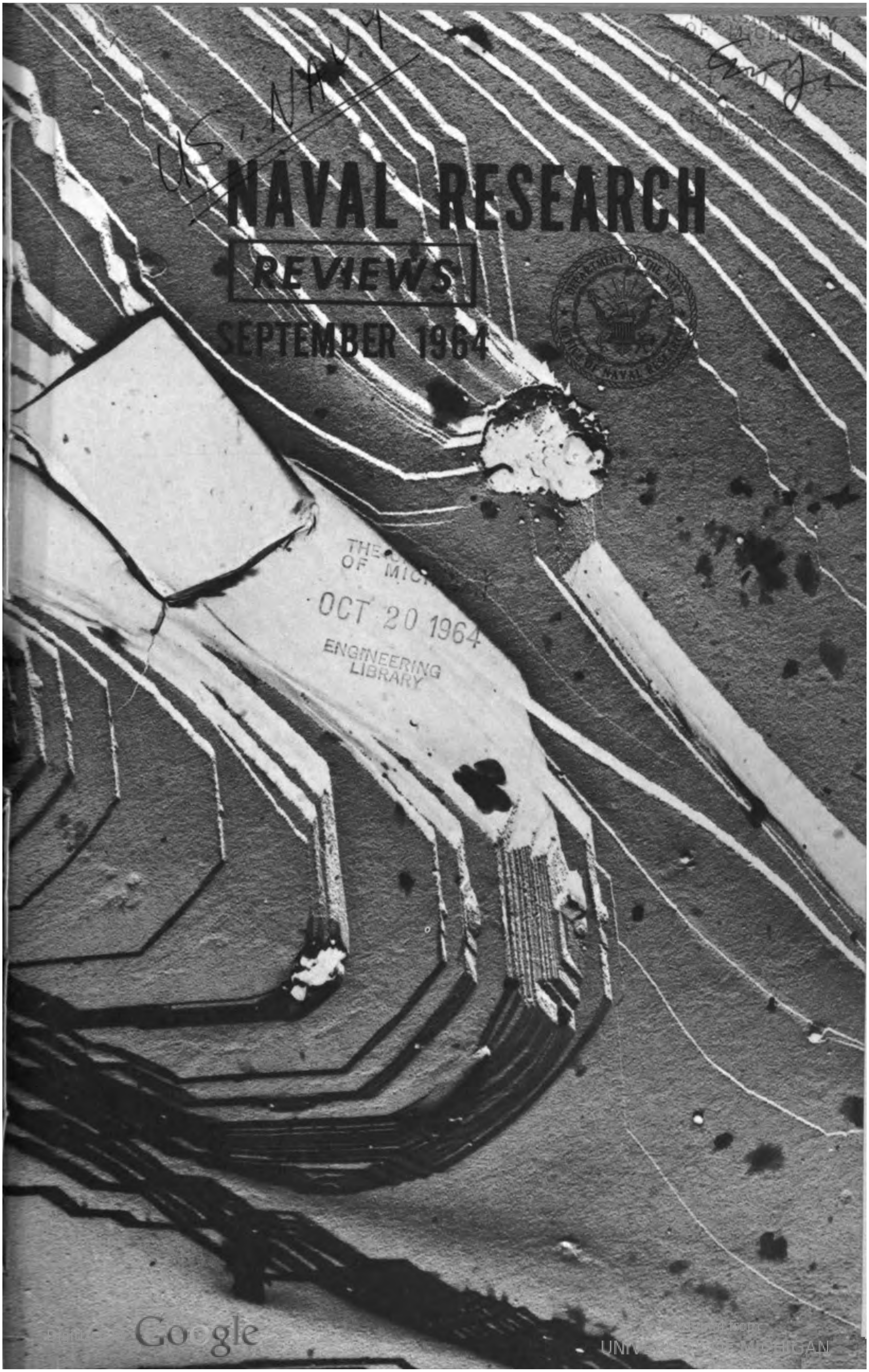
U.S. NAVY

NAVAL RESEARCH REVIEWS

SEPTEMBER 1964



INVENTIONS

Burnable Poison

Dr. Alvin Radkowsky, Chief Scientist of the Nuclear Propulsion Division of the Bureau of Ships, has been given a $25,000 cash award for his invention of the "burnable poison" method of control of nuclear reactors. He is the second individual in the Navy to receive this top money award since the present awards law was enacted almost ten years ago.

The "burnable poison" process prevents chain-reaction explosions of radioactive uranium in ship reactors, allowing an unlimited amount of uranium to be put into them and permitting reactor operation for much longer periods of time than would be possible otherwise. It is thus of great significance to the Fleet and has saved many millions of dollars.

The award was presented by Secretary of the Navy Paul H. Nitze in a ceremony held at the Pentagon on July 29. Attending the event, in addition to the Secretary, were ADM David L. McDonald, Chief of Naval Operations; RADM W. A. Brockett, Chief of the Bureau of Ships; RADM C. A. Curtze, Deputy Chief of the Bureau; VADM H. G. Rickover, Assistant Chief of the Bureau for Nuclear Propulsion; and RADM J. A. Brown, Assistant Chief of the Bureau for Design, Shipbuilding, and Fleet Maintenance.

Secretary of the Navy Paul H. Nitze (left) congratulates Dr. Alvin Radkowski after presenting him a check for $25,000.

—Continued on back cover (inside)

The Brain as a Self Organizing System*

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The scientist has been impelled to learn what his own body is like and how it functions. From the time of Aristotle, neuro-anatomists have examined the brain, but knowledge of its function is only just beginning to emerge in the 20th century.

In addition to the need to learn the basic laws of nature, the scientist must be aware constantly of the importance of the application of such knowledge. The study of how the brain handles information inherent in speech sounds has a bearing in three applied areas of research.

With the development of the nuclear submarine and the deployment of these vessels to defend the Nation, new problems in communication within the Fleet have arisen. Although underwater listening has tapped a major source of information for guidance of conventional submarines, the ability of nuclear submarines to remain submerged for months at a time has placed greater demands on the use of sonar equipment as well as voice communication between submarines and other vessels of the Fleet. At one end of the listening, or echo-ranging, system and at both ends of the voice-communication links is a human being who must interpret and make decisions based on the sounds which he hears. Upon his knowledge and ability to recognize and interpret correctly acoustical messages produced or transmitted underwater, at least part of the operation of the submarine depends. A knowledge of how the brain handles acoustical messages may lead to an improvement in the ability to listen, interpret, and make judgments based on such sounds.

Recently a new engineering, or applied, science has arisen, called bionics, in which biological principles are applied to the design of mechanical devices. Pattern-recognition devices and their accompanying learning circuits are one form of such products. The knowledge of how the eye and ear extract information from the environment is providing the basis for the design of the systems. Understanding how the brain handles information and is involved in logical thought should

*The research described in this article has been supported by the Office of Naval Research, the Institute of Neurobiological Diseases and Blindness, the Institute of Mental Health, and the IBM Corporation.

contribute to the development of learning computers and other automata which simulate the function of the human mind, and it should lead to improvements in the diagnosis and treatment of neurological and mental disorders, such as brain tumors and schizophrenia.

The research described in this article has been directed toward understanding how the brain actually encodes and recognizes acoustical messages, including those transmitted through speech, by studying the physics of information handling by the brain. The different sounds of words in a message are due to the different frequency or spectral components that are emitted by the voice in forming the words. A sequence of such words forms a message that stimulates the nerve fibers in the ear in a special way, causing the message to be converted into a sequence of patterns of nerve impulses, some of which are carried by the nervous system to the cortical mantle. Determining the nature and ultimate fate of the message in this part of the brain is the objective of this investigation. Although most of our efforts have concerned the brain responses of animals, because the basic anatomy of animals is less complex than that of humans and thus affords easier routes to understanding, preparations are being made to record data from the human brain also.

Since our last report, "How the Brain Handles Information," *(Naval Research Reviews,* May 1954), much progress has been made concerning the analysis of the messages received in the brain. The part of the brain which has been studied is the cortical mantle – the layer of gray matter which covers the cerebral hemisphere. It is only about 2 mm in thickness yet contains millions of nerve cells. Since we do not extract information from the eye or ear, it is necessary to assume that the cortical mantle contains the copy of the external environment. In Figures 1 and 2, photographs of the human and dog brain illustrate the various receiving areas for neurones from the skin of the body, the eye, and the ear. We know that destruction of the touch area and visual area result in the loss of the ability to perceive touch and to see. We also are aware that destruction of the brain surrounding the hearing area results in an inability to understand spoken words and to speak intelligently. The motor centers control the motion of the tongue, which is necessary for speech, and of other parts of the body, including the fingers. It is known that destruction of these areas results in the inability to move muscles or to speak. Almost all parts of the cortical mantle are connected with each other by means of an intricate network of short and long neurones, called the association pathways, which presumably can transform messages and "associate" them with messages in other parts of the brain. The lower centers of the brain have never been shown to be capable of such rich association; it is surmised, therefore, that the cortical mantle, with its rich interconnections, is the principal integrating and memory system for the higher processes of human thought.

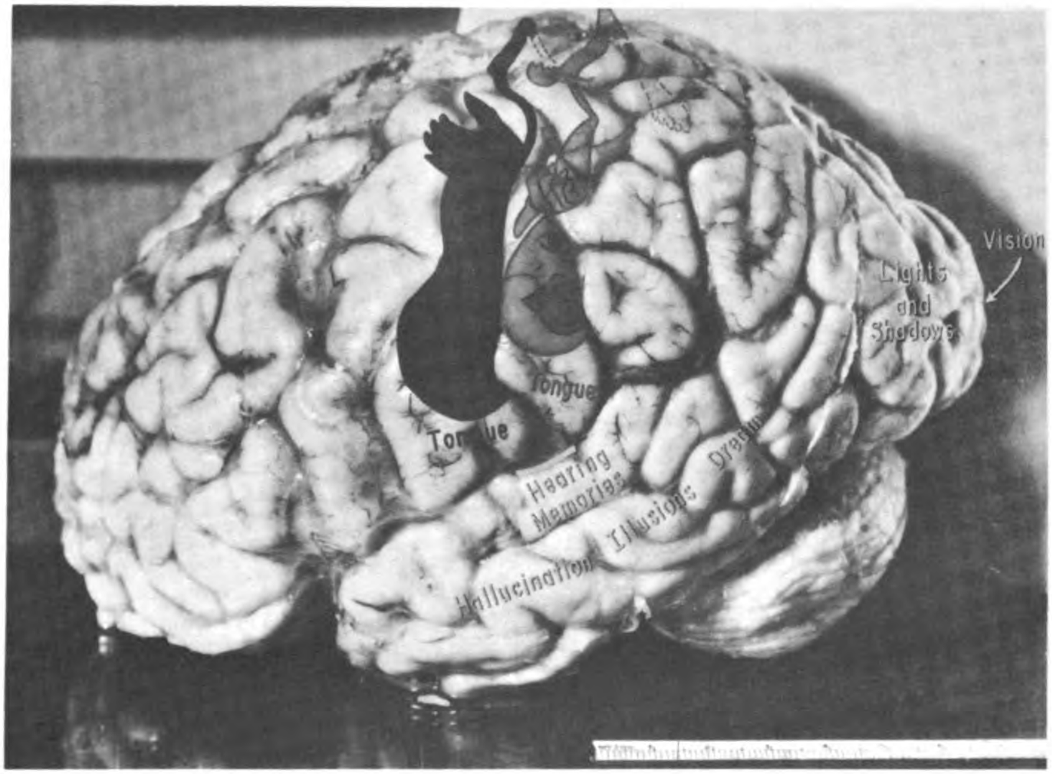

Figure 1 – A photograph of the human brain showing several functional areas of the cortical mantle. If the outline of the entire head were shown in the photograph, the forehead would appear at left and the back of the head at right. The dark area at left of middle controls the muscles of the opposite (right) side of the body. Areas controlling lip, nose, eye, and hand movements are indicated by the superimposition of those features on the dark area. The torso-control area is represented by the curving line at top of dark area, and the leg-control area is indicated, in part, by adjoining dotted lines. The lighter area marked off on the brain controls touch for the opposite (right) side of the body. The visual area is located at the rear of the brain. Next to it is an area which, upon stimulation, causes the patient to see lights and shadows. The hearing area is indicated by a small strip in the depths of a groove beneath the muscle and touch areas. The temporal lobe, upon stimulation, produces memories, hallucinations, illusions, and dreamy states.

