage is mild anesthesia, after which the diver becomes a god. If a passing fish seems to require air, the crazed diver may remove his mouthpiece and offer it to the fish as a divine gift. I am personally quite receptive to nitrogen rapture. I like it and at the same time fear it like doom. It destroys the instinct of life."

The above are some incidents and statements about nitrogen narcosis by men who have been there. In a more formal manner, Rashbass, of the British Royal Naval Physiological Laboratory, states: "Nitrogen narcosis is the term which has been applied to certain changes in personality and performance in men subjected to raised pressures of air." Other writers describe it as ". . . an altered mental state induced by breathing atmospheric nitrogen under pressure . . ." and ". . . a form of intoxication with a tendency toward laughter and overconfidence, some loss of clear thinking and, very rarely, hallucinations and mystical states . . . there is a lack of coordination, and clumsiness is noticeable."

From the diversity of these accounts, it seems that this phenomenon is quite similar to alcoholic intoxication, and the subjective symptoms are inpart dependent upon the personality structure of the individual exposed. Experienced divers have jokingly calibrated the pressure or depth in terms of "so many martinis." For example, 200 feet is equal to three martinis.

There is considerable speculation concerning the physiological basis for these behavioral manifestations of nitrogen narcosis. One theory maintains that the high partial pressure of nitrogen affects the transmission of impulses across the synapes and consequently inhibits activity of the control nervous system. Another attributes the impairment to decreased metabolic activity in the nerve cells brought about by the high partial pressure of nitrogen. A third theory indicates that the reticular activating system is the primary center affected and, because of its pacing function for the cerebral cortex, brings about decreased alertness, vigilance, and impaired behavior.

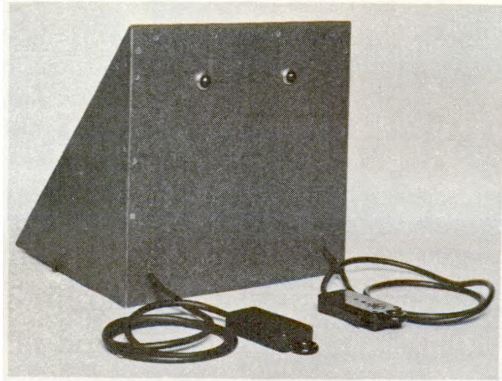

Figure 1--Equipment for measuring choice-reaction time

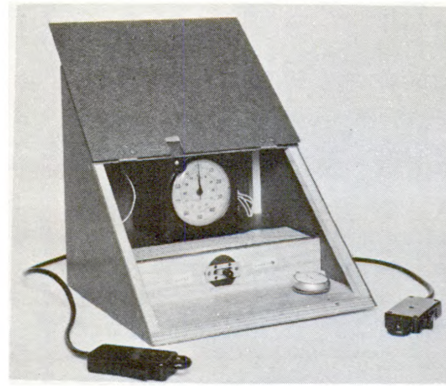

Figure 2--Experimentor's controls of choice-reaction-time apparatus

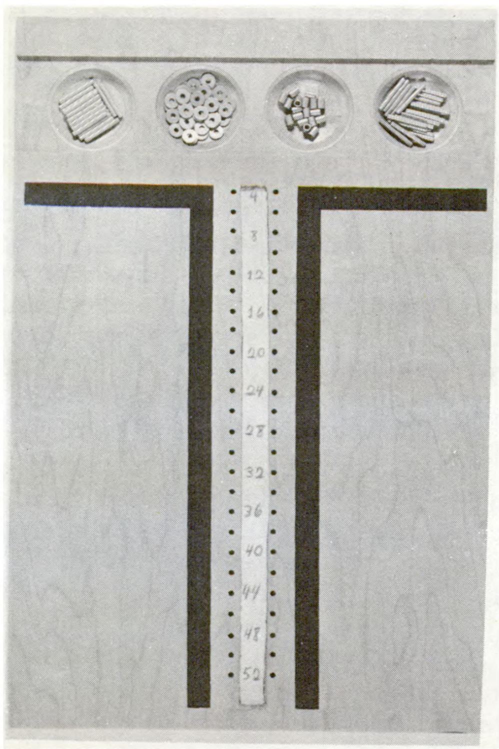

Figure 3--Modified Purdue Pegboard Test Equipment

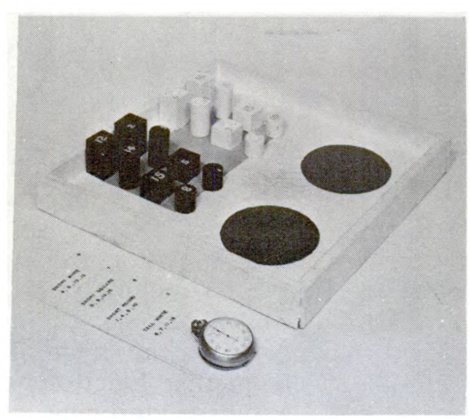

Figure 4--Conceptual-reasoning test, showing examples of four problems

There are major research programs concerned with a determination of the exact physiological basis of nitrogen narcosis, and the varied theories will eventually be resolved. The study now being conducted at the U. S. Naval Experimental Diving Unit is directed primarily toward a determination of the extent of behavioral impairment or decrease in performance efficiency and its systematic relation to increasing degrees of nitrogen partial pressure.

The initial experiment had three general goals: (1) to evaluate the relative merits of various measuring instruments for detecting impairment; (2) to determine if performance impairment occurred at depths as shallow as 100 feet; and (3) to investigate the hypothesis that, under stress conditions, the higher intellectual functions are detrimentally affected prior to simple motor or psychomotor tasks. All previous experimentation had been conducted at depths below 150 feet. In fact, there are statements in the literature to the effect that performance impairment does not occur until a diver has exceeded depths of 200 feet. Thus, from a practical aspect, it would be beneficial to the Navy to have a single sensitive measure of nitrogen narcosis, relating it to various depths and durations of exposure, which could be used to test other gas mixtures and establish the performance limits of compressed-air diving.

The five subjects used in the experiment—two senior medical students and three experienced divers—underwent three measures of performance.

- Choice-Reaction Time. The subject was seated before a panel on which were two lights, a red one to the left and a green one to the right (Figure 1). In each hand he held a switch controlling the light on that particular side. The light stimuli were presented without prior warning at random intervals varying from 3 to 13 seconds (Figure 2). The subject's task was to close the proper switch for the proper light, i.e., the left-hand switch for the red light and the right-hand switch for the green light. Performance was measured in terms of hundredths of a second for correct responses.

- Modified Purdue Pegboard Test (Figure 3). The subject was required to place a small metal pin, about 1/8 inch in diameter and 1 inch long, in a small hole in a board. He was then to place a small washer over the pin, a metal collar over the washer, and another washer over the collar. The score was the number of parts assembled in several 30-second periods.

