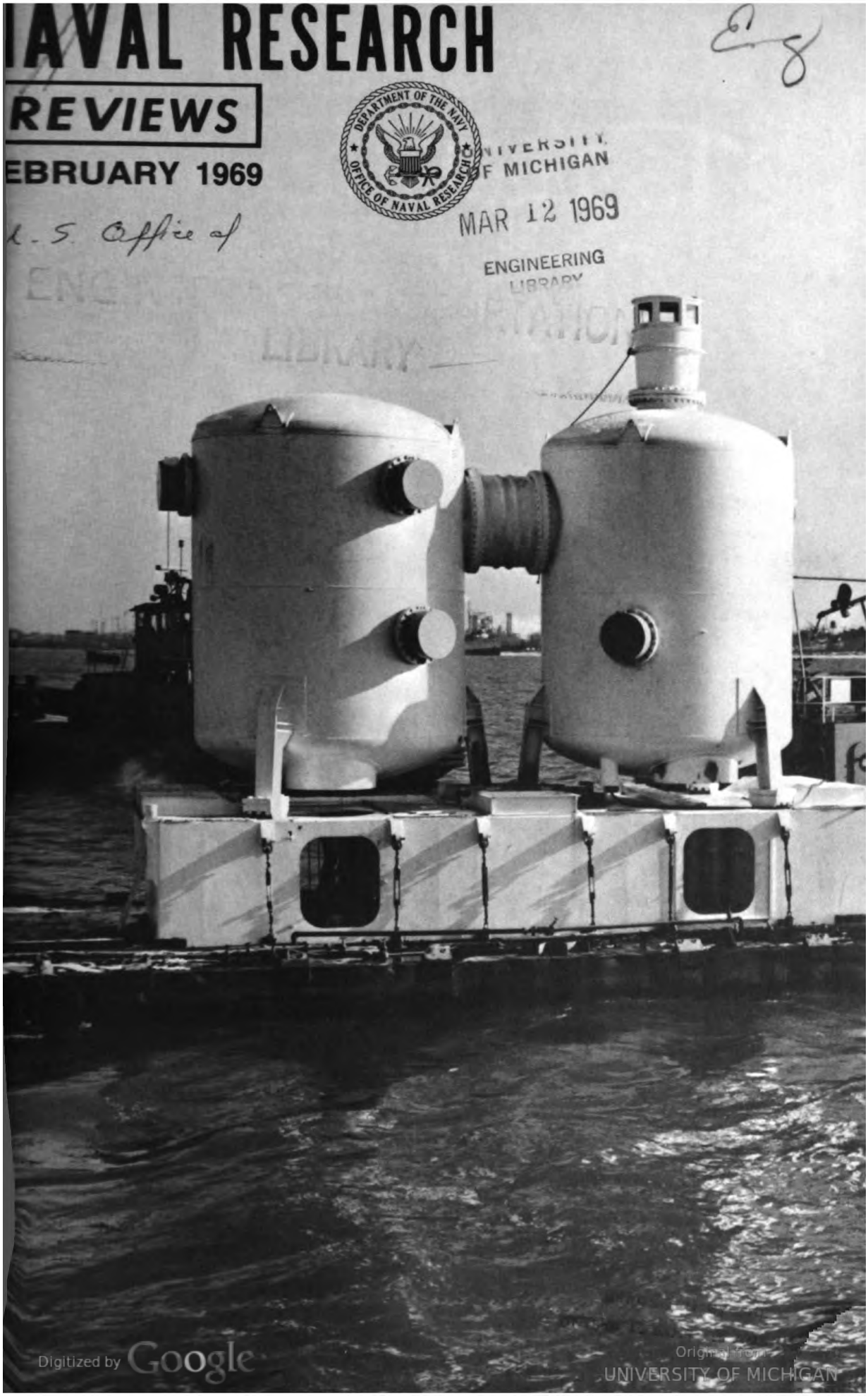
NAVAL RESEARCH REVIEWS

FEBRUARY 1969



DR. RICHARD COURANT CAME TO NEW YORK UNIVERSITY IN 1934 FROM THE UNIVERSITY OF GOTTINGEN WHERE HE ESTABLISHED AND DIRECTED THE MATHEMATICS INSTITUTE. AT NEW YORK UNIVERSITY HE FOUNDED THE INSTITUTE OF MATHEMATICAL SCIENCES IN 1953 AND DIRECTED IT UNTIL HIS RETIREMENT IN 1958. THE INSTITUTE WAS RENAMED THE COURANT INSTITUTE OF MATHEMATICAL SCIENCES.

DR. COURANT'S WORK WITH HIS TEACHER, DAVID HILBERT, GAVE PHYSICISTS THE NECESSARY MATHEMATICAL TOOLS FOR APPLYING TO PRACTICAL PROBLEMS THE THEORIES OF QUANTUM MECHANICS. WITH OTHER COLLEAGUES, HE PIONEERED IN THE DEVELOPMENT OF NUMERICAL ANALYSIS, WHICH PROVIDES THE ESSENTIAL METHODS FOR THE EFFECTIVE USE OF MODERN COMPUTING IN MATHEMATICAL PROBLEMS. DR. COURANT WAS ONE OF THE EARLIEST OFFICE OF NAVAL RESEARCH INVESTIGATORS.

TEKTITE I: 1440 Hours on the Bottom of the Sea

On February 15, four aquanaut-scientists will dive 50 feet under the waters of Greater Lameshur Bay, St. John Island, Virgin Islands. They will return to the surface 60 days later.

The dive will mark the beginning of one of the most ambitious undersea missions ever attempted: TEKTITE I.

TEKTITE I is a multi-agency/industry program to determine the capability of a small group of men to satisfactorily perform a scientific research mission while living isolated on the ocean floor under saturated diving conditions for a long period of time.

The program is jointly sponsored by the Navy, National Aeronautics and Space Administration, and the Department of the Interior, with participation by the U.S. Coast Guard. The prime contractor is the General Electric Company, which is furnishing the undersea habitat and assisting in program planning and scientific mission coordination. TEKTITE I is the first undersea program to be undertaken by a group of federal agencies in cooperation with private industry.

The four marine scientists, all from the Department of Interior, will swim from the habitat each day to conduct various scientific projects. They virtually will be living in a marine laboratory, both on the ocean floor and in the habitat's working spaces. This environment provides an unprecedented opportunity for long-term marine investigation.

While the four marine scientists are conducting their underwater research mission, they will be continuously observed by behavioral and biomedical teams. The objectives here will be to identify man's psychological and physiological reactions to a long-term mission performed in an isolated, hostile environment common to undersea and space missions.

TEKTITE Site

The underwater site of Project TEKTITE is Beehive Cove in Lameshur Bay, a south shore indentation in St. John Island. The Cove is in the Virgin Islands National Park which is administered by the National Park Service of the Department of the Interior. The park's land and water area cover 15,150 acres including extensive coral reefs. Beehive Cove was selected for the site largely because it contains an extraordinary reef which supports an abundance of reef-fish populations, providing an excellent opportunity for direct biological and oceanographic studies.

TEKTITE SITE: Aerial view of Greater Lameshur Bay, off St. John Island in Virgin Islands National Park, where four Department of the Interior scientists will spend 60 consecutive days on the ocean floor, 50 feet below the surface.

Beehive Cove is near Cabritte Horn Point, the tip of a stubby peninsula three-quarters of a mile long which forms the eastern side of Lameshur Bay. The Bay consists of Greater Lameshur Bay on the east side and Little Lameshur Bay of the west. Rocky and roadless, the peninsula is not conducive to land travel between Beehive Cove and the TEKTITE base camp. Boats will ply the 1300 yards between the base camp docks and the cove where the TEKTITE support barge will be moored to the peninsula shore. The barge will contain the TEKTITE control van and the umbilical lines to the underwater habitat.

Navy Interest in TEKTITE I

Navy interests in TEKTITE I are reflected in Program management and coordination, development of the TEKTITE I behavioral and biomedical scientific mission objectives, and operational and technological program support.