This investigation of the cortical mantle had its beginnings about 23 years ago. One of the most advanced oscilloscopes of the time was available to initiate the study. During the ensuing years, the number of oscilloscopes increased to 10 and eventually to 50, permitting the accumulation of data from 50 brain locations simultaneously. Concurrently, as new facts emerged, methods of investigation and concepts of the nervous system were unfolding. New electrodes were designed to meet the needs of the experiments. An assembly of 50 electrodes in current use is shown in Figure 3. The electrodes cover one subdivision of the auditory cortex, thus allowing the entire pattern of the activity caused by the message to be visualized or recorded at one time as well as over a period of time. The weak brain potentials,

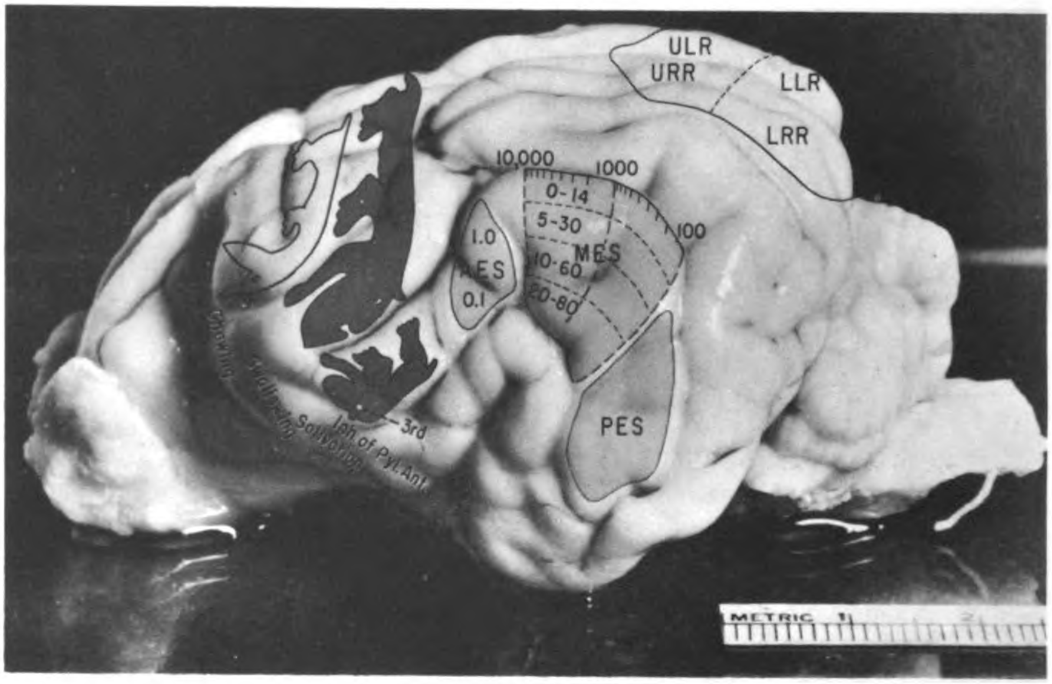

Figure 2 — A photograph of the dog brain. The areas outlined correspond to the control areas designated in Figure 1. The difference in size of the two brains is indicated by the scale at the bottom of the photographs. The light colored area at the left (toward forehead) controls the muscles of the opposite (right) side of the body. The two dark gray areas receive information on touch for the opposite (right) side of the body. At the upper right is the visual cortex; areas in which messages are received from the upper left, upper right, lower left, and lower right retina are indicated. The auditory, or hearing, cortex is shown in the middle of the brain, in light gray, and in the touch area (marked "3rd"). The "MES" area possesses the most systematic organization of connections from the ear. The sites of maximum excitation in the "MES" area are shown to have a systematic organization from 100 to 10,000 cycles per second. At right angles to this arrangement are shown the decibels required to excite various portions of the auditory cortex. The messages received by this part of the cortex come from the left ear.

less than 200 millionths of a volt, are amplified by means of 50 amplifiers and displayed on 50 cathode-ray tubes (see Figure 4). The display on the cathode-ray tubes has served as a monitor to plan the experiments and to select the brain activity to be studied.

Two types of sounds were used as messages to the ear. One was an elementary sinusoidal signal, which allows parcelling of the activity at the cortex into quanta of information. The second, of course, was speech. The equipment for generating the various sounds is shown in Figure 5. The sounds could be presented to each ear separately or to both ears together.

As the investigation progressed, it became possible to formulate a mathematical and statistical model of the events which were to be studied with the 50 electrodes on the brain. Since the electrical activity of the brain varies continually in its amplitude with respect to time,

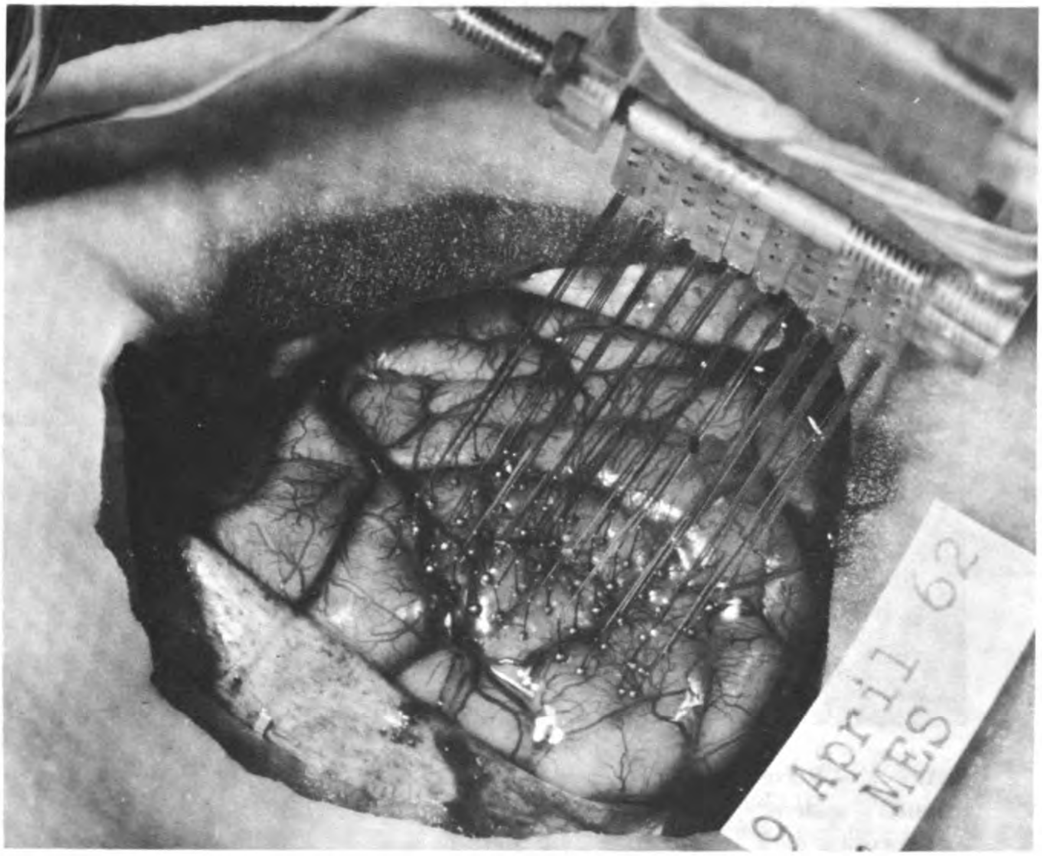

Figure 3 — Fifty electrodes situated on the "MES" auditory area of the dog brain (see Figure 2). Spacing between each adjacent pair of electrodes is approximately 2 mm.

refined multivariate statistical methods, including time-series analysis, were chosen to study the nature of the variations and relations of the amplitude at different locations and times. For a number of years during the development and refinement of the statistical procedures, measurements were made semi-automatically and placed on IBM cards. Computations were performed with standard punchcard equipment. As discoveries were made, the semi-automatic hand measurements were replaced by a telemetry system capable of sampling and converting into digital form the brain voltages at a rate of 14,450 per second. These numbers were stored in sequence on magnetic tape by the system shown in Figure 4, middle. For a year the data were analyzed with an IBM 1620 data-processing system, which has now been replaced by an IBM 1410 data-processing system, shown in Figures 6 and 7.

The general manner in which the spectrum of a sound is represented in the auditory cortex has been known for some time. The different frequencies of the spectrum stimulate different portions of the ear, which in turn sends a cluster of nerve impulses to different places in the auditory area, indicated in Figure 2; in this figure the sites of

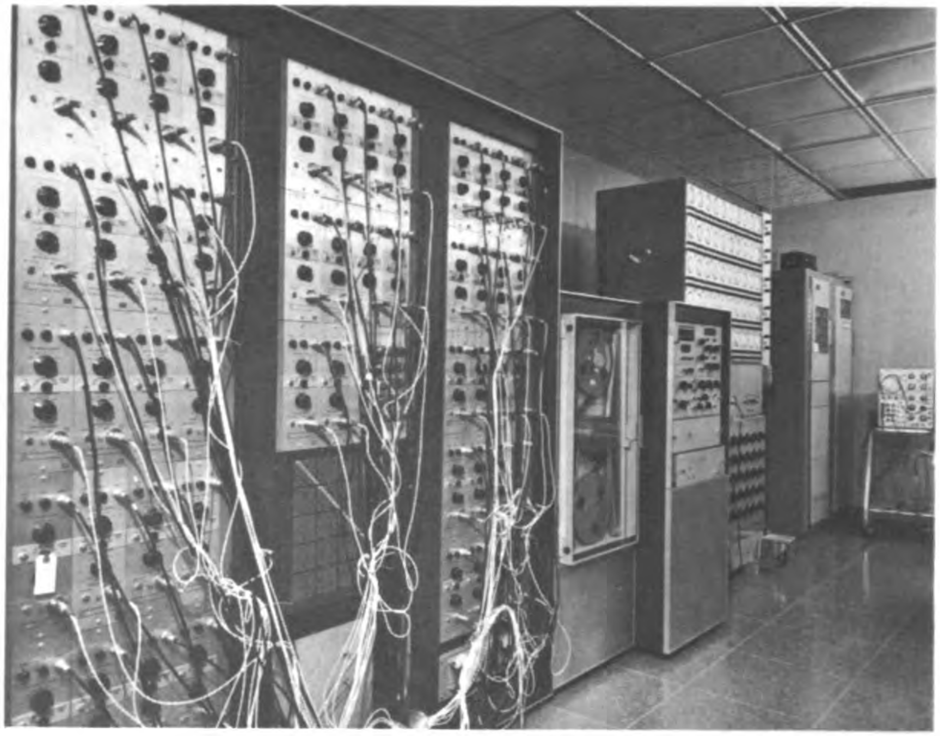

Figure 4 – Recording equipment. At left, 50 high-gain preamplifiers; center, telemetry system for measuring potentials; in background, 50 cathode-ray oscilloscopes.