- Conceptual Reasoning. This test, developed at the U. S. Naval School of Aviation Medicine to meet a specific need in the evaluation of reasoning ability under conditions of hypoxia, involves a very complex task, and a detailed description would be quite lengthy. In essence, the subject is sequentially presented a series of conceptual reasoning problems regarding physical characteristics of small wooden blocks: tall-short, white-black, hollow-solid, etc. (Figure 4). The solutions are reached by a process of successive hypothesis testing and the retention and use of the results to determine additional

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hypotheses to be tested, until the subject discovers a pair of physical characteristics which constitute the correct answer to a particular problem. Once the subject has been instructed in the correct procedure, the individual problems are equally difficult.

...experimenter (C.H.M.) on the outside. The total...

Prior to the actual experimental period, the subjects were trained to a plateau level of performance in all three tasks. During the experiment proper, each subject was tested individually in decompression chamber (Figure 5). In these chambers the air pressure can be increased up to 350 psi, thus simulating sea-water depths to 780 feet (Figures 6 and 7). One of the experimentors (R.J.K.) administered the tests from inside the chamber and relayed the information to the second experimental session consisted of three phases: a measure of performance of all three tests at sea-level pressure; three four-minute measures of each test at simulated 100-foot salt-water pressure; and a measure of

Figure 5--Test for manual dexterity inside the decompressure chamber

performance in each of the three tests during the final period of decompression at 10 foot depths.

All subjects showed a decrement between their sea-level performance and 100-foot performance significant at the one-percent level of confidence (or in a predicted 99 out of 100 cases). This is the first reported objective measurement of performance decrement at depths as shallow as 100 feet. All three instruments used for testing were thus sufficiently sensitive to measure the narcotic effect at 100 feet. Additional experimentation will be required to determine the relative sensitivity of these instruments at both shallower and deeper depths. One could not generalize from the single experiment that decrement in performance was greater and occurred sooner in the reasoning test than in either of the other two measures. On a simple percentage basis,

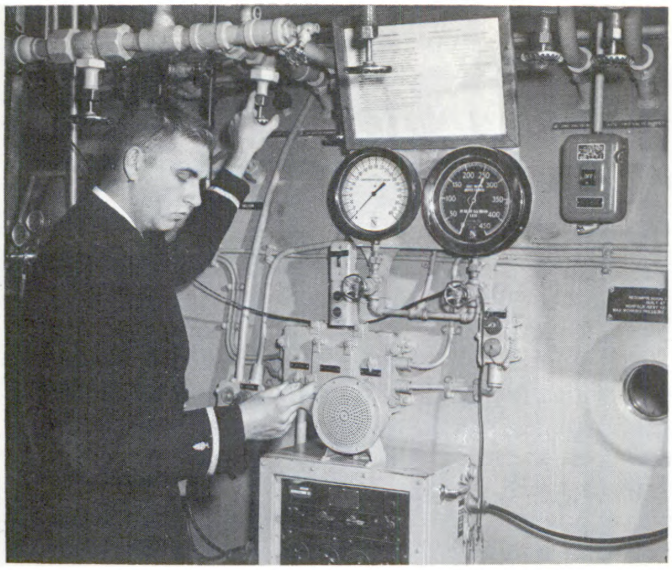


Figure 6--Exterior of decompression chamber, showing pressure gauges

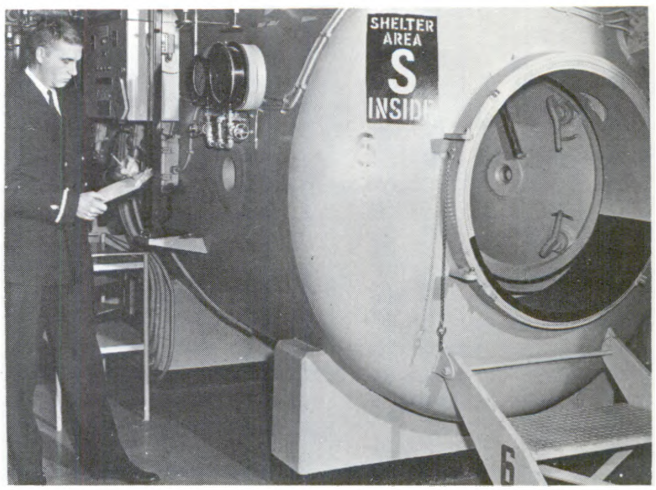


Figure 7--Entrance to decompression chamber

however, the reaction-time measure decreased 17 percent from the sea-level norm, the motor-coordination test decreased 9 percent, and the reasoning test showed a decrement of 36 percent. In summary, there were differences in the degree and time of occurrence of performance impairment among the individual subjects, although all showed a statistically significant loss in efficiency between their performance at sea level and that at a simulated depth of 100 feet. In all cases, impairment was greatest in the reasoning test and least on the motor-coordination test, with the reaction-time test occupying the middle position.

The results of this initial investigation were quite worth while, both from an experimental point of view and in terms of possible application. If impairment is present at 100 feet, a decision is required concerning the relationship between the choice of respiratory gas—that is, compressed air or various oxygen-helium mixtures—for a given depth and the complexity of the task to be performed. If the individual is merely to fasten a line to an object on the bottom, he can doubtless do it, using compressed air, at 100 feet; but if the task involves underwater demolition or defusing an enemy mine, the diver should be provided with a gas mixture that allows him the optimum use of his skills and sensory acuity.

Additional research is aimed at increasing the divers' effectiveness and safety. Since impairment was demonstrated at 100 feet, further experiments will be conducted to establish a decrement curve showing the maximum manifestations of the narcotic effect at varying depth-time relationships. In addition, the development of sensitive measuring instruments will permit comparative evaluations of the effects of varying depth, gas mixture, and task complexity with those of other theoretical variables. Some suggested variables are the administration of drugs, task over-learning, changes in breathing rhythm, and exercise. The possibility also exists of determining significant decreases in respiratory response to carbon dioxide due to narcosis of the central respiratory center.

CAPT Ruebush

CAPT Trenton K. Ruebush, MSC, USN, 48, Navy parasitologist, who died after a heart attack in Cairo, Egypt, on September 26, 1959, is a native of Dayton, Virginia. He graduated from Bridgewater College and received his Master's and Ph. D. degrees from the University of Virginia.

Before beginning his Naval career in May 1941, he spent 5 years at Yale University as an instructor in Biology. His first duty station was the Bureau of Medicine and Surgery in Washington, D.C. Later he moved with the Parasitology Department to the Naval Medical Center in Bethesda, Maryland. During World War II, he served in the South Pacific on malaria control.

In 1948, CAPT Ruebush made an 11-month expedition through Africa with a group from the University of California who were studying tropical diseases. For his work on this expedition, he received a commendation from the Secretary of the Navy.