The Navy is the "lead agency" of the three sponsoring agencies supporting TEKTITE I. Through the Office of Naval Research, the Navy has the responsibility for overall program management and for administration of the General Electric TEKTITE contract. An additional Navy responsibility in TEKTITE, and perhaps the most important, is mission safety, in both the scientific and operational conduct of the program.

A scientific management responsibility of the Navy, through the Office of Naval Research, is the planning of the behavioral and biomedical programs, and the integration and coordination of the overall TEKTITE I scientific program. Navy laboratories have contributed significantly to the TEKTITE I mission objectives in these programs. For example, from laboratories such as the Naval Medical Research Institute have come the behavioral program elements relating to crew selection and work performance studies. The microbiology element of the physiological program was developed by the Naval Biological Laboratory.

In addition to the stated scientific goals in the mission objectives, TEKTITE I provides the Navy an opportunity for exploration in related areas of underwater technology. These areas include underwater medicine and safety, and engineering and construction, to name but a few. The experience gained by the Naval Submarine Medical Center and the Naval Facilities Engineering Command in the TEKTITE program will have impact on future long duration scientific studies, and will provide new tools for naval operation readiness.

The Navy is providing the operational direction for implementation of the scientific mission plans and objectives. Naval command experience will provide the operational leadership necessary to carry out the scientific program. In addition, practical operation requirements are being met by the Navy, such as transporation, logistics, and communication and facility requirements for the scientific personnel who will be at the project site for the conduct of the mission.

It is anticipated that the Navy effort in TEKTITE I will be of benefit not only to the agencies involved, but to the national interest at large. The basic information to be gained regarding man's response to living under a hazardous and isolated condition has the promise of usefulness not only in national defense, but also in undersea scientific endeavor and the peaceful exploitation of resources of the sea.

NASA Interest in TEKTITE

Project TEKTITE will provide a unique opportunity to study the performance of a four-man crew of scientists under conditions of stress and isolation, to assess methodology and to collect data for use in predicting the behavior of crew members in future space flights. The four scientists will experience a true feeling of isolation since they cannot return to the surface readily. Of practical application to future space missions is information on how a four-man crew interact when confined in a small habitat for a long period of time performing useful work.

The marine scientific mission provides a meaningful goal which is necessary in order to maintain a continuous high level of motivation.

With such motivation, the behavioral measures become significant for future long duration space flights.

The data and methodologies derived from the biomedical and behavioral programs will be applied in the planning of extended future space missions.

In NASA, these studies are being supported by the Office of Manned Space Flight, the Office of Advanced Research and Technology, and by the Office of Space Medicine. Both the Langley Research Center and the Manned Spacecraft Center are providing experimental imputs in this research.

THE INTERIOR DEPARTMENT'S ROLE

The Department of the Interior is taking part in Project TEKTITE to help determine what useful marine research can be accomplished by placing man in the sea. For years marine scientists have speculated on the advantages of having direct access to the undersea environment for extended periods of time. To this end, SCUBA gear and research submersibles have provided only partial solutions. Surface diving with SCUBA gear has distinct time and depth limits. Dives with submersibles are also limited in duration and suffer the additional disadvantages of restricted vision and little or no direct access to the environment. Pressurized ocean floor stations or manned habitats offer a third approach which appears to have many advantages for prolonged studies at Continental Shelf depths.

The overall objectives of the Department of the Interior in the ocean floor program are:

- To determine the advantages of saturation diving as a research technique for marine scientific studies.
- To carry out an operational research program on the ocean floor to demonstrate that scientists can live and work effectively in the ocean environment.

Although TEKTITE has been preceded by several underwater-living experiments, some at considerable depth, it will be the first such project in which research on biological and geological processes are given special attention.

Five Bureaus in the Department of the Interior are participating in Project TEKTITE—Bureau of Commercial Fisheries (BCF), National Park Service (NPS), U.S. Geological Survey (USGS), Federal Water Pollution Control Administration (FWPCA), and the Bureau of Land Management (BLM). The Bureau of Commercial Fisheries has been designated the lead agency for Interior's portion of the project.

To achieve the goals set by the different agencies involved in the mission, three scientific programs have been developed: Marine Sciences Program; Behavioral Program; and Biomedical Program.

MARINE SCIENCES PROGRAM

Biological Studies

Phytoplankton, the microscopic plants that drift along in ocean currents and provide food for larger animals in the ocean' food web, will be studied. Water samples containing plankton will be pumped to the TEKTITE habitat from several different depths so that the productivity or biological richness of the area can be measured. The zooplankton (microscopic animals), which feed on the phytoplankton and in turn are fed on by fishes, will also be studies, particularly in respect to their relationships between other marine life and the physical environment of the reef area. Plankton studies of this type are usually done from shipboard with suspended sampling devices. Observations made directly from the ocean floor habitat, however, are expected to yield far better sampling control and continuity than can be gained from a ship.

Various methods used for measuring the production of marine life in ocean and reef areas will be compared to determine the relative advantages of one method over another. Most productivity estimates of this type are based on measurements of oxygen produced and consumed in a given period. During the TEKTITE Project special equipment will be used to enclose some organisms while measurements are made of their oxygen production and absorption of radioactive carbon (C^{14}). These studies may help make it possible to standardize methods and reduce variations in estimates of organic production in ocean waters.

Most marine organisms exhibit definite patterns of activity or behavior in foraging, mating, escaping from predators, *etc*. Knowledge of these activities is necessary to understand better the life history of a particular species, and if it is a commercial variety, to design fishing gear for its capture. In the early phases of the project, spiny lobsters (they are the source of what are commonly known as "lobster tails"), reef and predator fishes and certain mollusks will be tagged with tiny sonic transmitters. Thereafter, movements and habits of these animals will be monitored on a small portable sonar device capable of receiving signals from the transmitters even if the animal is secluded in a deep coral burrow up to four miles away. The receiver will enable the scientists to track the tagged animals and record their location and activity in daylight or darkness. When a lobster is located, its identity can be determined by a brand, visible at night under ultraviolet light. By

monitoring several representative organisms, the biologists will obtain information on growth and survival, feeding habits, daily migrations, reproduction, responses to environmental changes, and other pertinent information occuring over the two-month period. Observations such as these are extremely difficult to make working from the ocean surface.

During the TEKTITE experiment, the types of sediment in Lameshur Bay will be identified and mapped. A few small portions of the sea floor have previously been mapped by diving geologists, but TEKTITE offers the first opportunity to develop a close familiarity with a sub-sea area comparable to what a geologist has with his onshore terrain. These data, combined with acoustically derived profile records of the strata or sediment layers beneath the ocean floor will provide a three-dimensional picture of the recent sedimentologic history of the bay. Analysis of the relations between sediments will provide a basis for interpreting certain types of carbonate rocks and may prove useful to the petroleum industry.

Study will also be made of the production of biogenous sand (sand formed from the remains of once-living organisms). TEKTITE provides an opportunity to relate the sand to the contributing organisms (mostly corals and mollusks) and to study the balance between reef growth and destruction. Study of the variation of sand composition with grain size and location should provide information on the mechanical breakdown and processes of distribution of biogenous sand.

The dominant feature of many portions of the sea floor is biologic reworking of the sediment. Moreover, the effects of organic reworking in the geologic past are shown by tracks, trails, and burrows in many sedimentary rocks. Certain apparently structureless rocks are suspected to have been homogenized by bottom-dwelling organisms. Contemporary research indicated that the nature of organism reworking is related to the depositional environment. At present no data are available on this relationship in carbonate sediments in a reef-dominated environment. TEKTITE will provide an opportunity to collect some of this information as well as a chance to study briefly the role of biologic ingestion in sediment modification. The duration of the experiment will permit observation on the rate of organic mixing in different environmental settings. These observations may be of value to geologists in providing clues as to where to seek petroleum or other mineral deposits, and what happens to sediment when they are disturbed by marine organisms.

Additionally, TEKTITE will aid in the development and evaluation of underwater geologic techniques such as sampling and mineralogic separations. The lack of laboratory facilities in undersea habitats poses a major problem for undersea geologic research and creates a potentially limiting dependence on surface support. During the TEKTITE operation experiments will be conducted attempting to

establish procedures whereby routine sediment analyses could be made on the ocean floor without having to return samples to the surface.