Figure 5 – Sound-generation equipment.

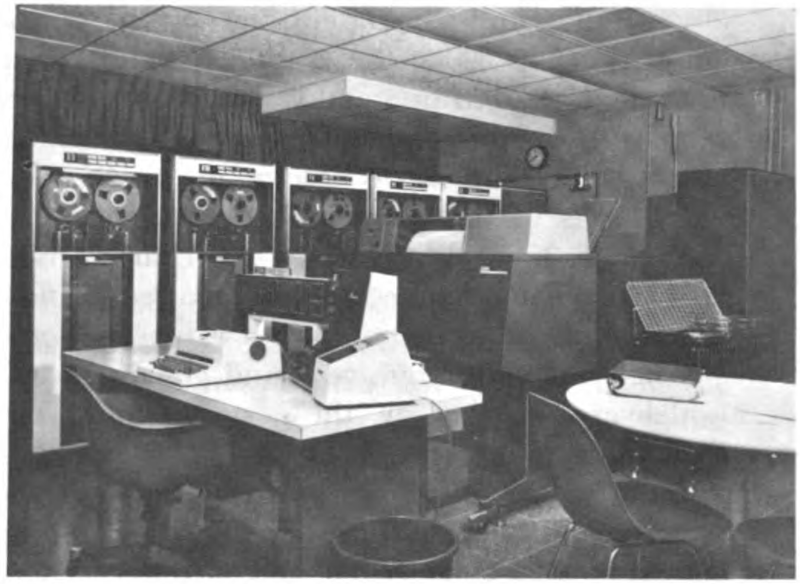

Figure 6 - View of the IBM 1410 data-processing system, showing the five tape drives. The magnetic tape drive, at left, can be connected to the telemetry system of Figure 4 to transfer data to the data-processing system.

Figure 7 – Another view of the IBM 1410 data-processing system, showing its relation to the 50 pre-amplifiers and an off-line magnetic-tape digital plotting system, at left, used for the preparation of curves. The black-out curtains provide a semi-dark area in the background for photographing signals on the cathode-ray tubes.

maximum potential on the mantle are shown relative to the frequency of sound which causes them. However, these response potential patterns merely reveal how the message involved in the spectrum is coded and received by the cortical mantle; they do not provide a solution as to the fate of the message. The electrical activity of the auditory cortex is dynamic in the sense that the voltages are continually changing in the absence of any sound stimulation. An understanding of the nature of this perpetual activity and how other parts of the brain act upon it is emerging. With the use of multivariate statistical and time-series analysis, a new picture of the auditory cortex is being created. The spontaneous electrical activity that is omnipresent even in the absence of sound stimulation can be regarded as a state of statistical equilibrium, in which the random potential averages and their variations, as measured by standard deviations, as well as any correlations, remain constant in the entire area over considerable periods of time. Undoubtedly, the above description is not entirely accurate, because other parts of the brain influence the activity. That the properties found for the auditory cortex are characteristic of it, alone, became apparent when other regions not involved in auditory function revealed different statistics, not only with respect to location but also to time.

When a short, impulsive sound generated by an elementary signal is delivered to the ear, the nerve impulses arriving at the auditory cortex cause marked changes in the statistical equilibrium of the electrical activity, forming what we may call a new statistical state of the activity. The average values, the standard deviations, and the correlations all change, not only at different locations on the surface and within the cortical mantle but also at different epochs of time. The determination of the basic effect of these complex changes on the information content of messages received from the ear is one of the principal objectives of this investigation. In the pursuit of this objective, other parts of the brain are coagulated, removed, and subjected to various types of injury, and drugs having known properties are applied to the cortex and to the deeper portions of the brain, to find out what relation such modifications have to the complicated new statistical state of the electrical activity on the arrival of messages from the ear. The number of different altered states for auditory messages that can be recognized with the present recording system and electrodes is huge—approximately one and a half billion. By using speech as the message, combinations of spectral patterns accounting for 90 percent of the information content of speech can be displayed in the area.

Studies now underway will determine the fate of the messages carried by neurons between the auditory area and other parts of the brain. One such definitely known pathway involves a region which, upon stimulation in man, is known to cause auditory hallucinations and to result in "inner" sounds recognizable by the patient. This pathway will be studied not only in the animal but also in human subjects who require surgery of the brain for other reasons. Preservation of the messages in these other parts of the brain represents basic short-term memories from which information can be extracted during various functions of the brain. It has become apparent that we do not extract information from the eye or ear but must extract it somewhere within the nervous system. When this site is disclosed, perhaps we shall know something more about the structural basis of the mind.

—Continued on page 15

The Control of Liquid Spreading

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The control of liquid spreading on solid surfaces is critically important in many technical applications. For example, the lubricating oils used in watches and precision instruments must not migrate from the bearings to hairsprings or optical surfaces. In certain other instruments, such as gyro bearings, spreading must be controlled because any excess oil would distrub accuracy and stability. Also, since it is impossible to relubricate moving parts in an orbiting satellite, an oil that does not flow onto open surfaces is essential to prevent its loss by evaporation. Until about 30 years ago, the only lubricants which were nonspreading came from such sources as neat's-foot oil or porpoise jaws; but quality control was inadequate. Other good nonspreading oils are now available, but they all solidify at low temperatures.

Several years ago the Naval Research Laboratory undertook to devise a nonspreading clock and instrument oil for use in aircraft at temperatures as low as −65°F. Wetting and spreading depend strictly on surface phenomena, but the behavior of liquids on solid surfaces is much more complex than early surface chemists realized. It was necessary, therefore, to spend several years studying pure liquids and superclean solids in order to clear up the apparent contradictions in spreading theory before the original problem of a low-temperature, nonspreading oil could be attacked.

An understanding of a few surface-chemical terms is necessary in the discussion of spreading. One term which hardly needs definition is "surface tension," the property of a liquid which causes it to expose the least possible surface to air or vacuum. Because of surface tension, raindrops and soap bubbles are round. Surface tension is really a measure of the ability of the molecules to attract each other; a molecule in the center of a liquid drop is attracted equally from all sides, and work must be done to get it into the surface against the unbalanced attraction from below. The bulk liquid is always trying to pull molecules back out of the surface into the interior, so the surface shrinks to the smallest area that can enclose the liquid. The work required to make one square centimeter of fresh surface is called the surface free energy.

The molecules in a solid surface also are in an unbalanced attractive field and hence possess a surface free energy, just as the liquid does. The surface energy of a solid, however, is very hard to measure accurately, since a new surface cannot be created without a large amount of totally extraneous work being done to deform the solid. What is needed

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is a surface property of solids which can be measured easily and is related closely to the surface energy of the solid.

It is well known that all molecules at small distances attract each other, not just molecules of one kind. The attractive force between molecules of unlike kinds is usually intermediate between the interactions of like molecules of the two kinds. A liquid will spread if its molecules are attracted more strongly to the solid than to each other. If, on the other hand, the molecules of the liquid interact with each other more strongly than with the solid surface, molecules at the liquid surface are pulled back into the liquid, and the margin of the drop recedes. If selected liquids are entered on a chart in the order of their surface tensions, and if we then note their spreading behavior on various solids, it is found that each solid can be entered on the same chart in a position such that all liquids below it spread and all liquids above it are nonspreading on that solid. Such a chart is shown in Figure 1. The dividing line is different for each solid, so the surface can be characterized quantitatively by noting the highest surface tension that a liquid can have and still spread on that surface. This quantity is called the critical surface tension for spreading on the surface. The critical surface tension is not the free surface energy of the solid, but must parallel it closely, and it can be measured.

One can read from this figure that petroleum oils will spread on nylon but not on Teflon, that silicones will spread on polyethylene, and that all the liquids will spread on clean metals or metal oxides. According to the figure, all oils will spread on metal or jewel surfaces because the critical surface tensions of metals and metal oxides are so high.

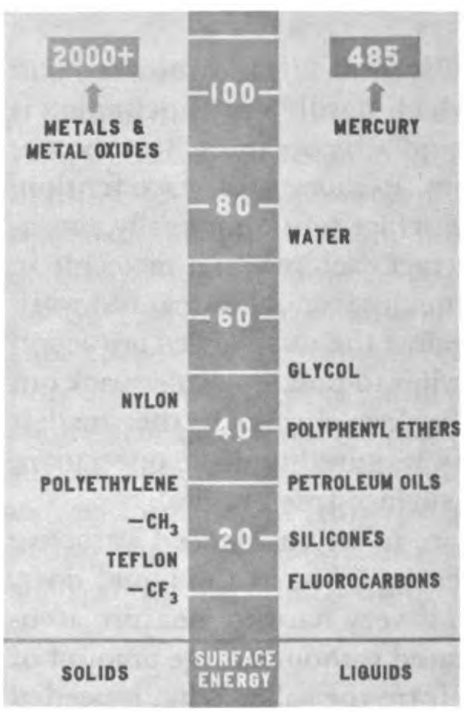


Figure 1 – Critical surface tensions (dynes/cm) for spreading of liquids on solids. All liquids shown at a lower position than that of a given solid will spread on that solid.

Very early in their work, the NRL chemists showed that a layer of surface-active organic molecules as little as one molecule thick, if firmly adsorbed to the metal oxide surface, makes the surface oleophobic—that is, oils become as nonspreading on it as on a Teflon surface. The polar end of the surface-active molecule attaches to the metal (Figure 2), and the low-energy tails, which end in CH_3 or CF_3 groups, are turned upward. This behavior results because the attractive forces between atoms which are responsible for surface tension extend only a few atomic diameters. Thus, if a monolayer of closely packed stearic acid molecules is adsorbed on a high-energy surface, the molecules of liquid are no longer attracted by the metal oxide, but behave as they would if they were on the CH_3 surface of a paraffin crystal. It was the presence of such invisible contaminating monolayers on solids which created the earlier confusion about the laws of spreading. Once clean surfaces and pure liquids were obtained, simple rules held.

With these facts firmly established, it became feasible to attempt prevention or control of spreading of practical oils on practical equipment. Let us consider an analogy between the control of "stray" molecules and the control of stray sheep. If a sheepherder wants to keep his flock together, he may employ three distinct techniques. He may build a corral around the flock; he may put a few goats into it, so that the sheep will crowd about the goats; or he may turn loose a few shepherd dogs, which will chase the strays temporarily back into the main group.