CAPT Ruebush served as Commanding Officer of the U. S. Naval Unit associated with the Army's Biological Warfare Laboratories at Fort Deitrick, Maryland, from January 1951 to July 1953. He was transferred to the ONR Branch Office in London as a Scientific Liaison Officer in July 1953. The technical reports he prepared during his duty in London set a standard for quality and interest of reporting which has been emulated in that office ever since.

In December 1955, CAPT Ruebush returned to Washington as Assistant Head of the Microbiology Branch, Office of Naval Research. He served at ONR Washington, first in The Microbiology Branch and later as Head of the Physiology Branch, until July 1959 when he was detached for duty in Cairo, Egypt. At the time of his death, he was Head of the Parasitology Department, Naval Medical Research Unit No. 3, Bureau of Medicine and Surgery.

CAPT Ruebush leaves his wife, Evagene, and three children, Trenton K, II, 13; Ann, 11; and Mary, 6.

Gas-Lubricated Bearings

A Resumé of the First International Symposium

The principles behind the design of a bearing that is lubricated by air or some other gas instead of oil were discussed at the first International Symposium on Gas Bearings held in Washington, D. C., on October 26-28, 1959. The symposium, sponsored by the Office of Naval Research, was the first devoted exclusively to broad scientific coverage of this new field.

The Franklin Institute of Philadelphia, Pa., conducted the symposium for ONR and nine cooperating Federal agencies. Eight foreign countries, including not only Western European nations but also Roumania, Japan, Austria, and Israel, were represented.

The opening paper, delivered by Dr. Dudley B. Fuller, of Columbia University and the Franklin Institute, presented a general semitechnical review of the development of gas-lubricated bearings. Dr. Fuller reported speeds ranging from 165,000 rpm for turbo-compressor units to between 400,000 and 500,000 rpm for shaft-rotor system currently under development. These high speeds compare with an approximate maximum speed of 100,000 rpm for the more conventional oil-lubricated bearings. He and other experts in the field covered further advantages of gas bearings--the ability to operate at extremes of temperature, absence of contamination, low friction, simplicity, quietness, reliability, and long life. They also discussed practical uses of these bearings, as well as their present limitations.

In his welcoming address, RADM Rawson Bennett, Chief of Naval Research, stressed the need for a fuller understanding of the fundamental phenomena involved in the design of gas-lubricated bearings. Because RADM Bennett's remarks were so timely and pertinent and so clearly presented the importance of this new field of science, the editors of Naval Research Reviews have included them here for the benefit of our readers.

Welcoming Remarks

RADM Rawson Bennett, USN
Chief of Naval Research

We have gathered here to begin the writing of a new chapter of science. Assembled in this auditorium from around the world are outstanding research men whose preliminary work has provided us with the framework of our text. As stated in the program, this is the first meeting devoted exclusively to broad international scientific coverage of gas-lubricated bearings.

By the end of these three days of sessions we should have a clearer idea of the problems ahead of us. We should have a general road map of the direction we must take to transform the development of gas-lubricated bearings from an engineering art to a science.

The calling of this symposium was a bold approach to the massive problem of solving the mysteries of gas-lubricated bearings. It was made possible principally because it was a coordinated effort of no less than ten government agencies. These include seven agencies from all three services of the Department of Defense, plus the Atomic Energy Commission, the Maritime Administration, and the National Aeronautics and Space Administration. We are naturally delighted that eight foreign countries, representing both Western and Eastern Europe as well as Asia, are participating in this symposium. It is indeed an honor for the Office of Naval Research to serve as a sponsor. My compliments to the Franklin Institute of Philadelphia for their part in the able management of this meeting.

As I have indicated, we are here to discuss the creation of a field of science. There does not yet exist a technology for this new type of bearing in which air or some other form of gas takes the place of lubricating oil. A glance at the titles of the papers which are to be read during the next three days reveals the word "theory" as occurring most frequently. Since we are dealing with the principles of aerodynamics in very small spaces, I am wondering if we should not call it the theory of microaerodynamics. Specifically, we are trying not only to learn how to build these bearings but also to discover the basic principles that affect their design. At present we have only a smattering of information about the fundamental phenomena behind their fabrication. Not until we gain more knowledge can a technology be developed.

It may seem to some people that we should not be wasting our time by concentrating on theory but that we should get on with the job of building more of these bearings. After all, air bearings have already been constructed quite successfully. Even if we counter with the fact that each such bearing has had to be virtually custom-designed and built by trial and error, it might be said that so were the first automobiles but mass production soon followed. The flaw in this analogy is that advances in automotive engineering in the past several decades have been slow and spotty. If a major fundamental research effort had been initiated in combustion, structural dynamics, and other allied fields when the first cars were built, I believe we would have much more efficient and possibly less expensive vehicles at our disposal today.

In engineering there is no substitute for knowing the principles behind what one is doing. That knowledge can come only from an extended program of research into basic theory. It is not surprising that the few men who tinkered with the idea of an electric motor in the middle of the last century—and even got one or two to work—have been given little credit. With little or no knowledge of the theory behind their ingenious inventiveness, they could not transmit their ideas to other men and thereby stimulate and foster further development.

Those who are involved in this program are firmly convinced that advances in rotary power machinery now dimly on the horizon will demand gas-lubricated bearings. Our onrushing technology is requiring higher speeds and higher temperatures as well as atmospheres, particularly in such applications as the interior of a nuclear reactor, where conventional lubricants are out of the question. Aside from this, a gas-lubricated bearing has the potential for years of reliable, frictionless operation with virtually no maintenance. This would be essential in the operation of manned satellites and space vehicles.

The Franklin Institute, supported by the Navy and the other organizations I have mentioned, began in 1957 a program of theoretical and experimental research to establish the basic principles involved in the design of these bearings. In the past year we have added the services of the General Engineering Laboratories of the General Electric Company. We are happy to have this highly qualified industrial concern working with us in this program.

A major factor in the rapid progress of our work is the interagency informal advisory group which has worked together with enthusiasm and determination. No one agency on its own could have moved forward so swiftly to the point of this symposium. It strikes me that the administration of this program might well serve as a model of how a research and development effort joining together several research agencies of the Federal Government can be successfully handled. I should point out that their work has been greatly aided by the voluntary, wholehearted contributions of time and effort by several private companies.

Finally, I would like to call attention to the participation of agencies not concerned with military affairs, which emphasizes the peaceful and broad applications of gas-lubricated bearings. This is further underlined by the fact that we have sought to make an exchange of information with scientists from various parts of the globe, regardless of their political alignments, so as to pool our knowledge on this subject.

We know, for example, that gas bearings are virtually required in certain advanced nuclear-power plants where oil would likely contaminate the reactor or actually be destroyed. It can readily be seen, therefore, that the gas-lubricated bearing will promote the peaceful use of atomic energy and help make this new source of power available in all parts of the world.