Finally, by living in the submarine environment, the geologist has an opportunity to conduct other aspects of underwater research. He can monitor changes in the sediment and the sedimentation processes as frequently as he wished. He can observe continuously the interaction between sediment and bottom-dwelling organisms. Along with other studies he can measure the chemical and physical properties of the sea floor in a natural state.

General Environmental Studies

Continuous monitoring of the environment during the project will be carried out in support of the planned ocean floor program. Continuous records of water temperature, salinity, current speed and direction, pressure, ambient light, water chemistry, and bioluminescence will be made, and the effect of these elements on the behavior patterns of marine organisms or changes in the sediment characteristics will be determined.

Acoustical Studies

The widespread use of sonar for fishery applications and the increasing technical developments within the field point to a specific need for detailed studies on the effectiveness of sonar for differentiating between fish species either by a characteristic signal return from a single fish or by signal recognition of the swimming or schooling behavior of groups of fish. The TEKTITE Project will provide a unique opportunity for these studies, where sonar target species can be identified and correlated with their acoustical "signatures."

Additional uses for sonar are in various project support functions. The routine task of compiling charts of pertinent topographic and geologic features underwater is beset with several problems of little or no consequence to the land surveyor. The use of sonar for providing reliable range and bearing data appears to offer much promise for underwater survey and geologic delineation work. Furthermore, the location and range of free swimming divers during any underwater operations is of prime importance for safety reasons. Indications are that narrow band sonar can be an important aid in diver tracking and navigation.

BEHAVIORAL PROGRAM

The behavioral program is one of the principal reasons for conducting an extended ocean floor mission such as TEKTITE. The program,

one of the most exhaustive ever designed for aquanauts, is intended to obtain data on a multitude of behavioral aspects from the amount of food consumed by the aquanaut-scientists to subtle changes in their moods at different times.

Notwithstanding the exhaustive nature of the program, all data collection methods have been devised to minimize interference with the marine science program on the ocean floor.

The objective of the behavioral program is to evaluate individual and group behavior in a situation where the mission is real rather than experimental, the duration quite long, and the environments are relatively hazardous.

The data gathered will provide information useful in planning future missions involving stress such as manned undersea stations or extended manned spaceflights. It will provide valid criteria in the selection, training and group composition of the crews for future undersea and space missions.

By studying the individual and group response to factors such as living space, volume, layout of work and rest area, lighting, recreational facilities, and waste management, it may be possible to develop more effective standards for designing similar systems in the future.

During the 60 days on the ocean floor, the aquanaut-scientists will be subjected to measurements designed to record (1) task performance, (2) social interaction and (3) personal adjustment.

Methods of Data Collection

One of the principal methods of collecting behavioral information will be by closed circuit television, which will allow objective recording of observed behavior by personnel on the surface.

One camera is located in each of the four habitat rooms. Two portable waterproof TV cameras with remotely controlled pan, tilt, zoom, and lens adjustment will be placed in the water on tripods in the vicinity of the habitat. On the surface, six TV monitors with switching facilities to select any or all cameras or open microphones will be set up in the control van. In addition, a video tape recorder and playback will be installed.

Other methods of data collection include automatic recording of a specified events such as entrance and egress from the water, use of entertainment facilities and use of communication systems; systematic recording of brain waves, (EEG) during sleep; photography; diaries and report forms; interviews; as well as an analysis of the amount and quality of the work performed by the aquanauts.

Prior to the mission, the aquanauts will undergo a series of measurements designed to gather data on demographic, personality, social and adjustment factors, sleep habits, habitat evaluation and food preferences.

Monitoring of task performance will permit the assessment of the ability of crewmen, singly or as teams, to perform manual, sensory and intellectual tasks required in the mission plan. The tasks in question will include routine activities such as monitoring the habitat systems, preventive maintenance, repairs of malfunctions, and housekeeping tasks; or more demanding mental tasks such as the mission-oriented scientific activities, or the handling of emergency and unplanned situations.

The purpose of the social interaction measurements is to monitor interactions between individual crew members and between the crew and topside personnel which affect the objective of the mission, and the morale and survival of the crew.

The objective of the personal adjustment measurements is to ascertain any variations in emotion, motivation, and fatigue of the crew which may occur.

Other important parts of the behavioral program of TEKTITE will be the Habitability and Human Engineering Evaluation of the habitat, phycho-physiological measurements (including sleep EEG) and the use of a psychomotor test which includes manual dexterity and decision making. These evaluations will be conducted jointly with engineering medical safety and other personnel in the program.

BIOMEDICAL PROGRAM

The objectives of this program are threefold: to aid in the monitoring of the medical aspects of a safe crew operation; to collect certain biomedical data; and to correlate this data with all the scientific aspects of the program.

For 60 days, the TEKTITE aquanaut-scientists will be breathing two gas mixtures. In the habitat, the mixture will be composed of approximately 92 percent nitrogen and 8 percent oxygen in which the partial pressure of the oxygen is maintained at the same level in the air atmosphere at sea level. When in the water, the aquanauts will breathe air under pressure equal to the pressure of the water.

The data collected will help determine whether the two breathing mixtures and pressure affect blood composition, respiration, vision, and hearing of the aquanauts. Also of interest, will be the collection of bacteriological data to ascertain the actions and interactions of microorganisms found in the immediate environments of the aquanauts whether in or out of the water.

Hematology

Prolonged breathing of the two mixtures may affect the formation and destruction of blood cells or produce other changes in the functional capabilities of the blood. In order to permit a valid assessment

of any change in the blood, measurements will be taken periodically. The aquanauts themselves will take the blood samples from each other. The sample will be then sent to the surface in a pressure pot and sent to a laboratory for analysis.

Pulmonary and Respiratory Studies

Before and after the 60-day exposure to the denser atmosphere, the rate, depth and minute volume of respiration will be measured by having the aquanauts inhale progressively, zero, two, four and six percent carbon dioxide in 21 percent oxygen. This will allow a determination of how increased atmospheric pressure alters the respiratory response to carbon dioxide. Related measurements will monitor the changes in the rate of diffusion of the carbon dioxide across the alveolar and capillary membranes.

Other respiration measurements before, during and after exposure, are designed to determine how the denser breathing mixture affects the ventilatory function—the lungs' bellow-like muscular activity of breathing in and out. It is possible that this particular atmosphere may increase the workload of the lungs. However, the changed workload may condition the respiratory muscles permitting the lungs to have the same efficiency as in a normal atmosphere. At the same time, breathing work and efficiency will be monitored by measuring esophageal pressure. Additionally, before and after exposure, efforts will be made to find out if the dense atmosphere results in any increase in pulmonary compliance—the ease of expansion of the lungs—and airway resistance—the opposition offered by the airways to the flow of air into and from the lungs.

Microbiology

These measurements are intended to provide information on how the body bacteria of the aquanauts is affected by the water immersion and the factors of temperature and microbiological content. Efforts will also be made: to determine whether new microorganisms are introduced in the habitat as a result of such exposure; to monitor the interchange of microorganisms among the aquanauts; and to predict the results of interaction of the microorganisms present on the bodies of the aquanauts with their immediate environment. The data will be collected by examining bacteriological samples taken from the bodies of the aquanauts. Bacteriological content of the habitat will be measured by taking concurrent atmospheric samples as well as swabs of the habitat itself. Periodic water samples will be obtained at various distances from the habitat and analyzed for bacteriological content.

Vision

Since vision disturbances are not anticipated, only "before and after" tests will be conducted to demonstrate that visual acuity has remained unaffected.

Hearing

Before and after their undersea stay, aquanauts will be tested by standard audiometric techniques. Analysis of the audiograms may indicate whether exposure had any effect on the hearing acuity of the aquanauts.

AQUANAUT STATUS ASSESSMENT

At least once daily a general physical assessment of the health of the aquanauts will be required. The aquanauts will give themselves a physical check-up and send the results to the surface. Among their daily measurements will be radial pulse and blood pressure. They will also take color photographs of any skin lesions they may incur and send them to the surface for analysis. This will enable the on-site medical officer to determine their general health or possible onset of disease.