These techniques are analogous to methods used to prevent the movement of oil away from its assigned station in lubricated equipment. A corral can be formed of any low-energy monolayer or of any thicker film, such as Teflon or one of the other fluorocarbon film-formers. In the past, watch and clockmakers have coated the surface around

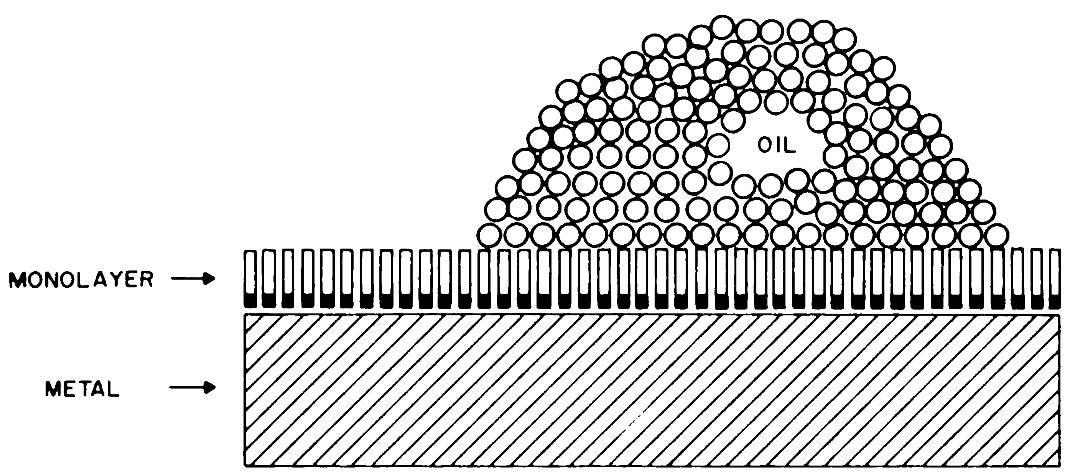


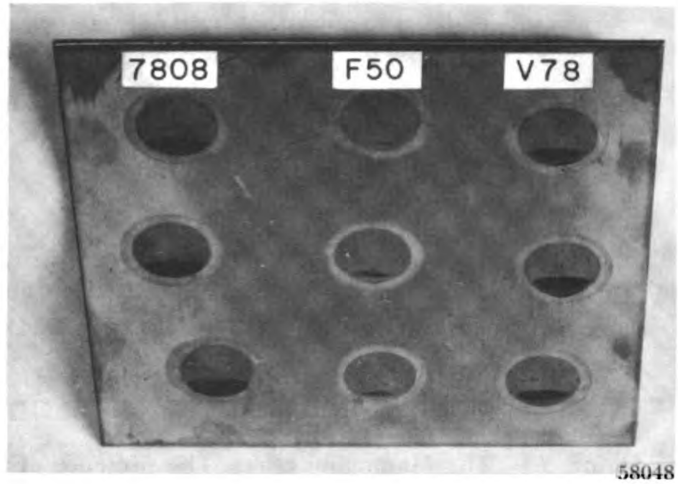
Figure 2 — Illustration of how a polar-nonpolar monolayer deposited on a metal surface prevents an oil drop from spreading

bearings with a monolayer of stearic acid to retain the oil, although stearic acid corrodes brass, and the coating is not permanent. Our research revealed that the inclusion of a few parts per million of a silicone in the solvent used to clean the mechanism will leave a low-energy film of silicone that is as effective as stearic acid and much more durable. Even more attractive for many uses is the application of a narrow band of a fluorocarbon resin about the lubricated spot. Not even silicone liquids can creep across this fence. Figure 3 is a dramatic illustration of the effectiveness of this technique. These oil drops have been contained against the force of gravity for almost one year but still show no signs of "jumping the fence."

This corral technique has already been adopted by one large producer of mechanical calculators for certain critical bearings. Its usefulness is now being studied in miniature gyro bearings, where two or three milligrams of oil must provide near-perfect lubrication for two years of continuous operation. It is too soon to say what the outcome will be, but the preliminary results are promising.

The "goat" method of keeping the sheep together is not as exact an analogy as the corral method is. What one really does is stir in a little bit of instant fence. To accomplish this, suitable surface-active molecules are dissolved in the oil and are preferentially and strongly adsorbed at the oil-metal interface, making the surface beneath the drop oleophobic. Consequently, the oil draws back into a smaller drop, leaving a barrier, or fence, of low-energy surface along the edge. One can demonstrate the presence of this fence by trying to get a spreading drop to merge with this drop. The spreading oil is stopped before it can touch the rim of the nonspreading drop. We were able to show that all of the empirically developed nonspreading watch oils work because they contain small proportions of surface-active molecules, or instant fence. It was now thought possible to design a nonspreading oil that would be usable at −65°F. Although it was possible, in theory, to make almost any lubricating oil nonspreading, it turned out that good nonspreading instrument lubricants must have an unusually high surface tension. This is because they must be nonspreading on oil-contaminated surfaces as well as on clean metal. The usual oily contaminants give the solid surface a critical surface tension of about 30 dynes per centimeter, so we need an oil with a surface tension of about 32 or 33 dynes if it is to be nonspreading on a soiled surface. Ordinary low-temperature oils do not have a surface tension this high. Aromatic structures are usually required to achieve such a high surface tension in a hydrocarbon or ester oil, but the aromatic oils have high viscosity, especially at low temperatures. The search for a good nonspreading oil at −65°F has therefore been difficult. Recently we have succeeded in synthesizing a hybrid ester (benzyl-2-ethylhexyl azelate) that promises to meet all the requirements.

Figure 3 – Oil drops which have been contained within fluorocarbon barriers on a vertical metal plate for nearly one year. Number 7808 is a synthetic diester used as an aircraft turbine lubricant, F50 is a chlorinated silicone, and V78 is a petroleum oil for gyro bearings.



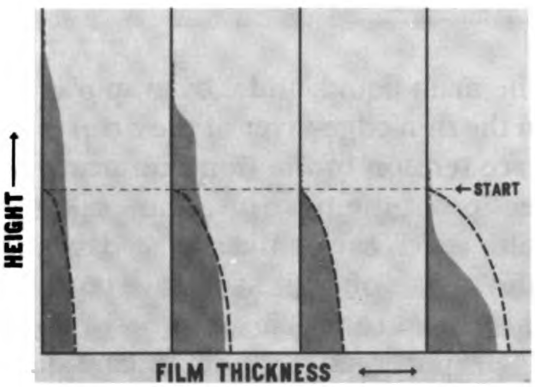


Figure 4 – Spreading of four different oils on a vertical surface. The film thickness has been exaggerated 200 times in the interest of clarity. The dotted curves indicate the profile the oils would have assumed had they simply drained under gravity.

During our study of nonspreading oils it became apparent that very little was known about the spreading oils. Different oil samples show radically different behaviors. Figure 4 illustrates what happened when we placed four drops of oil (a silicone, an aromatic hydrocarbon, and two alkyl aromatic hydrocarbons) on a vertical metal surface. Two of the oils advanced up the vertical surface against gravity; one made a zero contact angle on the metal surface but did not advance; another with a zero contact angle flowed downward even faster than it should have under gravity. If the oils had simply drained from the surface under gravity, their profiles would have corresponded to the dotted lines, the exact shape depending on the viscosity of the oil. The dotted lines intersect the solid surface at the original boundary of the film.

The whole business was disconcerting, but the confusion eventually was untangled when we discovered that a really pure low-volatile oil spreads extremely slowly. Rapid spreading, or negative spreading, could be traced directly to the presence of slightly more volatile materials of different surface tension. If the minor volatile component has a

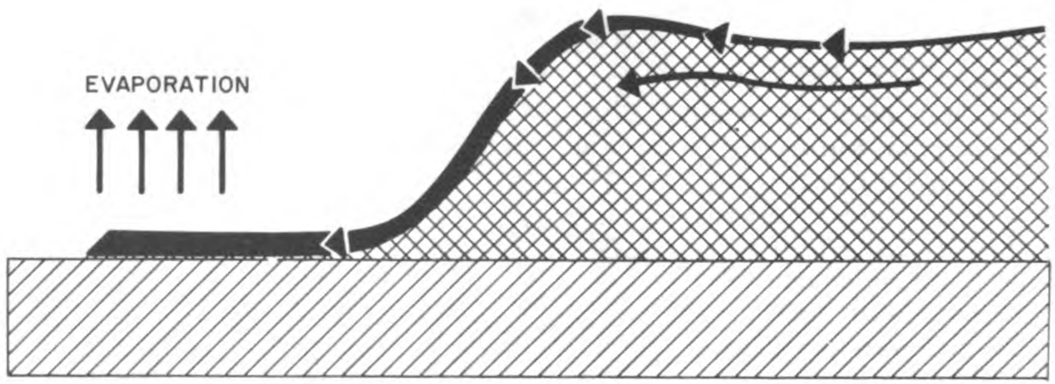


Figure 5 – The Marangoni effect. The presence of a volatile component in oil creates a surface tension gradient in the oil film which causes the surface layer of molecules to flow outward toward the region of highest surface tension. In this figure the thickness of the liquid surface outline has been made proportional to the surface tension at that point.

surface tension lower than that of the main liquid, and if by evaporation it is removed more completely from the thin edge-layer of the drop than from the thicker portions, the surface tension of the thin film near the edge will rise toward the surface tension of the pure oil. This creates a surface tension gradient in the oil film which causes the surface layer of molecules to flow outward toward the region of highest surface tension. The process is shown schematically in Figure 5. The thickness of the liquid surface outline has been made proportional to the surface tension. It is greatest at the edge and least over the bulk liquid. The movement of this film toward the spreading edge drags along some of the oil beneath it because of the viscous coupling and so causes the bulk of the film to follow the advancing edge. The principle is not new. Thompson used it 100 years ago to explain the "tears" or droplets that creep up the sides of a liquor glass. Evaporation of alcohol from the initial thin film raises the surface tension toward that of pure water; the gradient pulls up a film entraining more liquor; and the process continues until the alcohol-impoverished ridge becomes unstable and leaks back into the main liquid. No one had ever dreamed that this phenomenon, called the Marangoni effect, would be detectable in liquids with as low a volatility as lubricating oils.

Now that we know the Marangoni effect is applicable to oils, we can increase or decrease their spreading rate almost at will, even to the point of making such notorious travelers as the silicones slow-spreading. This is where the sheep dog analogy applies. To reduce the rate of spreading, one puts in a volatile component of higher surface tension, so that edge depletion will lower the surface tension at that location, and surface flow will occur from the edge to the center. Thus the spreading molecules at the edge are "herded" back into the bulk liquid. This trick for the control of spreading (like the efforts of a sheep dog) is inherently temporary; eventually all of the volatile component will escape, but there are many situations in which temporary control is enough.

In brief, then, a sustained basic study of wetting and spreading phenomena has provided us with not one but three alternative routes to the prevention of spreading of oils. It has, in addition, shown us how to accelerate the spreading rate of a wide variety of liquids by a large factor. Even more important, this work has paid off unexpectedly in larger applications. For example, it has provided a key to understanding the formation of adhesive bonds. This new approach is now being applied here and at other laboratories to the improvement of fiberglass-reinforced rocket cases, the adhesive assembly of air frame components, and the reduction of ice adhesion on naval equipment.