May I express my deepest respect for the formidable task which has been accepted and my admiration for the dedicated effort in this important area of research. Without men who are willing to take the risks of crossing new frontiers in science, it is clear that civilization would soon be at a standstill.

The first man in history to be picked up from the ground by a high-performance aircraft in flight recently received the Navy and Marine Corps Medal for his feat. Late in 1958 Marine Gunnery Sergeant Levi W. Woods, of Camp Lejune, N.C., participated in an air-sea rescue test by a P2V Neptune traveling at 125 knots at an altitude of about 500 feet.

In actual practice, a kit is dropped to the man to be picked up. He uses a helium cartridge to inflate a balloon which carried a pick-up line to the required altitude. He then straps himself into the lift harness, and the rescue aircraft intercepts the suspended line in its yoke and winches the man up into the plane.

TRIESTE Shatters Deep-Sea Record

During the International Geophysical Year, the bathyscaphe TRIESTE was busy gathering scientific data in the Mediterranean Sea near Italy. As last month's issue of Naval Research Reviews went to press, we left the blimp-shaped vessel enroute to the Marianas Islands, where it would engage in a three-month series of explorations conducted under the joint sponsorship of the Naval Electronics Laboratory and the Office of Naval Research. The tests are part of the long-term oceanographic and marine research program being pursued by the Navy.

The first dive of the series has now been completed. On November 15, Dr. Andrew Rechnitzer, scientist in charge, and Dr. Jacques Piccard shattered the depth record of 13,400 feet by descending to the unprecedented depth of 18,600 feet. Dr. Rechnitzer and Dr. Piccard, who with his father built the bathyscaphe, have worked together since the TRIESTE was delivered to the Navy in August 1948.

Heavy seas and inclement weather postponed the dive for two days, but, finally, at 10:00 on Sunday morning, the two scientists commenced their historic journey into underwater regions never touched before. With one lone pilot fish following them curiously for the first few feet, the blimp-shaped vessel settled slowly into the deep Marianas Trench at an average of one mile per hour. After a thousand feet, the sea darkened to midnight black, but at 1500 feet the phenomenon of bioluminescence gave the illusion of a starry night. At 6000 feet the quantity of this bioluminescence dwindled, and once again it was black. At exactly 3.5 miles from the surface, almost a full mile below that ever reached by an oceanographer, Dr. Reichnitzer had the first glimpse by man of the ocean floor in the Marianas Trench. On the bottom for only ten minutes, he observed no fish, only shrimp and numerous small holes of burrowing animals.

A biting temperature of 42 degrees inside the sphere was the major physical discomfort endured by the two men, despite the fact that they were confined 5-1/2 hours in a space equal to that of a normal household refrigerator. By the time they had reached the bottom, the 36-degree temperature outside had penetrated the thick walls of the bathyscaphe. This was particularly annoying, because the scientists had become wet from the waist down while boarding the vessel in rough water.

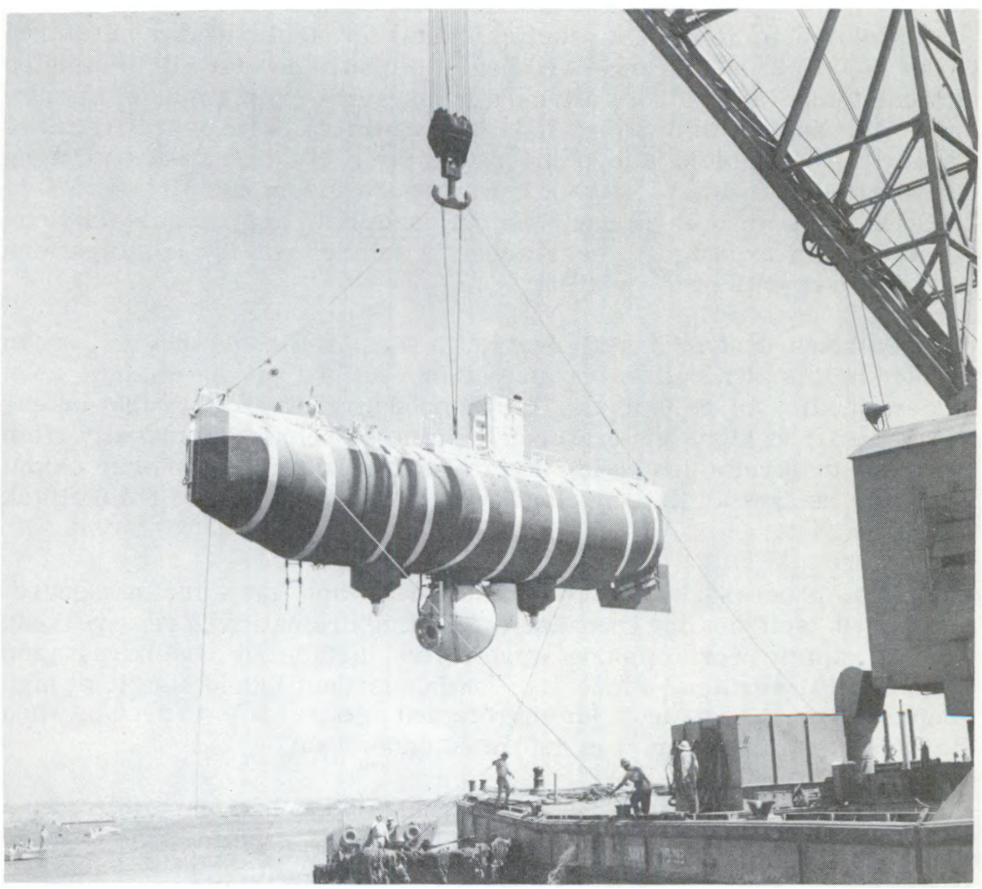
The ascent was just as smooth as the descent. The 70-ton vessel appeared on the surface at 3:45 p.m. at nearly the origin of the dive, indicating that there was relatively little deep-wake current.

Dr. Rechnitzer had some interesting tales to relate after having submerged to the bottom of the sea. He said, in part:

> "It was indeed a great sensation coming face to face with the bottom of the ocean . . . We left the attending vessel bobbing on the rough surface as we descended untethered and on our own into the eerie calm below . . . At the surface the sun-lit water appeared as an electrifying blue through the

eight-inch-thick plastic windows. . . . Numerous tiny greenish-white lights surrounded us [at 1500 feet]. . . . Dropping ballast to slow our descent for landing on the bottom created billows of underwater dust which temporarily obscured details of the sea floor."

This phase of the Navy's long-term research program to explore the deep ocean has been in the planning for two years (Naval Research Reviews, April 1957). Some of the underwater data being sought includes more knowledge of sunlight penetration, underwater visibility, natural underwater sounds, transmission of man-made sounds, water currents, water temperatures, sea-floor configurations, and the effect of deep-water pressures on various mechanical devices. As Dr. Rechnitzer put it, "We probably know more about the surface of the moon than we know about the bottom of the ocean." This series of dives and exploration will undoubtedly bring to light many mysteries of the deep yet unknown to mankind.