Participating in the biomedical program is the University of Pennsylvania. Medical personnel from the university will oversee coordinate performance of many of the biomedical and medical status measurements to be used the the physiological evaluation of the aquanaut-scientists before, during and after 60-day mission. The University of Pennsylvania which has long-standing interest in undersea missions, will relate the biomedical aspects of TEKTITE I to its own program of undersea environment research.

The aquanaut-scientists have spent seven days in the University of Pennsylvania Hospital providing medical personnel baseline biomedical data. After the mission two full days will also be utilized for the same purpose. During these two periods, baseline behavioral data will also be collected.

HABITAT DESCRIPTION

The basic habitat consists of two interconnected vertical cylinders 18.1 feet high and 12.5 feet in diameter mounted on a base structure. Each of the cylinders contains two compartments. The left side houses the crew quarters on the lower deck and the bridge or control room above. The right cylinder connects with the left by means of a four and a half foot diameter transfer tunnel running from the bridge to the upper half of the right cylinder, the engine room. The lower half of

the right hand side houses the wet room which is continually left open to the sea for easy access in entering and leaving the habitat.

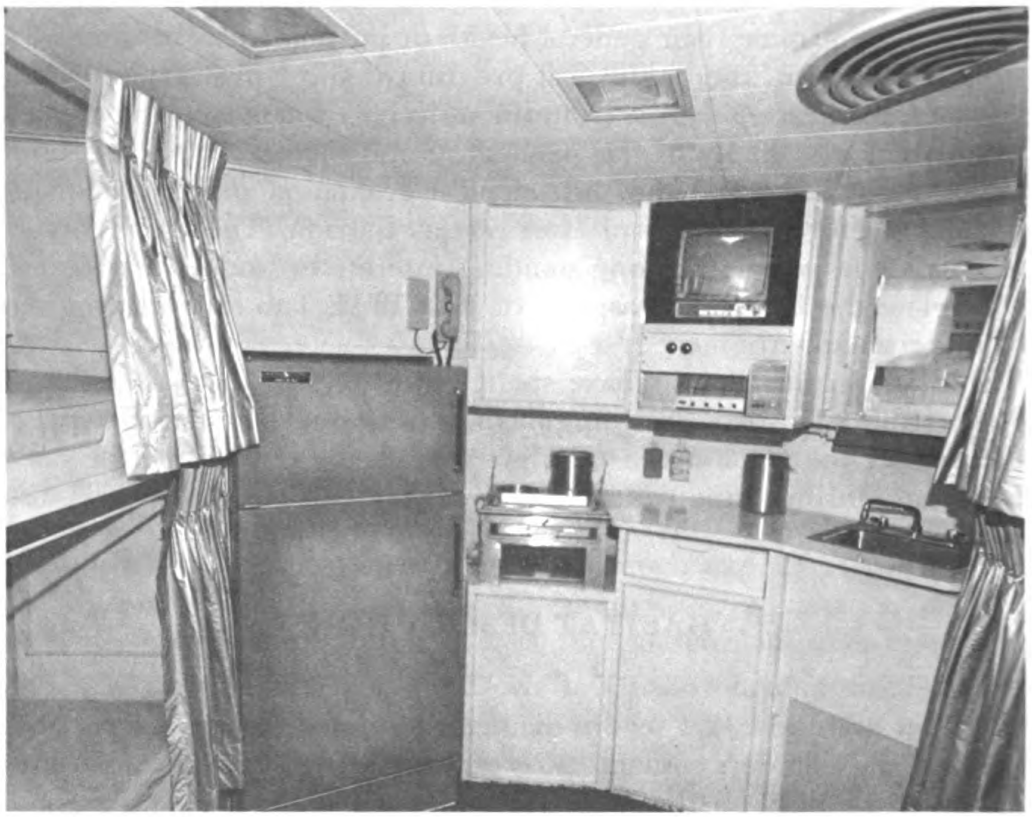
The right side of the habitat also supports a five-foot high, two-foot diameter cupola mounted on top of the cylinder for additional observation purposes.

Internal Lay-Out

The crew quarters contain a small galley, bunks, storage for personal gear, and entertainment equipment consisting of radio and television facilities. An emergency exit hatch and scuba equipment are located in the crew quarters.

The bridge serves a dual purpose: (1) as the control center for the habitat system and (2) as a laboratory for the scientists.

The engine room contains the larger items of the environmental control system, the primary transformers, switch gear, and the large freezer for food storage. Since the four aquanaut-scientists will take a 60-day supply of food with them, this supply will not be replenished during the mission.



Interior view of crew quarters shows bunks for the four aquanaut-scientists, the entertainment console, and galley. The crew will live 60 days continuously below the water's surface using the GE designed and built habitat as home and laboratory.

Since the wet room is always open to the base, and therefore directly to the sea, it is the only compartment which does not have controlled humidity; it houses the SCUBA gear, for use by the crew while conducting experiments outside the habitat, and an outlet for recharging the SCUBA bottles. In addition, it contains a laboratory including a wet sink where the scientists can perform specimen preparation. It also contains a hot shower.

Communication

The bridge, which is the communications center, is connected to the Surface Support Facility by phone, intercom and voice sonar. Each compartment is equipped with an intercom station connecting it with the other compartments as well as the support barge, an open mike and closed circuit TV monitor for the behavioral program, and audible and visual alarms. The bridge also has sound-powered phone and voice sonar links to the Surface Support Facility. In addition, the Bridge is able to monitor the open mikes and any two of the closed circuit TV cameras. The voice sonar also permits direct communication with crew members when they are out of the habitat.

In the wet room there is a timer for recording the times when the individual crew members leave and enter the habitat. Externally there are audible and visual alarms and two closed circuit TV monitors. One of these monitors will be fixed so as to observe the habitat entrance while the other will be used for remote observations of selected areas by the crew. There will also be both fixed and portable lights outside the habitat.

Environmental Control System

The Environmental Control System will provide a comfortable, clean atmosphere for the crew. The oxygen partial pressure will be maintained at the normal sea-level value with nitrogen used as a diluent.

Surface Support Facility

The Surface Support Facility will provide the direct surface support required by the habitat. The equipment will be mounted on an Ammi barge either moored or jacked-up near the habitat site. On the barge will be a van containing the duty stations for the test director, medical duty officer and behavioral observers. The electrical generating equipment, air compressors, purge bottles and stand-by breathing gas are also located on the barge, as well as the habitat water supply. All these utilities are connected to the habitat by umbilicals. The Surface Support

Facility also provides safety services for the habitat. A deck decompression chamber (DDC) and a personnel transfer capsule (PTC) will be available for the transfer of the crew at the end of the mission or in case of an emergency. In addition, a safety patrol with qualified divers, in a small boat, will be standing by at all times.

Other Equipment

There will be five way stations located in the general area of the habitat. These stations will provide several benefits to the crew. They will make excellent observation posts from which the aquanaut-scientists will be able to observe the immediate area and, if desirable, record their observations in a dry environment. These way stations will also enable the scientists to make minor adjustments to their equipment or to carry on a conversation with their comrades in the habitat. Also, if the occasion should arise, the way stations will provide a place of refuge from sharks.

A simple dumbwaiter system will be installed adjacent to the habitat for the dry transfer of small items between the surface and the habitat. Typical items to be transferred are blood and urine samples from the crew, marine biological and geological samples for surface laboratory analysis, and special tools or equipment for the scientists.

UNDERWATER CONSTRUCTION FOR PROJECT TEKTITE

The Naval Facilities Engineering Command, the Navy's underwater construction manager, is responsible for the design and development of the systems used by the SEABEES to launch, emplace and integrate TEKTITE I components on and under the surface.

The underwater emplacement of the habitat is to be accomplished by 12 selected construction divers detailed to SEABEE Amphibious Construction Battalion TWO (ACB-2) from the SEABEE Battalions of the Atlantic and Pacific Fleets. Another detachment of SEABEES has already constructed a base camp of permanent structures to support approximately 100 scientific, support and other personnel who will reside at Lameshur Bay during the construction and experiment phases of Operation TEKTITE.