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*The Brain as a Self-Organizing System—**Continued from Page 8*

How does the brain organize itself or change the state of its activity? Apparently it does so by acquiring a set of nerve connections that enable it to deal differently with different environments. The physical basis of the encoding and preservation of messages must be demonstrated as described above before changes or alterations in such states can be studied. This concept implies that the nervous system as a whole is never the same from moment to moment because of infinitesimal or gross changes in its anatomy and activity caused by messages it receives from the external environment and from within. This situation exists because the brain consists of living tissue and because the connections between cells can undergo changes without direct modification by an external source, so necessary to effect changes in electronic circuits.

By applying special techniques it is possible to expose the entire hemisphere of an animal, place 50 electrodes on it, and study the activity of the brain while the animal is fully conscious. Provisions have been made for training the animal to receive various types of acoustical messages before and after modification of the cortical mantle, by means of drugs or other techniques, to see how changes of state of the mantle are affected by the learning process.

It is hoped that the study of these problems will enable men to communicate with each other with greater certainty in the ocean depths and in other environments in which communication is now difficult to effect.

Log of the Aquanauts

Lester E. Anderson, Gunners Mate First Class, USN

Robert A. Barth, Chief Quartermaster, USN

Sanders W. Manning, Chief Hospital Corpsman, USN

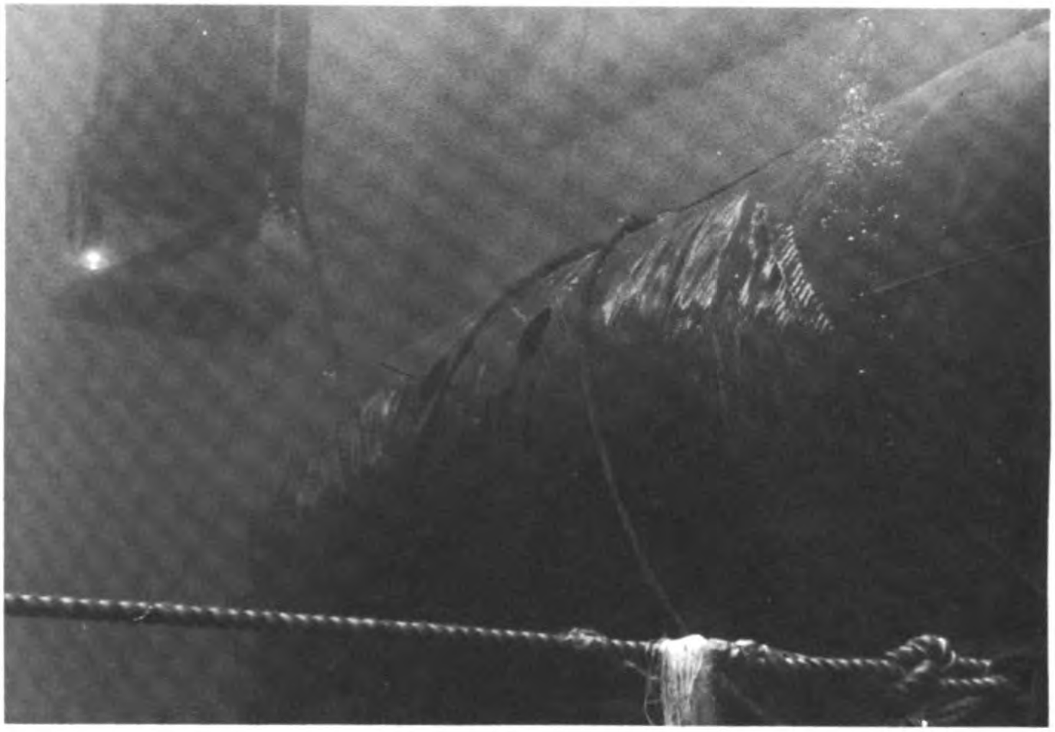
LCDR Robert E. Thompson, Medical Corps, USN

THE FOUR AQUANAUTS

In NAVAL RESEARCH REVIEWS, *July 1964, appeared accounts of plans for Project SEALAB I and of some of the physiological implications of deep diving that does not involve the environmental separation provided by submarines, diving bells, and pressurized suits. As pointed out in these accounts, SEALAB I was undertaken to determine man's ability to live and work at an ocean depth of 192 feet for extended periods of time. The men were to be tested, physiologically and psychologically, while working both inside and outside of a 40-foot-long chamber maintained at a pressure equal to that of the surrounding water (86 pounds per square inch) and while breathing from an atmosphere consisting mostly of helium.*

Project SEALAB I is sponsored by the Office of Naval Research in collaboration with the Bureau of Ships and the Naval Medical Research Laboratory, New London, Connecticut. The Sealab capsule was designed and constructed at the Navy Mine Defense Laboratory, Panama City, Florida.

When the July accounts were written, the experiment was scheduled to begin early in July and last for three weeks. The plans called also for Astronaut LCDR M. Scott Carpenter, USN, an experienced diver, to join the 4-man crew midway in the experiment to observe similarities between survival undersea and survival in space. Unfortunately, a two-week delay occurred in placing Sealab on the ocean bottom, principally because of inclement weather at the site of the experiment—the Argus Island research tower located 30 miles southwest of Bermuda—and technical difficulties experienced in lowering the capsule. Therefore, the sojourn was shortened from three weeks to about 11 days. Unfortunately, also, LCDR Carpenter broke his arm a short time before the experiment was to begin and was unable to join the other aquanauts in the Sealab capsule.



Sealab I at a depth of 192 feet. The submersible decompression chamber and the base of the Argus Island tower are in background.

Divers make final adjustments to the umbilical supply line prior to the lowering of Sealab on July 18.

At 5:30 P.M., EDT, on July 20, the four Navy divers descended to the capsule in a small submersible decompression chamber. The trip took only about two minutes, after which the men left their "elevator" and entered the Sealab through an open tube at the bottom of that chamber.

What transpired in and around Sealab during the next 11 days is recorded in the following excerpts from the day-by-day "log" which was kept topside.

744-410 O-64-3

First Day

The aquanauts awakened at 7:30 A.M. After eating their breakfast of corned beef, crackers, and hot coffee, they called the surface support vessel, a barge labeled "YFNB-12," by telephone. Because the large helium content of the Sealab atmosphere distorted their voices, the message was routed through an "unscrambler." "We are doing fine," the aquanauts reported. "It is nice and comfortable down here. We could stay forever."

The divers checked the atmospheric controls to make certain that the breathing mixture in the capsule was maintained as required—80 percent helium, 16 percent nitrogen, and 4 percent oxygen. They also tested the communications systems, which included telephones, electrowriter, telegraph, and television.

Then they commenced their first trip into the undersea world outside of the Sealab. Wearing specially modified scuba gear, they swam about the immediate area, observing the physical features and marine life of the ocean bottom and making brief sorties around the base of the Argus Island tower. Visibility was good: when looking vertically, the men could see clearly the hull of the support vessel on the ocean surface, 192 feet above them. Horizontally, their view extended about 60 or 70 feet.

Before the men retired that evening, they were given extensive medical examinations. Their conditon was good.

Second Day

The men awoke in good spirits, completed the morning's physiological and psychological examinations, then continued making general observations in the vicinity of the Sealab. By this time they were feeling quite at home in their new environment, even in the presence of the many undersea creatures that shared it with them. Two large groupers were exceptionally friendly. They were easily distinguishable from others of their species, one of them having skin that looked like gray velvet (he was named "Wally") and the other having a black fin and tail (he was called "George").

In the afternoon, the team began a work program, the first objective of which was to imbed ultrasonic beacons in the ocean floor. The beacons were to be used by the swimmers as direction finders.

Late in the day the aquanauts were startled when, upon looking toward the ocean surface, they saw the entire fish community dive frantically toward the Sealab. The reason for the "stampede" was soon evident: two 10-foot sharks were in pursuit. For about five minutes the sharks thoroughly upset the tranquility of the area.

Third Day

The day's assignments began with the drawing of blood samples and the recording of various physiological data. Later in the morning a trolley car, similar to a dumb waiter, was put in operation between the surface and the undersea habitation to enable equipment and materials to be transferred rapidly between the two levels.

After lunch, the aquanauts took a one-hour nap. Aboard the support vessel on the ocean surface, CAPT George F. Bond, medical officer in charge and originator of Project SEALAB, observed the aquanauts' condition closely. He noted on this occasion, as he had on others during the past two days, that the divers were drowsier, particularly after eating, than they would have been at sea level. They also displayed, unknowingly, some lack of willingness to do physical work. CAPT Bond commented that "they move slower than normal and do not like to be rushed. It seems as if they are making every effort to conserve their energy."

After their siesta, the aquanauts continued working "outdoors." They returned to their "home" at about 4:00 P.M., recorded their body temperatures, and took hot showers. They had an early evening meal, rested for an hour, then underwent more psychological and physiological testing.

They retired at about 9:00 P.M.

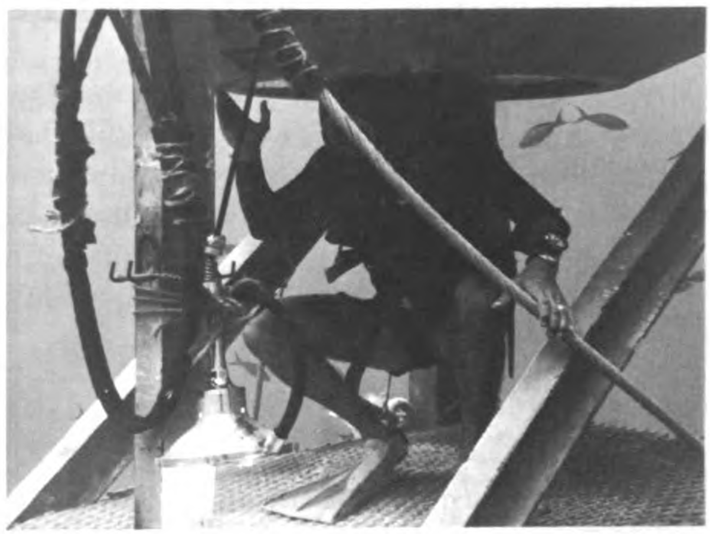
Fourth Day

On their morning and afternoon swims, the aquanauts installed a current meter on the ocean floor, accomplishing the task in about 30 minutes, and assisted photographer-divers sent down from the surface in making a pictorial record of the Sealab operation.

In the evening, they took motion pictures of their activities in Sealab. Before retiring at 11:00 P.M., they engaged in long technical discussions with project officers on the surface support vessel.

The temperature within Sealab was now being maintained at 86°F. This relatively high heat level was required because helium, the main ingredient of the breathing mixture supplied to the aquanauts, transfers heat at a rate approximately seven times that of air. Laboratory tests made before the Sealab project was undertaken had indicated that the temperature might have to be raised to 91°F. for human comfort. Thus six electric heaters had been installed in the small compartment. However, at no time had it been necessary to operate the heaters at full capacity.

A diver enters the "back porch" of the underwater laboratory.



An aquanaut leaves the submersible decompression chamber enroute to Sealab.