The bathyscaphe TRIESTE is lifted from the water in the San Diego diving area by a floating crane. The circular area beneath the blimp-shaped structure contains a window from which pictures can be taken and undersea life observed.

NZ: The Coating That Keeps Rare Metals Metallic at 2200° F

A Navy-developed protective coating, capable of automatically "healing" itself when flaws or defects occur, makes it possible for the heat-resistant metal columbium to be utilized at temperatures as high as 2200° F. The coating, which utilizes ordinary grades of zinc as the starting material, was developed by metallurgists at the U. S. Naval Research Laboratory with support from the Navy's Bureau of Aeronautics.

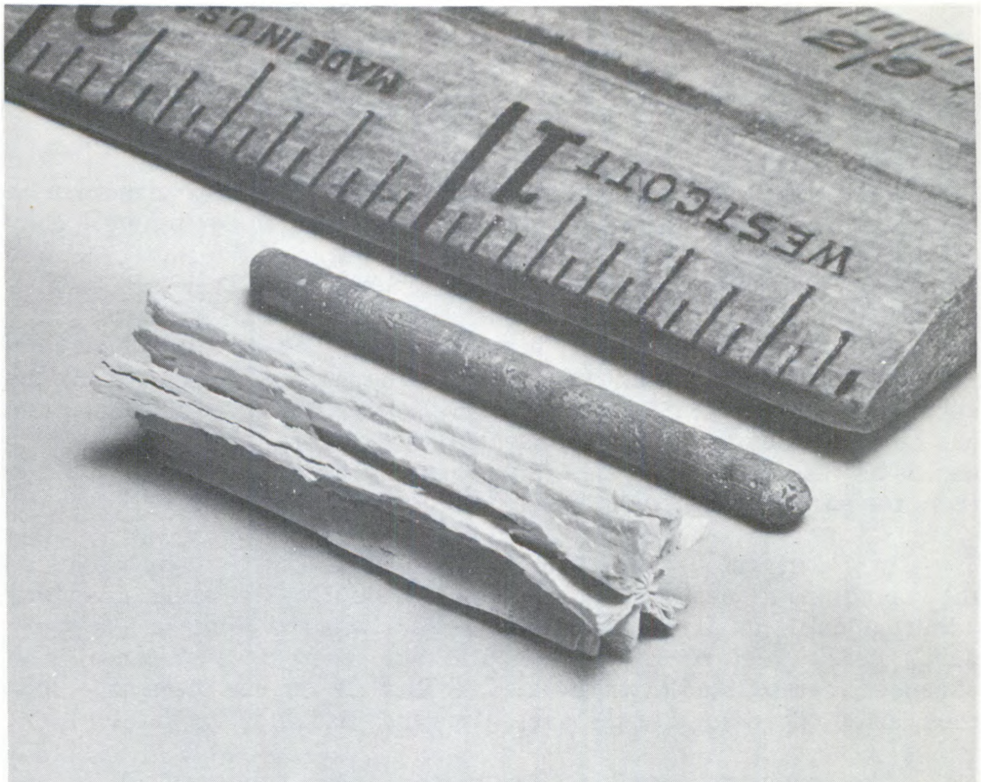
The new coating prevents oxidation of alloys of columbium, which is one of the high-strength refractory metals that include molybdenum, tantalum, and tungsten. Alloys of these metals can stand up to temperatures which turn iron, nickel, and cobalt into soft putty or liquid. The main drawback to using these refractory metals in the past, however, has been that when exposed to oxygen in the air at high temperatures they turn to powder.

Columbium, the most practical metal for achieving temperatures in the 1800 to 2500° F range, will begin to turn to powder within minutes at these temperatures when attacked by oxygen. Applications of the new protective coating to this metal, as demonstrated in tests at NRL, have shown that columbium alloys can retain their characteristics for long times to meet a wide variety of hardware requirements in the 1600 to 2200° F range while in an environment containing oxygen. Higher temperatures are expected to be reached in future tests by modifications and improvements of the coating.

Although zinc ordinarily boils at a temperature of 1680° F, it can be used in this application because it is retained on the surface as a zinc-rich alloy of columbium. NRL metallurgists explain that on exposure to air at high temperatures the zinc is released gradually from the alloy to form a protecting layer of complex zinc-columbium oxide. This layer serves as the "envelope" which shields the metal from attack by oxygen.

This process takes place automatically when flaws are introduced. It is called "self-healing" because the coating dramatically repairs these flaws by rapidly reestablishing a protective surface over the bare region on the metal surface. Since the coating is ductile and plastic at high temperatures, it is difficult for unprotected or bare spots to develop when the base metallic material is deformed under load.

The zinc coating has been demonstrated to be compatible with a wide variety of columbium alloys. Application is simply accomplished either by dipping the columbium in a molten zinc bath, by electroplating, or by applying it in a vapor form in a vacuum chamber. The latter method makes it practical to coat large components, such as complex combinations of sheet, tubes, and supporting structures which are often not amenable to applications of other types of coatings.



Effect of heating in air to 1800° F uncoated columbium and columbium coated with NZ-1. Uncoated specimen is corroded to crumbly white powder in less than 6 hours while the coated specimen remained virtually unchanged.

Industry and other Government laboratories have been informed by the U. S. Naval Research Laboratory of the new coating for columbium and columbium alloys, and have been conducting series of tests to evaluate its practical use in the construction of aircraft structures and engines required to withstand extremely high temperatures. Previous coatings, developed for such purposes, have generally tended to be useful only within very limited temperature ranges. They have been restricted to applications on particular alloys or have been applicable only for coating very small parts. None has demonstrated capabilities for self-healing.

One of the several potential uses of the NRL-developed coating for columbium will be to permit an increase in the operating temperature and therefore the efficiency of jet engines for aircraft propulsion and for auxiliary power generations in rockets. The new coating is also expected to be applicable for the construction of high-temperature nuclear power plants and manned glide reentry vehicles (return from orbit). Evaluations of the capabilities of the coating to meet the specific requirements for each of these applications are now under way at various laboratories.

Research Notes

Blow and Go

Two Navy men demonstrated early last month that escape can be made from a submarine at 300 feet without special equipment. They were CDR George F. Bond, MC, Officer in Charge of the Naval Medical Research Laboratory, and Chief Enginemen, C. G. Tuckfield, an instructor at the New London Submarine Escape Training Tank.

The new method, known as "blow and go," was made from the submarine ARCHERFISH off the port of Key West, Florida. This method has been used by the Navy for the past three years, but not from such depths as the 300-foot level. Four previous escapes have been made from the same submarine at depths of 150 and 200 feet.