Fifth Cryopreservation Conference to be held at Buffalo, New York, August 7-9, 1969. Additional information may be obtained from LCDR Vernon P. Perry, MSC, USN, Tissue Bank, Clinical Investigation Department, Naval Medical Research Institute, National Naval Medical Center, Bethesda, Maryland 20014. Phone: Area Code 301-295-1123. Sponsored by the Office of Naval Research and held in conjunction with the Sixth Annual Meeting of the Society for Cryobiology.

Mechanical Failure Technology

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The Office of Naval Research has formed a multi-service group to conduct studies in mechanical failure technology with the hope of preventing mechanical failures in service by analysis, detection, and control studies. The problem of machine or component failure was long accepted as an inevitable operating hazard. Early attempts to reduce the likelihood of failure involved primarily design improvements based on experience as the frequency of failure increased. More recently, preventive maintenance programs have been developed which greatly reduced the possibility of failure. Rising costs of maintenance programs and machine down time have provided a strong incentive for the development of effective reliability programs particularly for the highly complicated marine and aircraft propulsion systems that require vastly improved levels of machine system reliability. A variety of statistical and other techniques recently have been developed to make certain that high reliability levels are constantly achieved. For very critical applications, redundancy is often used.

High reliability, preventive maintenance and redundancy are costly while the consequences of failure have become more severe. Furthermore, even more sophisticated designs cannot eliminate the possibility of failure. The material properties and the operating environment are both subject to significant statistical variation so failure cannot be eliminated. It is clear that further steps are necessary to reduce the frequency of failure.

There is one element of failure prevention which has often been neglected, that is, our understanding of the failure process. We have come to think of one failure as a completely random and unpredictable event. We have also come to think that the failure of a component can be caused by a large variety of events and once the causes are there, failure results. This is not necessarily so, as indicated by the following example of journal bearing failure.

Journal bearings generally fail by wear or seizure. However, if one prepares a list of the causes of bearing failure (and this has been done) approximately 30 important ones could be suggested. They vary from such things as excessive oil temperatures to dirt trapped between the bearing surfaces. However, if one analyzes these failures from the point of what happens to the bearing itself the list can be shortened considerably. Bearing failure processes based on this approach are given in Table I.

TABLE I
SLIDING BEARING FAILURE PROCESSES

Change of clearance
Change of shape
Surface roughening
Shaft-bearing rubs
Fatigue

The many causes of failure can be reduced to a few very definite, manageable processes when analyzed from the point of view of what happens to the bearing. What this example points out is that much can be done to understand failures by a more thorough study of the failure processes in machine components. The purpose of this paper is to describe the scope of the failure technology area, the Mechanical Failure Working Groups and some of its programs.

SCOPE OF MECHANICAL FAILURE TECHNOLOGY

Mechanical failure technology is the application of science to the understanding of mechanical failure processes. Often the failure process is described in terms of cause and effect; such a description is, if dirt gets in the bearing it will score. What mechanical failure technology tries to do is understand what happens between the dirt and the scoring and put this in terms of descriptive variables. In Table II the various steps in such a study are outlined.

TABLE II
STUDY OF MECHANICAL FAILURE PROCESS

Define what is failing (component).
Define what constitutes practical failure.
Define the changes in the component and ancillary systems which can lead to failure.
Define the sequence of events which lead to failure.
Put the failure process in terms of its significant variables.
Describe the effect of operational variables on the failure process.

The study begins with the definition of the component and a description of a failure. Thus, various changes in the component which lead to failure can be outlined. The first three steps have been discussed using a bearing for an example. To carry this example further, let us select one of the bearing failure processes the "shaft bearing rub." In Figure 1 the coefficient of friction and the temperature are plotted for the small initial area of contact. At zero time the rub occurs and there is a transition from hydrodynamic to boundary lubrication. This brings about a temperature rise from 80°F (coefficient of friction of .02) to 400°F (coefficient of friction of .10). However, before the temperature reaches 400°F, the lubricant failure temperature is reached at 350°F. Unlubricated sliding results with a friction coefficient of 0.3. This means that the temperature should rise to 1200°F. However, when

it rises to about 800°F a process known as "junction growth" occurs, friction increases to 0.80 and most likely seizure would result. Thus, we can qualitatively describe the failure in terms of the friction coefficient, the temperature, and the area of contact. It would then be necessary to describe the failure in terms of bearing variables such as pressure, velocity, *etc.* This is but one example of a detailed study of failure processes. The work here is by no means complete and there are several other processes even for a journal bearing. The task, however, is not excessively large and there are not that many failure processes.

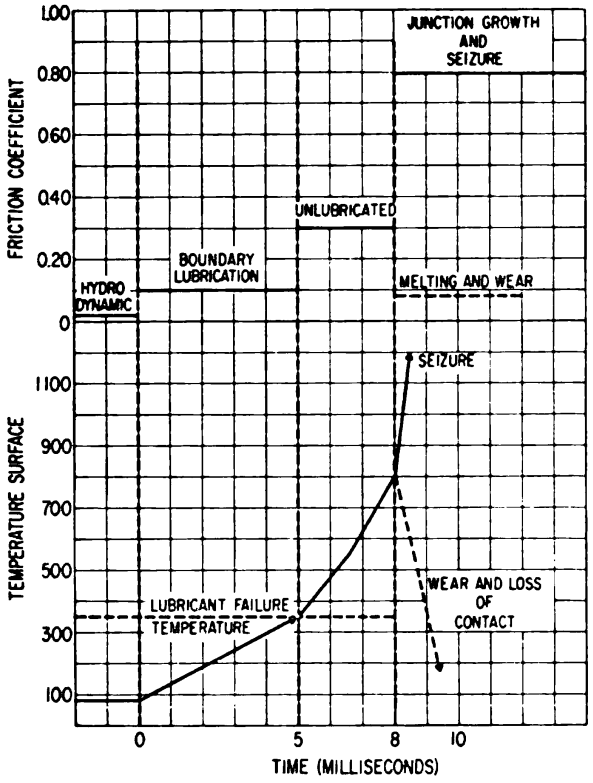


Figure 1

There is much which can be learned from a greater understanding of the failure process. However, since the objective of the program is to prevent mechanical failures in service, the strongest incentive is to utilize this information in two areas:

- Improved Designs or Design Criteria
- Development of Diagnostic Information.

The translation of failure information into practice is relatively simple. Take again the example of the bearing. Referring to Figure 1 some apparent ways to prevent failure are obvious. Limiting the time of contact would be an obvious solution. Not so obvious is to find a material with special frictional properties. Suppose that a material could be found which instead of experiencing junction growth and seizure, actually melted and wore rapidly. This would lower the temperature and remove the area from contact by wear and lubrication could then be restored. Such materials do exist. Plastic materials with the correct melting point were shown to behave in such a manner.

Thus, the scope of mechanical failure technology is the study of failure processes in components to evolve better designs and criteria or diagnostic instrumentation. In this way, significant contributions can be made to reducing failures in practice.

MECHANICAL FAILURE WORKING GROUP (MFWG)

The Office of Naval Research is sponsoring a government working group to study all aspects of mechanical failure technology. The group consists of representatives from the Aeronautics Space Administration, Atomic Energy Commission, Federal Aviation Administration, Maritime Administration, the military services, universities, and industry. The committee of sponsors are representatives of governement agencies who contribute financially to the program. They have selected a steering committee which determines the courses of action which the group should take. Four committees have been appointed as technical advisors to the steering committee. These committees are the Diagnosis and Detection Committee, the Mechanisms of Failure Committee, the Design Committee, and the State of Art and Applications Committee. The Mechanisms Committee concerns itself with understanding the failure processes, the Diagnosis Committee with development of detection instrumentation, and the Design Committee with improving the overall design for machinery. The State of the Art and Applications Committee is charged with appraising and keeping abreast of the literature on mechanical failures, and also determines those applications where problems are severe enough to justify attention of the steering committee. In this regard it can be realized that the subject of mechanical failures is very broad and much work has already been accomplished. Certain technical areas have advanced or are advancing at a sufficiently rapid rate so that little attention is needed. Other fields are making very little progress and are a limiting item in design. The committee will direct its activities to lagging areas. Initially the committee is investigating main power sources and auxiliary items. Those systems, components and failure mechanisms presently under consideration by the committee are listed in Table III. The subject of failure is limited by the criticalness of the application. Attention is primarily being directed at those applications where a failure could mean loss of life or a loss of mission.