Aquanaut Thompson, at left, and a diver from the surface gather marine biological samples.

Aquanauts Manning, Anderson, and Thompson enjoy a meal in the undersea habitat.

A view of the interior of Sealab from the entrance hatch. The berthing area is in rear. Aquanauts Thompson and Manning occupy main compartment.

Fifth Day

All conditions were normal when the aquanauts awoke at 9:00 A.M. During the night the standing watch made good observations of marine life.

After the physiological and psychological examinations were completed, Aquanaut Barth went out to feed the fish. By now he had so completely won the confidence of the groupers that they not only ate out of his hand, but on a few occasions tried to make off with his thumb, mistaking it for part of the meal. Barth carried the undersea television camera along so that personnel on the YFNB-12 could watch the show on their television monitor. Kinescope recordings were made of the entire process, which lasted 75 minutes.

Later in the day, the aquanauts implanted devices on the ocean floor to measure underwater visibility.

In the evening, they rigged large spotlights around and above the Sealab to illuminate their habitat for night-time photography.

The physical condition of the men remained good.

Sixth Day

When the aquanauts awoke this morning, they had been living on the ocean bottom for 144 hours.

During an early morning conversation with the surface vessel, LT Thompson told of trying to catch a trumpet fish. Apparently, he said, the trumpet fish will allow you to believe that you have captured him. Then, just as your grip tightens, he scoots away. Thompson told also of lowering a thermometer into the water to record the temperature outside of Sealab. As he did so, the groupers "Wally" and "George," thinking food was being served, made several strikes at it.

At 10:30 A.M., the Sealab became an underwater chapel. LT Thompson thanked God for watching over them and giving them the friendship of the undersea creatures, and he asked that "the Lord take care of those who take care of us." The service was concluded with the singing of "Onward Christian Soldiers," accompanied by LT Thompson on the harmonica.

Even though the sea was now heavier than it had been at any time since the experiment began, the day was both bright and peaceful in the underwater realm.

Seventh Day

Today, Aquanaut Manning almost lost his life. The accident occurred during the visit to Sealab of Star I, an experimental one-man submarine built by the Electric Boat Division of General Dynamics Corporation. The dive was made to test the ability of the aquanauts to observe the craft's operation and to assist it in landing on the ocean bottom.

Manning's job was to photograph the event. He had taken about 15 feet of film on a 50-foot roll, when he suddenly began feeling light headed. Realizing that his scuba gear was not functioning properly (apparently his gas supply had been cut off, causing him to breath his own exhalation), he commenced swimming back to the capsule. He had reached the entrance tube and had just begun to climb up it when he lost consciousness.

At that moment, Anderson, who was standing watch inside the capsule, heard an unusual sound. Apparently Manning's scuba gear struck the tube wall as he fell unconscious. Upon climbing down the tube to investigate, Anderson saw Manning's limp body drifting away. Quickly, he pulled him into the Sealab, removed his mask, and restored his normal breathing. Within five minutes he had revived completely, and after careful examination was found to be fit to continue the experiment. Fortunately, the only enduring physical effect of the experience was a reddening of his eyes.

At 5:35 P.M., the Navy's four-man aquanaut team marked its first week of residence in the Sealab—the longest period of time man had remained submerged, at this depth, under similar conditions. The men remained cheerful and content in their surroundings.

Eighth Day

This morning the aquanauts completed a battery of medical tests to determine their condition after living for one week under the intense pressure of the 192-foot-depth level. To all indications, their health and spirits were excellent.

They now began conducting a series of shark experiments. The purpose of the investigation, which was conducted in cooperation with the University of Miami, was to determine the effects of sounds and colored lights on shark behavior. The aquanauts made extensive journeys outside of Sealab to install acoustic devices and electric lights for the experiment. The underwater television camera was positioned so that any shark coming into the area could be observed in complete safety. The men were to watch the action through the portholes in Sealab and from the heavily screened-in area under the habitat called the "back porch."

Late in the afternoon a shortwave radio was installed in the Sealab, and a marine-band linkage was established through Washington, D.C., enabling the aquanauts to converse with people all over the United States. The first contact was made with a ham radio operator in Savannah, Georgia. The gentleman in Savannah found it difficult to believe that the transmission he was receiving came from a station 192 feet beneath the surface of the ocean.

The shark-attraction system was turned on in the evening for several hours, but no sharks appeared.

Ninth Day

Late this morning, the aquanauts conversed by radio with RADM John K. Leydon, Chief of Naval Research, in Washington, D.C. RADM Leydon congratulated the aquanauts for the progress they had made thus far, and he wished them well during the remainder of their underwater sojourn.

Because the forecast for the next 24 hours called for bad weather at the Argus Island site, LCDR Roy E. Lanphear of ONR, Sealab's operational commander, decided to bring the aquanauts back to the surface. At 6:00 P.M., therefore, the topside cranes began hoisting the capsule toward the surface. The slow process of decompression, which could take as long as 96 hours, was carried out under the watchful eyes of CAPT Bond. All systems in the Sealab continued to function perfectly.

Tenth Day

Decompression continued on schedule under the close scrutiny of Sealab officers aboard the YFNB-12. The officers monitored the upward journey by means of television cameras located both inside and outside of the capsule.

During the day, his Excellency, the Governor of Bermuda, Lord Martonmere, visited Argus Island to observe the operations underway in support of the project. The Governor was accompanied by the American Consul General, Mr. George W. Renchard; the Commanding Officer of the U.S. Naval Station, Bermuda, CAPT Roy S. Belcher, USN; and the Commanding Officer of the U.S. Air Force Base, Bermuda, COL Oren Poage.

By midnight, Sealab had been raised to the 100-foot level.

Eleventh Day

At 7:32 A.M., the aquanauts left the Sealab at the 81-foot level and entered a submersible decompression chamber. At 2:40 P.M., the chamber was raised onto the cargo deck of the Argus Island tower. The aquanauts were in excellent condition, and their spirits remained high.

Early the next morning, the hatch of the submersible decompression chamber was opened, and the four Navy aquanauts stepped into the sunshine of their natural environment. After brief discussions, they were flown to the U.S. Air Force Base Hospital at Bermuda for a medical debriefing. All tests indicated that the men were in good health.

–Continued on page 36.

On the Naval Research Reserve

Roster of Research Reserve Companies

There are 118 Research Reserve companies located throughout the United States. These companies are listed below by Naval Districts. For each company the time of meeting, meeting place, and the commanding officer are given.

FIRST NAVAL DISTRICT
NRRC 1-1
1930, 1st & 3rd Mondays
Room 4-270, M.I.T.
77 Massachusetts Avenue
Cambridge, Massachusetts
CDR Aaron S. Soltes, USNR

NRRC 1-2
1930, 1st & 3rd Wednesdays
U.S. Naval & Marine Corps Reserve Training Center, Fields Point,
Providence, Rhode Island
LCDR Pierre F. Smith, USNR

NRRC 1-3
1930, 1st & 3rd Tuesdays
No meetings during July & August
Room 10-11, Dickinson Hall
University of Massachusetts
Amherst, Massachusetts
LCDR Joseph S. Marcus, USNR

NRRC 1-5
1930, 1st & 3rd Mondays
No meetings during July & August
Stratton Hall
Worcester Polytechnic Institute
Worcester, Massachusetts
LT John P. Gagliardo, USNR

NRRC 1-7
2000, 1st & 3rd Tuesdays
Wentworth Hall, Dartmouth College
Hanover, New Hampshire
CAPT George Z. Dimitroff, USNR

NRRC 1-8
1930, 1st, 2nd, & 3rd Thursday
Woods Hole Oceanographic Institution
Woods Hole, Massachusetts
CDR Robert J. Tilden, USNR

THIRD NAVAL DISTRICT
NRRC 3-1
1830, 1st & 3rd Thursdays
Room 1609, 16th Floor
745 Fifth Avenue
New York, New York
LCDR John J. O'Connor, USNR

NRRC 3-2
1930, 2nd & 4th Mondays
Engineering Building
U.S. Naval Training Device Center
Port Washington
Long Island, New York
CDR Andrew J. Hangarter, USNR

NRRC 3-3
2000, 3rd & 4th Mondays
Room G14A, School of Medicine
University of Buffalo
Buffalo, New York
LCDR Leonard M. Seale, USNR

NRRC 3-4
2000, 1st & 3rd Tuesdays
Room 106, Bausch & Lomb Hall
University of Rochester
Rochester, New York
CDR Thomas S. Ely, USNR

NRRC 3-5
2000, alternate Thursdays
Hartford Electric Building
176 Cumberland Avenue
Wethersfield, Connecticut
CDR Otis R. Gilliam, USNR

NRRC 3-6
2000, 1st & 3rd Mondays
General Electric Company
Electronics Park
Syracuse, New York
CDR Henry B. Latimer, USNR

NRRC 3-7
2000, 2nd & 4th Thursdays
U.S. Naval Reserve Training Center
Scotia, New York
LT Lawrence C. Pedersen, USNR

NRRC 3-8
1900, 2nd & 4th Tuesdays
16th Floor, 285 Madison Avenue
(Young & Rubicam, Inc., 40th St.)
New York, New York
CDR John F. Place, USNR

NRRC 3-9
1930, 2nd & 3rd Wednesdays
Brookhaven National Laboratory
Upton, Long Island, New York
LCDR Silvio J. Tassinari, USNR

NRRC 3-12
2000, 2nd & 4th Tuesdays
Building 148, USN Medical Research Laboratory
U.S. Naval Submarine Base
Groton, New London, Connecticut
LCDR Russell L. Sergeant, USNR

NRRC 3-13
2000, 2nd & 4th Thursdays
Grace-New Haven Community Hospital
789 Howard Avenue
New Haven 4, Connecticut
LCDR Gilbert B. Solitare, USNR

NRRC 3-14
1800, 1st & 3rd Tuesdays
U.S. Naval Reserve Training Center
75 Oakley Street
Poughkeepsie, New York
CDR Norman J. Smith, USNR

NRRC 3-15
1845, 2nd & 4th Tuesdays
Room 1511, 90 Church Street
New York, New York
CDR John D. Strachan, USNR

FOURTH NAVAL DISTRICT
NRRC 4-1
2000, alternate Wednesdays
10 Guyot Hall
Princeton University
Princeton, New Jersey
LCDR Joseph B. Kearns, Jr., USNR

NRRC 4-2
1930, alternate Thursdays
No meetings during July & August
Franklin Institute
20th Street and Parkway
Philadelphia, Pennsylvania
LCDR Robert H. Haig, USNR

NRRC 4-3
2000, alternate Thursdays
U.S. Naval & Marine Corps Reserve Training Center
4902 Frobes Avenue
Pittsburgh 13, Pennsylvania
LCDR James J. Walsh, USNR

NRRC 4-4
1900, alternate Mondays
303 Wagner Hall
Military Science Building
Pennsylvania State University
State College, Pennsylvania
LCDR James C. Dean, USNR

NRRC 4-5
2000, alternate Mondays
U.S. Naval & Marine Corps Reserve Training Center
3920 Kirkwood Highway
Wilmington, Delaware
CDR Clayton E. Ranck, USNR