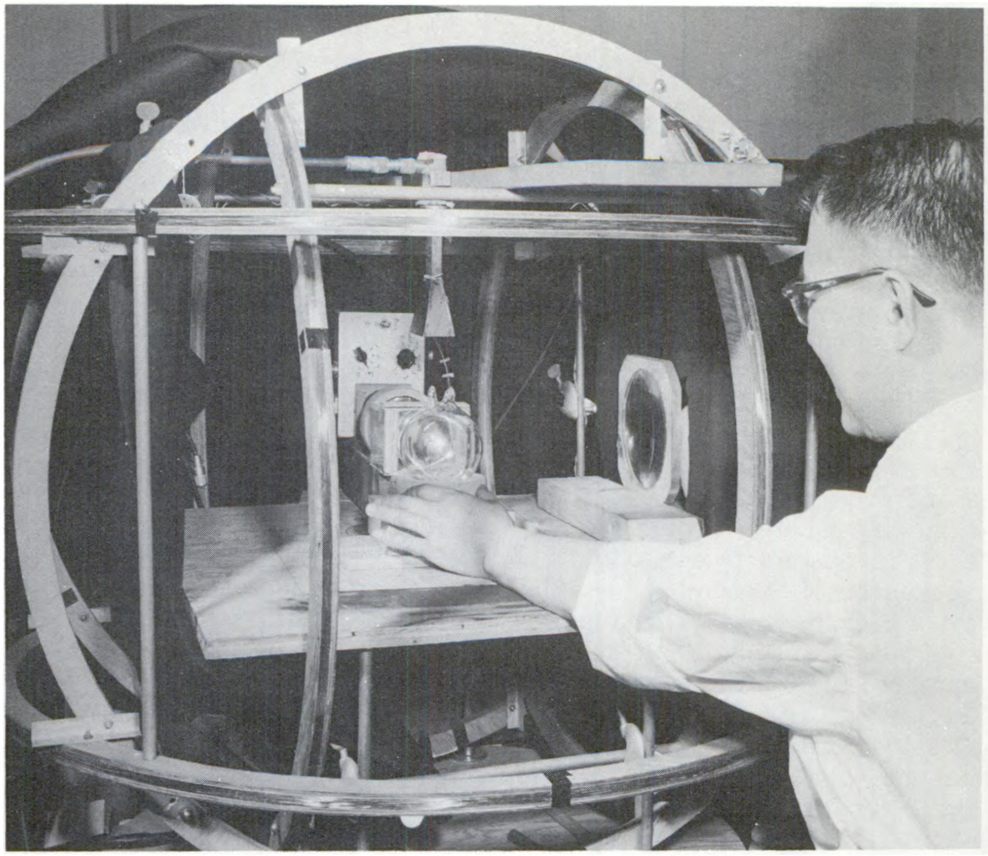
In making the escape, CDR Bond and Chief Tuckfield first entered the submarine's escape lock and closed the doors, after which water was admitted until the pressure within the lock was the same as sea pressure. At 300 feet, pressure is about 135 pounds per square inch. The escapees then inflated their life jackets with air, opened the escape door lock, and stepped out. At the same time they exhaled completely.

The ascent required less than one minute, during which the escapees did not breathe. If their lungs had been filled with air at high pressure, the expanding air as they neared the surface could have ruptured their lungs or forced nitrogen in their blood with resultant "bends."

Measuring Frequency and Time

The new weapon, radar, communication, and navigation systems which will come into use in the next few years will require a frequency standard with accuracy and long-time stability several orders of magnitude better than now available. Frequency-measuring equipment in use today in the military services is inadequate to meet all CNO requirements. For example, a ship's frequency standard must now be recalibrated with respect to the shore frequency standard every three months. The need exists for more reliable and accurate time standards for use in the Fleet and at shore stations, in addition to a much wider distribution of the Navy's time service.

Scientists at the Naval Research Laboratory have constructed an atomic frequency standard employing the new optical-pumping techniques being investigated in collaboration with the National Bureau of Standards. Known as the gas-cell atomic frequency standard, it can provide a resolution of ±1 part in 10 billion. It is being used to conduct research in the field of gas resonance, particularly the study of atomic-resonance effects in small glass cells containing alkali metal



A gas cell is positioned in the light beam of NRL's experimental atomic frequency standard prior to observations of atomic-resonance effects.

vapor, as applicable to frequency-standard use. This work is expected to lead to small, easily carried (about 1-foot square), atomic frequency standards with a stability equivalent to that of a clock which does not gain or lose one second in 300 years.

Submarine With Built-In Silence

The Naval Shipyard at Portsmouth, N. H., accepted an interesting challenge when it was awarded a contract to build the nuclear submarine THRESHER, scheduled to be launched in March 1960. The submersible ship will be the first to have "built-in" silence from bow to stern.

Newly developed designs in quiet machinery will be placed in the THRESHER, now under construction. Many of the new concepts being incorporated in the new nuclear ship were first used in the submarine JALLAO when it was overhauled in the Portsmouth Shipyard.

Noise in submarines is being reduced by designing machinery with less vibration, thereby contributing to better dynamic balance. This also minimizes wear and tear, which in turn reduces future dynamic unbalance.

Improvements in the construction of "silent" submarines will make the ships more immune to detection by sonar. Since sound is the important "ingredient" in sonar, the less noise the submarine emits the less likely it is to be detected.

On The Naval Research Reserve

Commanding Officers Conferences

Two conferences of Commanding Officers of Research Reserve companies were held recently in the Fifth and Sixth Naval Districts. The conferences were planned and arranged by CDR Walter C. Avery, USN, Fifth and Sixth Naval District Research Reserve Liaison Officer, in cooperation with the Commandants of these Naval Districts. In attendance were the Commanding Officers or their representatives from Research Reserve Companies in the two districts.

Commanding Officers of companies in the Fifth Naval District met at the Office of Naval Research in Washington, D. C., on November 7 and 8. In addition to the topics discussed by CDR Avery, presentations were made by the following from ONR: CAPT J. P. Aymond, USN, Special Assistant to the Chief of Naval Research (Research Reserve); Dr. F. D. Rigby, Director, Mathematical Sciences Division; and Miss Eleanor Kehoe, Training Specialist (Research Reserve). Informative talks were made by representatives from the Fifth Naval District and the Bureau of Naval Personnel: LCDR B. T. Morrison, USN, Special Programs Officer, Fifth Naval District and LCDR G. W. Turner, USN, Reserve Officer, Promotion Branch, BuPers. The agenda consisted of subjects pertinent to Research Reserve companies. Among these were the following: district plans, policies, and administration as regards the Research Reserve; scientific aspects of ONR; reserve officer promotions; mobilization concepts; recruiting; active and inactive duty training;

Participants at the Fifth Naval District Research Reserve Commanding Officers' Conference: (Seated left to right) LCDR B. T. Morrison, USN, (Special Programs Officer, Fifth Naval District); CDR J. W. Smith, USNR; CAPT J. P. Aymond, USN; CDR W. C. Avery, USN; CDR U. Liddel, USNR; (Standing left to right) CDR E. W. Peterkin, USNR; LCDR F. D. Hansing, USNR, (Alternate Mobilization Liaison Officer); LCDR J. B. Eades, Jr., USNR; LCDR E. F. Kehoe, USNR; LCDR W. W. Roessler, USNR; CDR W. F. Anderson, USNR; LCDR R. L. Chambliss, Jr., (Mobilization Liaison Officer); CDR C. M. Preston, USNR; CDR L. E. Rozeboom, USNR; LCDR I. H. Bowman, USNR; CDR C. M. Cox, USNR.