A member of a technical committee is a scientist or engineer who is directly engaged in research or development within the indicated technical area. These committees meet several times a year for small roundtable discussions on current activities, problems and solutions. These meetings are essentially a forum for technical discussions where ideas can be interchanged informally. Once a year each committee reports its progress to a larger audience in an open meeting. Technical papers on the subject are presented as well as the committee reports.

The secretary coordinates the work of the technical committees by providing logistic support including arranging meetings, and preparing and distributing minutes and reports. The associates are those people interested in the objectives of the group who wish to attend

TABLE III
TECHNICAL AREAS OF CONSIDERATION

Systems	Components	Mechanisms
Gas Turbines	Valves	Buckling
Steam Turbines	Structures	Creep
Gasoline Engines	Pressure Vessels	Shock
Diesel Engine	Blades	Fatigue
Compressors	Shafts	Fracture
Pumps	Sliding Bearings	Friction and Wear
Heat Exchanger	Gears	Lubrication
	Cams	Stress Corrosion
	Couplings	
	Seals	
	Rolling Elements	
	Pistons	

the meetings and keep abreast of developments. The MFWG is supporting a number of programs in the mechanical failures area. These are described in the following section.

CURRENT WORK TASKS OF THE MFWG

The following are the work tasks which are currently being investigated.

TASK TITLE: Mechanical Failure Technology Bibliography

TASK DESCRIPTION: The task is to conduct a literature search covering a period of five years (1962-1966) concerning all aspects of mechanical failure technology. From the search, those reports deemed pertinent will be categorized, indexed, and abstracted. Subsequent phases of the basic contract will call for a yearly updating of the Mechanical Failures Bibliography through 1970.

TASK TITLE: Shipboard Failure Detection

TASK DESCRIPTION: The objective of this work is to demonstrate that sensors and techniques for their use can be developed to detect very early or incipient faults before failures progress to the point where they degrade system performance before they are recognized. The work will include:

- Development of test data collection requirements and procedures;
- Data collection;
- Malfunction classification;

- Data analysis for malfunction detection and assessment of failure prediction capabilities using "Frequency of Binary Word" or other appropriate techniques.

TASK TITLE: Mechanical Failure Detection

TASK DESCRIPTION: By analysis and experiment, correlate the wear of spur gears with the noise and vibration which they produce.

Design and construct a preliminary model of a detector which will provide an indication of the severity of wear of the gears and which will signal when wear has proceeded to the point where a failure can be anticipated. The design will be based on:

- The results of data analysis and comparison using the techniques recently developed and
- Correlating information on internal gear mechanics.

Test the effectiveness of the detector by laboratory experiments and make refinements and improvements as indicated.

TASK TITLE: Material Failure Mechanism

TASK DESCRIPTION: This is a study of fundamental failure mechanisms in metals focused on the metallurgical investigation of the rolling contact fatigue occurring in roller and ball bearings. The work will include:

- Electron and optical microscopic study of fatigue damage surrounding flaked areas in failed bearing parts which have been operated under controlled conditions;
- Ultrasonic detection and analysis of incipient failures;
- Investigation of mechanism of stressed induced transformations.

TASK TITLE: Failure Indicator Systems

TASK DESCRIPTION: Perform studies aimed at obtaining a optical laser failure indicator and predictor system. Utilize the bearing noise signature of good bearings. Develop an optical laser spectrum of these bearings. A hypothetical bearing noise (failure) will be added to the signal and the difficulty in recovering it will be analyzed (including the problem of optical filters). Optical means of getting the frequency spectrum, signal filtering, and cross correlation, and the basic requirements on the length of sample and frequency resolution will be investigated. Finally, the advantages and disadvantages of doing this optically *versus* digitally will be discussed, as well as means of implementing this system.

TASK TITLE: Component Failure and Detection

TASK DESCRIPTION: A component wear failure analysis will develop the following items:

- Definition of failure in the component;
- Description of processes which lead to failure;
- Outline of measurements which must be taken to detect this failure;
- The accuracy and time scale of the measurements;
- Means by which these failures may be avoided for contacts, brakes, clutches and piston rings.

Based on these results, instrumentation will be developed which will detect the major failure processes. This instrumentation will subsequently be breadboarded and evaluated.

TASK TITLE: Material Failure Phenomena

TASK DESCRIPTION: The objective is to study the phenomena which occur when individual peaks of a metal surface undergo contact. The investigation covers kinematic, dynamic and thermal aspects of the *contact occurrence* in regard to lubricant film, geometry, forces, motions, wear and heat generation. This study of elemental contact occurrences and effects in rolling and sliding will include:

- Development of the method of testing and the development and modification of testing equipment;
- Experimental studies of contact occurrences in time, friction and temperature analysis, other parameters and correlation with surface geometry;
- Analysis of the parameters such as forces, stresses and temperatures with an interpretation of the data and phenomena explaining the relationship of these parameters.

TASK TITLE: Prediction of Catastrophic Failure of Naval Aircraft

TASK DESCRIPTION: Critically examine the accumulated data currently available within the spectrometric oil analyses program sponsored by the Naval Air Systems Command. This program consists of periodically sampling the oil from virtually all operational aircraft and analyzing it for metallic content on a spectrometer. For one aircraft type, evolve an analytic model for predicting in advance the occurrence of catastrophic failures by means of multiple regression techniques.

TASK TITLE: Photo Extraction Techniques

TASK DESCRIPTION: Improve the detectability of defects in many materials which are presently difficult to evaluate non-destructively. Since basic radiography, as well as photographic extraction techniques are well within the state-of-the-art, emphasis is to be placed on the optimization for each type of material with its peculiar defects. The expected outcome of this effort is a set of firm recommendations

for radiographic exposure, photo-processing and extraction programs, suitable for adaption as a recommended test procedure.

SUMMARY

Considerable improvements can be made to reduce mechanical failures in service. To accomplish this, detailed studies of the mechanical failure processes in components are needed. From these studies improvements will result in design criteria and in instrumentation to detect incipient failure or malfunctions. A mechanical failures working group sponsored by the Office of Naval Research has been formed to investigate this area of activity and to conduct programs to reduce the incidence of mechanical failures in service.

The Mathematical Sciences: A Report

Even though mathematics is a vital part of engineering and physics, many layman think of higher mathematics as a research field which is of interest only to mathematics professors. Today, thanks in part to the versatility of modern high-speed computers, the mathematization of science is extending into what the National Academy of Sciences refers to as "the mathematization of culture." In a three-volume publication, *The Mathematical Sciences: A Report*, the National Academy describes the wide range of human endeavors and national goals which rely upon mathematical science and which are now developing mathematical power to and beyond its present resources. Some of the new mathematical applications which appear in economics, business management, medical research, military logistics, and operations planning, call upon fields of mathematics which were formerly underdeveloped both in application and research interest.

In addition to an analysis of the role of mathematics in the national scientific context, the National Academy Report presents in detail the problems of undergraduate education in the mathematical sciences and makes 22 recommendations to educators and federal science administrators for improving mathematics departments. The recommendations acknowledge three essential goals for mathematical education:

- To train the needed numbers of mathematicians for specialized research, application, and teaching.
- To provide the mathematical background for those students destined to be scientists and engineers
- To raise the general level of mathematical interest and knowledge among the future leaders of the coming generation who will be confronted with management problems presented to them by computers and consultants using mathematical arguments for decision choices.

The relevence of these goals to the training of Naval Officers gives this report a special interest to the Naval Academy and the Naval Postgraduate School.

The book may be purchased through the National Academy of Sciences, 2101 Constitution Avenue, N.W., Washington, D.C. 20418 for $6.00. It contains 256 pages.