NRRC 4-7
1930, alternate Thursdays
No meetings during August
Research Foundation
Ohio State University
1314 Kinnear Road
Columbus, Ohio
CDR Clarence H. Myton, USNR

NRRC 4-8
1800, alternate Mondays
U.S. Naval & Marine Corps Reserve Training Center
1089 East 9th Street
Cleveland 14, Ohio
LCDR Edward H. Bollinger, USNR

NRRC 4-9
1930, 2nd & 4th Mondays
U.S. Armed Forces Training Center
410 Gettsburg Avenue
Dayton 17, Ohio
LT Robert A. Hermann, USNR

NRRC 4-11
1900, 2nd & 4th Tuesdays
Room 202, Albers Hall
Xavier University
Cincinnati, Ohio
CAPT Edward F. White, USNR

NRRC 4-12
1930, alternate Tuesdays
No meetings during July & August
Technical Training Building
U.S. Naval Air Station
Willow Grove, Pennsylvania
CDR Carlton J. Nelson, USNR

NRRC 4-13
2000, 1st & 3rd Mondays
Building 11, U.S. Naval Base
Philadelphia, Pennsylvania
CAPT John J. Horan, USNR

FIFTH NAVAL DISTRICT

NRRC 5-1
1930, 1st & 3rd Tuesdays
U.S. Naval & Marine Corps Reserve Training Center
Warwick Boulevard & 75th Street
Newport News, Virginia
LCDR Perry W. Hanson, USNR

NRRC 5-2
2000, Mondays
Room 310, Hutcheson Hall
Virginia Polytechnic Institute
Blacksburg, Virginia
LCDR David P. Barnett, USNR

NRRC 5-3
1930, 1st & 3rd Tuesdays
Building 426, Fort Detrick
Frederick, Maryland
CDR Henry T. Eigelsbach, USNR

NRRC 5-4
2000, 1st & 3rd Thursdays
Board of Education Building
3 East 25th Street
Baltimore 7, Maryland
LT Frank I. Albin, USNR

NRRC 5-5
1700, 2nd & 4th Mondays
Room 215
Medical Education Building
Medical College of Virginia
Richmond, Virginia
LCDR Raymond H. Blackmore USNR

NRRC 5-8
2000, 1st & 3rd Thursdays
National Academy of Sciences
2102 Constitution Avenue, N.W.
Washington, D.C.
CAPT Robert K. Buchanan, Jr. USNR

NRRC 5-9
1630, 1st & 3rd Fridays
Alternate Wednesdays during First Quarter
U.S. Naval Research Laboratory
4555 Overlook Avenue
Washington 25, D.C.
CAPT Leland A. Depue, USNR

NRRC 5-10
2000, 2nd & 4th Tuesdays
Naval Medical Research Institute
National Naval Medical Center
Bethesda, Maryland
LCDR Denton W. Elliott, USNR

NRRC 5-11
2000, 2nd & 4th Tuesdays
Auditorium, U.S. Naval Engineering Experimental Station
Annapolis, Maryland
CDR John M. Vallillo, USNR

NRRC 5-12
1900, Mondays
Classroom 26, University Center
U.S. Naval Weapons Laboratory
Dahlgren, Virginia
CAPT William A. Kemper, USNR

SIXTH NAVAL DISTRICT

NRRC 6-1
1930, 1st, 2nd, & 3rd Thursdays
No meetings during First Quarter
U.S. Naval & Marine Corps Reserve Training Center
274 Fifth Street, N.W.
Atlanta 13, Georgia
LCDR Raphael B. Levine, USNR

NRRC 6-2
1900, Mondays (no set schedule)
204 Funchess Hall
Auburn University
Auburn, Alabama
CDR Roy D. Rouse, USNR

NRRC 6-3
1930, 2nd & 4th Wednesdays
ORINS Training Building
Oak Ridge, Tennessee
LCDR Howard E. Cochran, USNR

NRRC 6-4
1915, 1st & 3rd Tuesdays
U.S. Naval Reserve Training Center
1300 N.E. 8th Avenue
Gainesville, Florida
CDR Leonidas H. Roberts, USNR

NRRC 6-5
1930, 1st, 3rd, & 5th Mondays
U.S. Naval & Marine Corps Reserve Training Center
P.O. Box 48, Broad Avenue
Gulfport, Mississippi
CAPT Lewis S. Cotten, USNR

NRRC 6-6
1800, 1st, 2nd, & 3rd Mondays
NROTC Building
University of North Carolina
Chapel Hill, North Carolina
First Quarter: No meetings
Third Quarter: 1st four meetings at USN&MCRTS, Raleigh
Fourth Quarter: 1st four meetings at USN&MCRTC, Durham
LCDR Thurston A. Wilson, Jr., USNR

NRRC 6-8
1930, 1st & 3rd Tuesdays
U.S. Naval Reserve Training Center
Livingston & Parramore Streets
Orlando, Florida
CAPT Merlin C. Herold, USNR

NRRC 6-9
1900, 1st, 3rd, & 4th Mondays
Smith Hall
U.S. Navy Supply Corps School
Athens, Georgia
LCDR Acton R. Brown, USNR

NRRC 6-10
2030, 1st, 2nd, & 3rd Thursdays
Processings & Research Building
Miami 33, Florida
CDR Ethelbert D. Scrogin, USNR

NRRC 6-11
1730, Wednesdays
M-105, Mathematics Building
Clemson College
Clemson, South Carolina
LT William C. Mickelberry, USNR

NRRC 6-13
1900, 2nd & 4th Thursdays
American Red Cross Building
Laurens Street
Aiken, South Carolina
LCDR Dennie E. Ray, Jr., USNR

NRRC 6-15
1600, alternate Mondays
Room 110, Building 11
Eglin Air Force Base, Florida
LCDR Harold G. Wise, USNR

NRRC 6-16
1630, 1st & 3rd Tuesdays
PAFB Chapel Annex
B Street
Patrick Air Force Base, Florida
LCDR Furman J. Clark, USNR

NRRC 6-17
1900, 2nd & 4th Tuesdays
U.S. Naval Reserve Training Center
203 Leeman Ferry Road, S.W.
Huntsville, Alabama
LCDR James H. Hoyle, USNR

NRRC 6-18
2000, 1st & 3rd Mondays
Room 311, S-R Building
Peabody College
Nashville, Tennessee
CDR Ned L. Warren, USNR

EIGHTH NAVAL DISTRICT

NRRC 8-1
1930, alternate Tuesdays
Conference Room, 3rd Floor
Southern R&D Division Offices
1100 Robert E. Lee Boulevard
New Orleans, Louisiana
CDR E. P. Johnson, Jr., USNR

NRRC 8-2
1900, 1st & 3rd Thursdays
U.S. Naval Reserve Training Center
500 S. First Street
Baton Rouge, Louisiana
LT Cecil A. McCurry, USNR

NRRC 8-3
1930, Mondays
Biological Science Building
Texas A&M College
College Station, Texas
CAPT Walter H. Thames, Jr., USNR

NRRC 8-4
1930, 1st & 3rd Wednesdays
U.S. Naval Reserve Training Center
Houston, Texas
LCDR Milton "G" Gugenheim, USNR

NRRC 8-5
1900, Mondays
Experimental Science Building 115
University of Texas
Austin, Texas
LTJG George F. Sears, USNR

NRRC 8-7
1930, 1st & 3rd Wednesdays
U.S. Naval & Marine Corps
Reserve Training Center
1805 Yale Avenue, S.E.
Albuquerque, New Mexico
LT Charles J. Mauck,
USNR

NRRC 8-8
1930, 1st & 3rd Tuesdays
American Legion Building
Bartlesville, Oklahoma
LT Donald E. Griffin,
USNR

NRRC 8-9
1700, 1st, 2nd, & 3rd Tuesdays
Lecture Room, Administration
Building
Los Alamos Scientific
Laboratory
Los Alamos, New Mexico
LCDR R. L. Crawford,
USNR

NRRC 8-12
2000, 1st & 3rd Tuesdays
U.S. Naval & Marine Corps
Reserve Training Center
9638 Bachman Boulevard
Dallas, Texas
LCDR Floyd L. Cash,
USNR

NRRC 8-13
2000, 2nd, 3rd, & 4th
Thursdays
Room 352, Union Building
Oklahoma State University
Stillwater, Oklahoma
LTJG Delbert L. Rutledge,
USNR

NINTH NAVAL DISTRICT

NRRC 9-1
1900, 2nd & 4th Tuesdays
Navy Pier Campus
University of Illinois
Chicago, Illinois
LT Thomas McAvoy,
USNR

NRRC 9-2
1930, 2nd & 4th Tuesdays
Turner Hall
University of Illinois
Urbana, Illinois
LCDR Ernest E. Bair,
USNR

NRRC 9-3
1930, 1st & 3rd Mondays
Varied dates during July,
August & September
62 N. Hall
University of Michigan
Ann Arbor, Michigan
LCDR Dale E. Briggs,
USNR

NRRC 9-4
2000, 2nd & 4th Tuesdays
U.S. Naval & Marine Corps
Reserve Training Center
Milwaukee, Wisconsin
LCDR Richard Hood,
USNR

NRRC 9-5
1900, 1st, 2nd, & 3rd
Wednesdays
USNROTC Building
Iowa State College
Ames, Iowa
LT Burton J. Gleason,
USNR

NRRC 9-6
1930, 2nd & 4th Mondays
Room 208, Mechanical Engineering Bldg.
University of Minnesota
Minneapolis 14, Minnesota
LT John W. Barber, USNR

NRRC 9-7
1900, 2nd & 4th Tuesdays
Room 1, New Heavilon Hall
Purdue University
Lafayette, Indiana
CDR Ralph L. Davis, USNR

NRRC 9-8
1900, 2nd & 4th Wednesdays
Webster Groves Public Library
Webster Groves, Missouri
CDR David S. Gilmore, USNR

NRRC 9-9
1930, alternate Mondays
U.S. Naval & Marine Corps Reserve Training Center
Kansas City, Missouri
CDR F. J. Taylor, Jr., USNR

NRRC 9-10
1800, alternate Tuesdays
Elder Hall
Northwestern University
Evanston, Illinois
LCDR James P. Martin, USNR

NRRC 9-11
2000, 2nd & 4th Wednesdays
Varied dates during July and August
Room 209, Dy-Bact
South Dakota State College
Brookings, South Dakota
LT Roscoe J. Baker, USNR

NRRC 9-12
1930, 2nd & 4th Thursdays
Room 220, Chemistry Building
Colorado A&M College
Fort Collins, Colorado
LT Ronald A. Ryder, USNR

NRRC 9-13
1930, Wednesdays
U.S. Naval & Marine Corps Reserve Training Center
Fort Des Moines, Iowa
LT George G. Gutmann, Jr., USNR

NRRC 9-14
1930, alternate Mondays
119 Babcock Hall
University of Wisconsin
Madison, Wisconsin
LCDR Matthias Stelly, USNR

NRRC 9-15
1900, 2nd & 4th Tuesdays
Dow Abbott Road Building
Midland, Michigan
LCDR Robert W. Stephens, USNR

NRRC 9-16
1930, 1st & 3rd Mondays
221 Computing Center
Michigan State University
E. Lansing, Michigan
CDR Robin A. Drews, USNR