Participants at the Sixth Naval District Research Reserve Commanding Officers' Conference: (Front row left to right) CAPT J. P. Aymond, USN; CDR W. C. Avery, USN; CDR O. D. Mendenhall, USN, (Special Programs Officer, Sixth Naval District); LCDR E. F. Kehoe, USNR; CDR S. B. Sudduth, USNR; CDR N. R. Buchan, USNR; LCDR P. C. Lightle, USNR, (Alternate Mobilization Liaison Officer); LCDR J. S. Howkins, USNR; CDR J. D. Baer, USNR; Lt A. H. Hinners, Jr., USNR; LCDR Q. W. Lindsey, USNR; CDR C. Downes, Jr., USNR; LCDR P. F. Hurt, USNR; CDR R. S. Bolles, USNR; (Back row left to right) CAPT C. Kyselka, USNR; CDR C. A. Hoffman, USNR; CDR L. T. Palmer, USNR; CDR H. M. Tatum, USNR; CDR R. B. Martin, USNR; LCDR W. E. Park, USNR; LCDR J. E. Land, USNR, (Mobilization Liaison Officer).

and retirement benefits. Visual evidence of research in the Navy was shown by "CNO Film Report 3-59" and "Navy in the Space Age."

On the following week-end, November 14 and 15, the conference for Commanding Officers of the Sixth Naval District was held at the Naval Air Station, Atlanta, Georgia. The agenda followed the same general line as that for the Fifth Naval District conference. The Sixth Naval District was represented by LCDR O. D. Mendenhall, USN, Special Programs Officer.

Tenth Anniversary of Naval Reserve Research Company 1-3

Naval Reserve Research Company 1-3, which was commissioned at the University of Massachusetts at Amherst on 30 May 1949, celebrated its Tenth Anniversary on 3 November 1959. This special event was observed by a social hour at the Lord Jeffery Inn, Amherst; a banquet and lecture at the University's Student Union building was held afterwards.

LCDR A. L. Hepworth, USNR, a member of NRRC 1-3, served as toastmaster for the banquet. He introduced the Commanding Officer of NRRC 1-3, CDR S. F. Wexler, USNR, who welcomed the guests to the

Attending NRRC 1-3 Tenth Anniversary are: (Seated left to right) LCDR C. T. Shay; LCDR H. G. Abbott, Administrative Officer; CDR S. F. Wexler, Commanding Officer; CAPT J. P. Aymond, ONR Washington; CDR J. A. Sharpe, ONR Boston; LCDR E. E. Lindsey, Executive Officer; LCDR S. F. Salwak; and LT L. F. Michelson; (Standing left to right) LCDR W. Footrick; LTJG E. Walsh; LCDR J. B. Ludtke; CDR G. R. Richason; LT J. H. Mitchell, Active Duty Advisor; CDR G. A. Martson; CDR R. G. Richardson; LT J. E. Steckel; CDR R. C. Foley; LT R. L. Chamberland; LCDR J. S. Marcus, Membership Officer; CDR C. A. Keyser, Training Officer; LT R. K. Tiffany; LCDR W. D. Scott; and LCDR A. L. Hepworth.

meeting. CDR C. A. Keyser, USNR, the speaker of the evening, discussed "X-Ray Diffraction and Fluorescent Analysis," and used opaque projections to illustrate his talk.

Several honored guests and the 1002nd Army Research and Development Sub-Group were present at the function. In attendance, as distinguished friends and visitors, were: CAPT J. P. Aymond, USN, Special Assistant to the Chief of Naval Research (Research Reserve); CDR J. A. Sharpe, USN, Assistant for Research Reserve, Office of Naval Research Branch Office, Boston; COL J. C. Marchant, USAF, Professor of Air Science, University of Massachusetts; COL J. R. Weaver, USA, Professor of Military Science and Tactics, University of Massachusetts; and LTCOL J. J. Sullivan, Jr., USA, Officer in Charge, Springfield, Massachusetts, Area Command, XIII U. S. Army Corps (Reserve).

The festivities also honored two former members of the Company who are now on the retired list. Appropriate "diplomas" were presented to CAPT P. D. Davis, USNR, and LT L. F. Michelson, USNR.

Outstanding Companies

The Commander, Naval Reserve Training Command, has sent Letters of Commendation to Commanding Officers of Naval Reserve Research Companies which were evaluated as OUTSTANDING by the

Commandants of Naval Districts for fiscal year 1959. These letters read in part,

> "Such a creditable showing could result only from noteworthy leadership on your part. I commend you for your efforts which are reflected in the performance of your company and extend to you a hearty 'Well Done!'"

Letters of Commendation were received by the following Commanding Officers who served during fiscal year 1959:

LCDR John B. Simeone	NRRC 3-6
CDR Donald MacCreary	NRRC 4-5
CDR Dariel E. Howell	NRRC 8-13
LT Robert K. Larson	NRRC 9-5
LCDR Harold S. Cook	NRRC 11-2
CAPT Robert M. Fincher	NRRC 12-3
LCDR Roy S. Peterson	NRRC 13-2

Seminars Scheduled for Remainder of Fiscal Year 1960

Seven Research Reserve seminars were held during the first half of the fiscal year 1960. Before the close of the fiscal year (June 30, 1960), two more seminars are scheduled to convene. These are the Seminar in Submarine and Diving Medicine, to be held at New London, Connecticut, on March 21, and the Research Reserve Seminar, to be held at ONR, Washington, D. C., on June 6.

Statistics on the Research Reserve

The following figures were compiled from data submitted in the annual reports forwarded by Research Reserve Companies for fiscal year 1959:

Companies	111
Panels	4
Members	2,471
Ready Reserves (percent)	78
Standby Reserves (percent)	22
Attendance at drill meetings (medial percent)	82
Earned satisfactory federal year	1,930
Selected for promotion	209
Promoted	162
Received active duty for training	808
Captains	28
Commanders	219
Lieutenant Commanders	274
Lieutenants	210
Lieutenants (JG) and below	77
Completed correspondence courses	1,399

Title Index 1959[1]

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[1]Articles are arranged chronologically under the ONR division or laboratory having cognizance of the research described.
[2]Written by the editorial staff of Naval Research Reviews.
[3]Adapted from an article published in the University of Michigan Research Institute News, January 1959.