Navy THEMIS Program

The Office of Naval Research has awarded contracts, amounting to thousands of dollars, to 16 previously selected universities to carry out the Navy portion of the Defense Department's THEMIS project.

Project THEMIS was initiated in 1967 in a DOD effort to develop new scientific centers of research at academic institutions in response to long range scientific and technological requirements of the nation.

The project has two complementary objectives:

- The development of new science-oriented centers capable of contributing basic knowledge towards the solution of important defense problems of the future; and
- Stimulate research programs at universities which have not previously participated to a significant extent in defense research programs. All of the research programs are unclassified and are monitored by either the Navy, Army, Air Force or the Advanced Research Projects Agency.

The contracts awarded by ONR represents the first installment of funds for what are intended to be long-range research programs at the universities that will perhaps continue for several years. In 1967 there were 50 proposals accepted for research study with 16 of these going to the Navy, the same number as sponsored by the Navy this year. Contracts issued to the universities last year have all been renewed for continued investigations of their specific technology and science projects. New programs to other universities will be started in successive fiscal years.

The university proposals selected for Navy sponsorship in 1968, the annual funds allotted to them, and a brief description of the research to be conducted are listed below:

Catholic University of America ($394,000)

This university has been awarded contracts for two separate programs. One program funded at $201,000 will investigate cable systems employed between a vehicle to be moved and a powered vehicle as associated with naval and other applications. The objective of this program is to develop a body of knowledge applicable to the use of cable systems in deep-sea operations such as rescue, salvage, mooring, towing, sonar deployment, communications and ocean science.

The second program, funded this fiscal year at $193,000, will be concerned with the structure and time-dependent properties of glassy

materials and glass-forming liquids. Applications of these materials are essential to infrared transmitting glasses for high temperatures, deep submergence structures, aircraft windshields and laser glass with low scattering lasers.

Colorado State University ($465,000)

The Colorado University has also been awarded two contracts. An annual award of $215,000 is projected toward a comparison study of atmospheric lower winds over a variety of terrain conditions to those generated in laboratories for a similarity criteria. Favorable results will bear directly in problems involving the diffusion rates of radioactive chemical and biological agents, the dispersion of low flight-path missiles, local weather modifications, short wave length electromagnetic transmission as well as VTOL and STOL aircraft.

The second Colorado University study under a contract of $250,000 will be conducted in a field experiment in eastern Venezuela to obtain data on tropic weather since it presents problems different from that of temperate zones. An extensive meteorological-hydrological network, already existing in this region, will be used in an attempt to formulate weather forecasting rules and techniques in tropical climates. Special emphasis will be aimed at developing capabilities to forecast stream runoff and soil trafficability in the tropics. Knowledge of tropical weather conditions is vital to tropical naval operations.

Flordia State University ($230,000)

This program is aimed at research to advance the state-of-the-art in educational technology with the help of computer-assisted instruction. The main emphasis in the study will be an investigations of teaching strategies to optimize learning in the context of computer based or computer-managed systems. Navy training systems require advances and innovations in educational technology which will increase the efficiency of training.

University of Iowa ($200,000)

The object of this research program is to apply the theoretical principles and techniques of mathematics, linguistics, computer science, and engineering to the problems of automata theory. These efforts will supplement and support the existing Navy program in mathematical automata theory and linguistics directed toward significant naval applications in intelligence, command and control, and man-machine interaction.

Jefferson Medical College ($195,000)

Efforts will be made in this study to seek factors involved in the development of acute diarrheal disease with emphasis toward finding reasons why some individuals develop acute symptons while others do not when both are exposed to similar conditions.

The disease is a major cause of disability in military medicine and is prevalent in Marine Corps troops in Vietnam. Results of this investigation could lead to the development of preventive measures for the diarrheal state that often cripples naval operations where the disease persists.

Kansas State University ($288,000)

This is an investigation into the effects of nuclear or cosmic radiation on electronic materials, components, and devices. Theoretical models of electronic equipment will be used for the prediction of radiation-induced effects in these materials with an attempt to develop radiation resistant devices. Improved radiation-resistant components are required for the fleet, reactor control systems and satellites.

Lehigh University ($200,000)

Efforts will be applied under this contract to establish a quantitative understanding of the factors which influence recurring fatigue of materials and structures at welded joints. A knowledge of the causes of the fatigue behavior of joined structures, based on theoretical analysis and experimental observations, could aid design procedures prior to developments. The problem is revelant to a wide variety of naval structural applications.

University of Missouri ($200,000)

This program is directed toward a study of the cluster, growth and evaluation processes of liquid water drops, such as would occur in clouds. The detailed studies are aimed at the formulation of quantitative laws of these processes that could lead to the creation of a supporting technology for weather modification and forecasting cloud processes.

University of North Dakota ($263,000)

The contractor in this proposal will design, construct, and operate a unique high pressure facility for studying the effects of prolonged

exposure of animals in controlled hyperbaric environments. The main goal of this program is to achieve a recognized capability in the area of high pressure research as it relates to long term saturation exposures of animals to simulated deep submergence conditions. A comprehensive knowledge of animals to high pressure conditions is important to the Navy's Man-in-the-Sea program.

University of Oklahoma Medical Center ($202,500)

Research in this program will be directed toward employing an approach to uncover the physiological mechanism involved in shock. Particular attention will be paid to the role of the lung in contributing to the high morality rate of persons in the state of shock. Results from these investigations could lead to the development of suitable therapy for shock patients.

Renesselaer Polytechnic Institute ($202,500)

Experimental and theoretical research on radiation effects in gases, liquids, metals, and semi-conductor materials will be used for developing radiation detection devices and materials for use in intense radiation environments. Improved radiation resistant devices are required for the fleet, nuclear reactors, and for satellite systems.

Rice University ($175,000)

This program is slated for a study of the generation and detection of coherent and incoherent electromagnetic waves. A better understanding of x-ray optics, gamma-ray optics, and electromagnetic radiation would pave the way for improvement in navigational devices, low-light level and infra-red sensors as well as naval communications.

Southern Methodist University ($251,000)

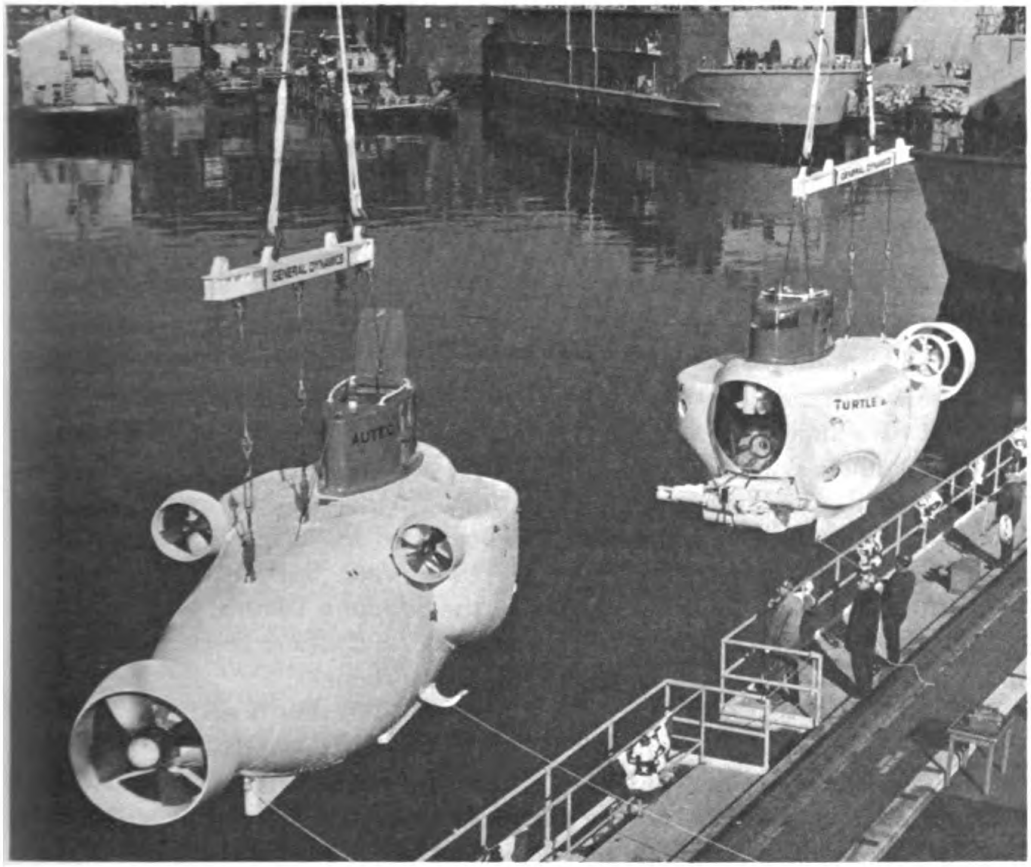
The contractor is developing statistical procedures under this program for the calibration and interpretation of signals from information processing systems which have associated instrumentation errors. The contractor will take the Navy relevant problem of underwater acoustic detection as a point of departure to suggest areas needing theoretical and practical attention. The procedures that are developed, however, would improve information processing systems and have many applications to other problems.