NRRC 9-17
1930, 1st & 3rd Wednesdays
National Bureau of Standards
Boulder, Colorado
CDR Robert S. Kirby, USNR

NRRC 9-18
1930, 2nd & 4th Wednesdays
U.S. Naval Reserve Training Center
Decatur, Illinois
LT Edward M. Bright, USNR

NRRC 9-19
1930, Mondays
Psychopathic Hospital
State University of Iowa
Iowa City, Iowa
LTJG James H. Cavanaugh, USNR

NRRC 9-20
1930, alternate Thursdays
104 Military Science Building
University of Kansas
Lawrence, Kansas
LT Bernard J. Judge, USNR

NRRC 9-21
2000, 1st & 3rd Thursdays
John Greene Hall
Denver Research Institute
Denver, Colorado
LT William J. Veigele, USNR

NRRC 9-22
1930, Tuesdays
Room 308, Dairy Industry
University of Nebraska
Lincoln, Nebraska
LT Warren E. Engelhard, USNR

NRRC 9-23
1930, 2nd & 4th Wednesdays
Naval Ordnance Plant
7500 West Roosevelt Road
Forest Park, Illinois
LCDR Henry C. Krass, USNR

NRRC 9-24
1930, 1st & 3rd Wednesdays
U.S. Naval Reserve Training Center
200 Riverside Drive
Waterloo, Iowa
LT Ross A. Nielsen, USNR

NRRC 9-25
1930, 1st & 3rd Wednesdays
U.S. Naval Reserve Training Center
Indianapolis, Indiana
CAPT Wendell Calkins, USNR

NRRC 9-26
1930, Tuesdays
U.S. Naval Reserve Training Center
Colorado Spring, Colorado
LCDR A. R. Ormond, USNR

ELEVENTH NAVAL DISTRICT
NRRC 11-1
2000, 1st & 3rd Tuesdays
U.S. Naval & Marine Corps Reserve Training Center
1700 Stadium Way
Los Angeles 12, California
CDR M. Jordan Nathason, USNR

NRRC 11-2
2000, 1st & 3rd Thursdays
U.S. Naval Reserve Training Center
2727 Paloma Street
Pasadena, California
CDR John S. McAnally, USNR

NRRC 11-3
2000, 1st & 3rd Mondays
1st Floor Conference Room (1-3-105),
U.C.L.A. Center for the Health Sciences
Los Angeles, California
LCDR Allen J. Curtis, USNR

NRRC 11-4
2000, 2nd & 4th Wednesdays
U.S. Naval & Marine Corps Reserve Training Center
600 North Alameda
Compton, California
LT Floyd M. Stephen, USNR

NRRC 11-5
1930, 2nd, 3rd, & 4th Tuesdays
U.S. Naval Reserve Training Center
Camp Decatur
San Diego, California
LT Edward H. Anderson, USNR

NRRC 11-6
2000, 2nd & 4th Thursdays
No meetings during July & August
U.S. Naval & Marine Corps Reserve Training Center
1201 N. 35th Avenue
Phoenix, Arizona
LTJG Gerald Bemel, USNR

NRRC 11-7
2000, 1st & 3rd Thursdays
No meetings during July & August
U.S. Naval & Marine Corps Reserve Training Center
1100 South Avernon Way
Tucson, Arizona
LCDR James M. Miller, USNR

NRRC 11-8
1645, 1st & 3rd Wednesdays
Naval Missile Center, Room 203, Building 351
Pacific Missile Range
Point Mugu, California
CDR Donald H. Drury, USNR

NRRC 11-9
2000, 2nd & 4th Wednesdays
Aerojet-General Corporation
Azusa, California
LCDR Alfred I. Weinstein, USNR

NRRC 11-10
1800, 2nd, 3rd, & 4th Wednesdays
No meetings during July & August
Room 17, Administration Building
Ventura College
Ventura, California
LCDR Paul Gannatal, USNR

NRRC 11-11
2000, 1st & 3rd Mondays
U.S. Naval & Marine Corps Reserve Training Center
3400 Airport Avenue
Santa Monica, California
LT Louis E. James, USNR

NRRC 11-12
1930, 1st & 3rd Thursdays
U.S. Naval Reserve Training Center
P.O. Box 1379
Santa Ana, California
LCDR John N. Echternach, USNR

TWELFTH NAVAL DISTRICT

NRRC 12-1
1930, 2nd & 4th Mondays
Third Floor
1000 Geary Street
San Francisco, California
LCDR Louis H. Davy, USNR

NRRC 12-2
1700, 1st, 2nd, & 3rd Mondays
Conference Room A, Building 111
Lawrence Radiation Laboratory
Livermore, California
CDR Richard C. Epps, USNR

NRRC 12-3
1930, 1st & 3rd Wednesdays
Room 101, Physics Lecture Hall
Stanford University
Stanford, California
CDR James R. King, USNR

NRRC 12-4
2000, Wednesdays as scheduled
Room 119, Agriculture Building
Fresno State College
Fresno, California
LCDR Lucile H. S. Smith, USNR

NRRC 12-5
1930, 2nd & 4th Wednesdays
Room 247, Cory Hall
University of California
Berkeley, California
LT Nathaniel L. Hawks, USNR

NRRC 12-6
1930, 1st, 2nd, & 4th Thursdays
Room 25, Freeborn Hall
University of California
Davis, California
LCDR Margaret L. Fuller, USNR

NRRC 12-7
2000, Thursdays as scheduled
Room 153, Engineering Building
Utah State University
Logan, Utah
LCDR Reynold K. Watkins, USNR

NRRC 12-8
2000, Wednesdays as scheduled
Room S-136
U.S. Naval Postgraduate School
Monterey, California
CAPT George J. Haltiner, USNR

NRRC 12-9
1700, Tuesdays as scheduled
Conference Room, Administration Building
Aerojet-General Corporation
Sacramento, California
CDR Terrell C. Griffith, USNR

THIRTEENTH NAVAL DISTRICT

NRRC 13-1
1930, 1st, 2nd, & 3rd Mondays
U.S. Naval Reserve Training Center
860 Terry Avenue North
Seattle, Washington
CAPT John H. Avery, USNR

NRRC 13-2
1900, 2nd & 4th Tuesdays
Community House
650 George Washington Way
Richland, Washington
LCDR Christian I. Anderson, USNR

NRRC 13-3
1930, 2nd & 4th Mondays
Room 410, Holland Library
Washington State University
Pullman, Washington
LCDR Irwin A. Dyer, USNR

NRRC 13-4
2000, 2nd & 4th Tuesdays
U.S. Naval & Marine Corps Reserve Training Center
Swan Island
Portland, Oregon
CDR Danny C. Marquez, USNR

NRRC 13-5
1930, 1st & 3rd Mondays
U.S. Naval ROTC Armory
Oregon State University
Corvallis, Oregon
LCDR Lafayette C. Harter, Jr., USNR

NRRC 13-6
1930, 2nd & 4th Thursdays
Army-Navy Reserve Center
Airport Road
Idaho Falls, Idaho
LCDR Chad K. Anderson, USNR

Log of the Aquanauts — Continued from Page 24.

Thus ended the operational phase of Project SEALAB I. Although several of the tasks that were originally assigned to the aquanauts could not be undertaken, because the sojourn beneath the sea was cut short, enough was done to demonstrate clearly that man can live comfortably and work efficiently in the ocean depths for long periods of time. There is now little doubt that those uncompleted tasks—for example, pouring concrete, drilling into the lava of the seamount, and mapping the ocean floor—could have been performed by the aquanauts.

The implications of such operations are indeed exciting to contemplate, not only in terms of the Navy's undersea objectives, but also with respect to a number of other National interests. Thus, as RADM John K. Leydon, Chief of Naval Research, remarked when he met the aquanauts in Bermuda shortly after their return to the surface, the undertaking had caught the imagination of the whole world. It was, he said, an example of what Edison was talking about when he encouraged the marriage of science and the Navy in 1916. That marriage has led to many remarkable achievements in the past several decades, the admiral explained, adding that many more remain to be realized, particularly in the ocean depths, which comprise an unexplored region more extensive than the entire surface of the moon.

Now underway is the exacting task of analyzing the data that was accumulated. This work will be done at the Naval Medical Research Laboratory, New London, Connecticut, the Navy Mine Defense Laboratory, Panama City, Florida, and the Office of Naval Research, Washington, D.C. When the investigation is completed and the necessary preparations have been made—perhaps early next year—another manned capsule may be lowered into the ocean, probably to a greater depth. The Sealab dream that began only about 7 years ago in the form of "dinner napkin" sketches is thus well on the way to fulfillment.

Previously, Dr. Radkowsky received the Navy Distinguished Civilian Service Award, the Meritorious Civilian Service Award, and an Atomic Energy Commission citation for "his outstanding work in the development of Naval nuclear power reactors."

Hydrodynamic Electromagnetic Propulsion

In recognition of the need for faster and quieter undersea craft and torpedoes, substantial research effort has been directed toward discovering new methods and techniques of propulsion. One technique studied at the Naval Ordnance Test Station, China Lake, California, involves the principle of the so-called Lorenz Force.

It has been known for a long time that in the presence of electric and magnetic fields a charged particle is subjected to a force perpendicular to the direction of the magnetic field and the perpendicular component of the electric field. By proper orientation of electrodes and magnets on the surface of a torpedo, for example, the Lorenz Force can be directed so as to cause rearward movement of ionized sea water. Thus a reaction motor having neither moving parts nor bearings is provided. Furthermore, since the force can be arranged so as to cause ion motion in other directions, the torpedo can be made to dive, ascend, or turn.

Such propulsion is considerably less noisy than the conventional screw, making sonic detection more difficult. Also, the absence of moving parts decreases both noise and mechanical wear, making this technique a promising one for submerged vehicles of all types.

Research at NOTS is continuing in an effort to provide powerful and efficient propulsion systems employing the principles of this invention, which is called "Hydrodynamic Electromagnetic Propulsion." A patent covering the concept, No. 3,138,129, was issued on June 23, 1964, to Lester T. Bankston and Hugh P. Jenkins, Jr.

Honors

During July, two investigators sponsored by the Biology Branch of the Office of Naval Research received signal honors. *Dr. Harry Sobotka* of the Mount Sinai Hospital in New York was awarded an honoray doctorate for his research in biochemistry from the University of Perugia, Italy in an elaborate ceremony which dates back to the 12th century. *Dr. E. Yale Dawson*, presently with the San Diego Society of Natural History, was invited to become Secretary-for-the-Americas of the International Darwin Foundation. His work in this capacity will be centered around the Galapagos Islands, an area of historical as well as biological interest.

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EDITOR: Richard D. Olson

NAVEXOS P-510

ELECTRON MICROGRAPH OF NASCENT SURFACE OF A LITHIUM FLUORIDE CRYSTAL CONTAINING INCLUSIONS. *The illustration was obtained by a procedure developed at the Naval Research Laboratory that involves placing a gas bubble on the crystal surface while it is growing. The bubble spreads instantly, blocking further growth on that portion of the crystal. Elsewhere on the crystal, growth proceeds uninterrupted until the bubble is enclosed. Upon examination by electron microscope techniques, the structure of new layers, the effects of local fluctuations, and the influence of other factors that affect the growth process can be studied in incredible detail.*