NAVAL SCIENCES—Continued

Better Weapons Through Operations Research, CDR R. L. Plass, April

Submarine Tactical Games, J. M. Newton, F. J. Wuest, A. E. Hickey, Jr., June

SUBIC,[2] August

LABORATORIES OF ONR

Current Levels of Atmospheric Radioactivity, Luther B. Lockhart, Jr., February

Rocket Astronomy During a Total Eclipse of the Sun, H. Friedman, March

Self-Luminous Sources of Light,[2] March

Network for Tracking Silent Satellites,[2] March

The Underwater Sound Reference Laboratory, John M. Taylor, Jr., May

The 100-Inch Airborne Radiometer, C. F. Bieber, H. L. Clark, June

The ONR Contract Astronomy Program, G. F. W. Mulders, July

Fire-Extinguishing System for Use at Polar Temperatures, J. K. Musick, J. A. Grand, July

Naval Radio Research Station,[2] August

The Role of Radar in Space Research, K. J. Craig, A. Shapiro, B. S. Yaplee, September

Project ORCON: A Plan to Use Pigeons to Guide Missiles,[2] September

NZ: The Coating That Keeps Rare Metals Metallic at 2200° F

Rapid Hypothermia - an Extracorporeal Method, D. Friedman, December

MISCELLANEOUS

Report on 18 Months of Unprecedented Scientific Activity,[4] February

Ocean Bottom Photography,[2] July

Undersea Cameras,[2] July

Viewing the Sun From the Stratosphere,[2] August

Protecting Navy Inventions, A. H. Helvestine, September

An Application of Photogrammetry to Radar Research Studies, Earl S. Leonardo, October

Nitrogen Narcosis and Its Effect on Performance, ENS R. J. Kiessling, C. H. Maag, December

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[2]Written by the editorial staff of Naval Research Reviews.

[4]U. S. National Committee for IGY.

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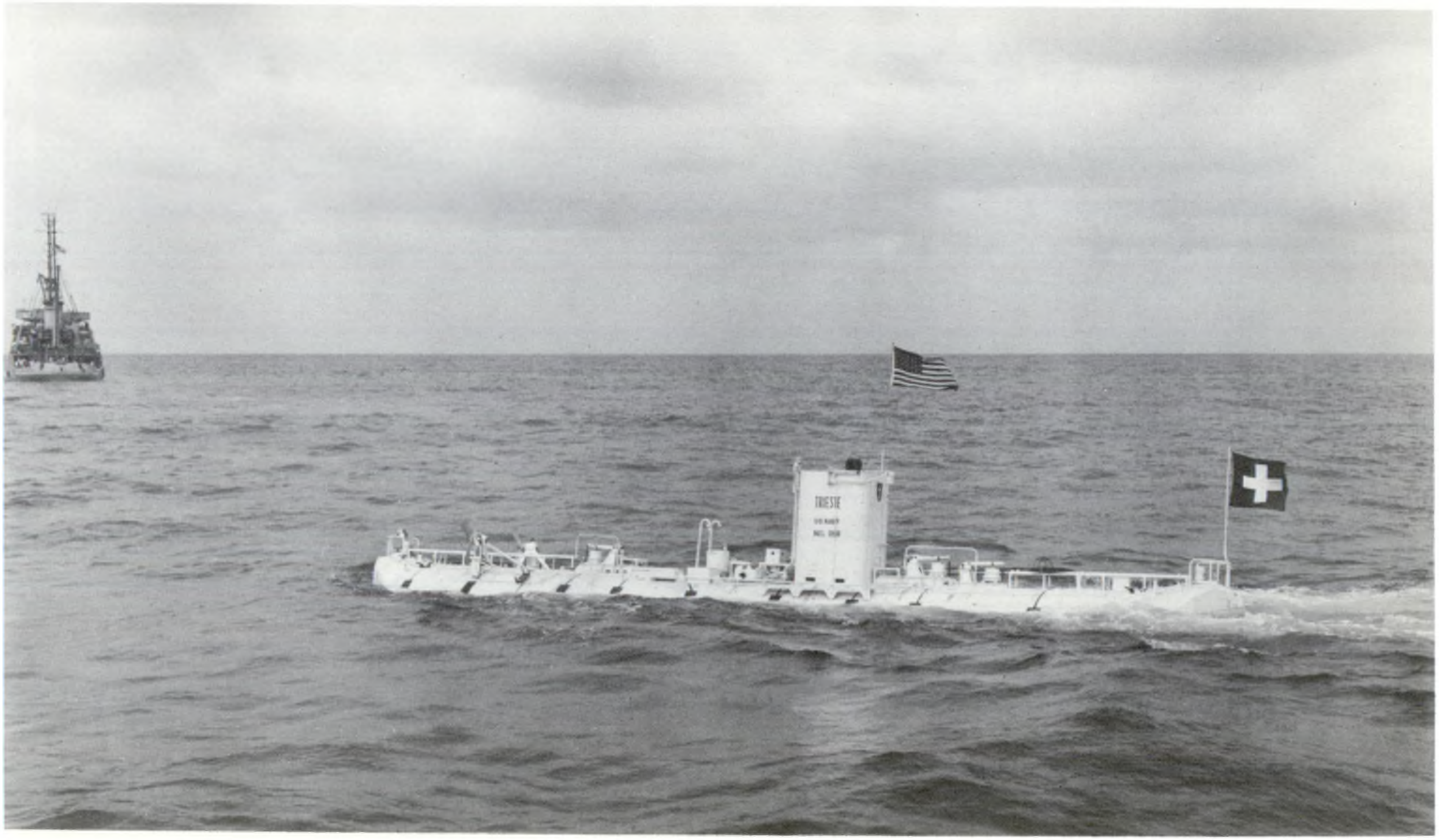

A U. S. Navy vessel tows the bathyscaphe TRIESTE to the San Diego diving area for tests prior to leaving for the Marianas Islands. The TRIESTE is capable of self-propulsion at slow speeds when submerged.

IN THIS ISSUE

NAVAL RESEARCH reports highlights of technical progress in research by Navy laboratories and contractors and the development of important naval research facilities. The magazine is listed for sale by the Superintendent of Documents, U. S. Government Printing Office, Washington, D. C. Subscription price: $1.50 per year in U. S. and Canada; $2.00 per year, foreign; $0.15 per individual copy. Changes of address should be sent to Code 740, Office of Naval Research, Washington, D. C. Use of funds for printing this publication was approved by the Director of the Bureau of the Budget, February 12, 1958.

ON THE COVER: A Navy Scuba diver makes a practice run with a Bloodworth marine power diver. **See story on page 6.**