West Virginia University ($208,000)

The objective of this research is to develop a body of knowledge in vertical and short takeoff aircraft aerodynamics for typically Navy

operating conditions and environments. Information from this research is vital to the current interest of the Navy in developing a vertical takeoff aircraft that could be used in a variety of air/sea operations.

New Minisubs Launched



Mrs. Thomas B. Owen, wife of RADM Thomas B. Owen, Chief of Naval Research, sponsored one of a pair of deep-diving research submarines at a ceremony held at the Electric Boat Division of General Dynamics, Groton, Connecticut. Previously known as AUTEC I and AUTEC II, the submarines were renamed Sea Cliff and Turtle. Mrs. Owen christened Sea Cliff; Mrs. Edward J. Fahy, wife of RADM Edward J. Fahy, Commander Naval Ship Systems Command, christened Turtle.

The two 20-ton, 26-foot-long submarines are equipped with two elaborate manipulating arms designed to duplicate the motions of the human arm and wrist; they are capable of lifting 100 pounds at full reach. The submarines are equipped with emergency escape systems.

Turtle will maintain the underwater components of the AUTEC Range in the Bahamas. She will inspect the miles of cable in depths down to 6500 feet, her test depth. Her two manipulating arms will retrieve and repair the numerous sophisticated instruments, and she will be prepared to recover ship equipment which might be lost on the advance AUTEC Range. Sea Cliff, who will be assigned to the Woods Hole Oceanographic Institution, under contract with the Office of Naval Research, will transport geologists and geophysicists investigating the deep scattering layers of the ocean floor.

Down to the Seas in Concrete

Dr. Ralph A. Burton
Office of Naval Research
London

If one tends to visualize a concrete boat as something like a floating basement, it may be a surprise to know that trim and graceful craft can be made of concrete no more than 5/8 inch thick. If one has ever had a basement that cracked and leaked, he would examine a concrete boat warily and would find his credulity strained by the fact that the concrete boats are both watertight and damage resistant. Nevertheless, this is what one finds at the Windboats Construction yards, Wroxham, Norfolk, England.

Concrete as a construction material for boats was adopted by the Windboats Shipyard in 1959 when a civil engineer recommended that they build such a boat as an experiment. Following considerable development, both in concrete mix and in constructional methods, the company made several launches which could be hired out for use by vacationers. Such launches are subject to considerable abuse in the hands of amateur pilots and normally need major repairs at the end of a holiday season. Much to the surprise of the manufactures the contract launches were found to be intact, and capable of being left in the water until the next season came around. Further development led to the construction of more ambitious sizes of boat, and the firm now manufactures a trawler of 47-foot length and 13-1/2 foot beam. Such boats are ordered primarily for use off the coast of Africa, the Solomon Islands, and other such places where wooden boats have very short life, and where metal boats require more maintenance than the owners wish to give them.

The boat yard in England has built over 160 different boats, and presently turns out a fresh hull every five days. Interest in the boats has developed over the past year and licensees are being set up throughout the world. Mr. T. M. Hagenbach, owner of the boat yard, expects that, ultimately, his yard will only be concerned with research and development of pilot models for new applications. Presumably the experience so obtained would be transmitted to the licensees, and the main construction efforts would be carried out by these. He cites an advantage of the technique in that very little plant investment is required, and that only a reasonable level of skill is required of the construction crew. He said that garage mechanics or others who had a basic facility for use of their hands could be trained to manufacture concrete boats in only a few weeks.

Hagenbach points out that many kinds of concrete boats have been attempted in the past. Indeed, he notes that a ferro-cement boat was built by a man named Lambot in France over 120 years ago. The boat, only 3.6 meters long and 1.35 meters across the beam, is in the museum at Brignoles, France. The shell is approximately 35 millimeters thick (much thicker than a comparable boat would be under present design techniques) and is said to be in good condition, still. Similarly, Prof. T. L. Nerzi of Rome has used the technique in the construction of a dozen boats, principally to demonstrate that the material is suitable for the purpose. Concrete barges left over from WWII may still be seen

floating on the Thames. This background and the fact that amateurs can build a passible hull from ordinary cement seems to confuse the issue as to what Windboats have accomplished. The answer is that they have brought the technology to the point where the material is competitive and attractive for many applications. Hagenbach notes that 75 percent of their knowledge is in the form of things not to do.

The actual construction of the hulls is done in secrecy in large hangar-like buildings, and the outfitting is done by conventional carpenters and shipwrights. On entering the boat yard, one sees the hull of a large trawler (47 feet long, 13-1/2 foot beam) of pleasing form, outfitted with engines and propeller, ready for sea once its wooden deckhouse is set on it. The decks of the boat are of concrete and are made integral with the hull. There are no structural beams throughout the interior, since the concrete shell itself is strong enough even for a boat of this size. There are some flooring members on which the engine is set and the packing gland for the propeller shaft is cast into the concrete hull. Fish tanks, mounting plates for the winches, and the bulwarks are part of the concrete unit, so very little finishing is required. Presumably the deckhouse (which simply serves as weather protection for the pilot) could also be made of concrete if this were desirable. For such a hull completely outfitted as described the materials cost is only $1296 and construction requires 2752 man-hours. On this basis the cost will vary from nation to nation (time and overhead for labor in Spain, for example, may be as low as 75 cents an hour).

Hagenbach says the hull can actually be made 15 to 30 percent cheaper than a conventional one, and that the boat would run five percent cheaper than conventional ones. The ease of maintenance is as great a consideration as is the cost itself.

The firm has also built: a 35-foot pilot boat for the Persian Gulf, a smaller 30-foot trawler for shell fishing in Somalia, a 47-foot seiner hull for South Yemen, a luxury 26-foot four-berth cruiser for sheltered water cruising (here more care was given to the finish than in the fishing boats, so that the general appearance after painting in no way betrays the concrete skin), a series of 33-foot houseboat with fiberglass cabins and all necessary luxuries including air conditioning, a 16-ton auxiliary sloop with sails designed for use in the West Indies. They have built police patrol boats for Nigeria, pontoons, buoys, floats, and tanks for water as well as oil. They have even constructed a prefabricated swimming pool which is carried as a shell and dropped into a hole which has already been dug for it. The firm has not yet foreseen any upper limit in the size of a ship which could be made by their techniques, and they are simply waiting for an order to start building something bigger.

Near the boat yard one finds the smokey remains of a burned-out hull. An explosion inside the boat blew the cabin top 50 feet into the air and sent the mast 200 yards away, the interior of the boat was completely gutted by fire and all wooden construction was consumed. The explosion caused only minor cracks at the transom corners of the hull, which is now used to demonstrate that concrete construction is fire-proof. It is also used in another very convincing demonstration in which the observer is given a four-pound sledge hammer and told to break the concrete. The hammer simply bounces back with a deep ringing sound on contact with the hull, and repeated blows flake off only a thin layer of the external material down to the first layer of iron mesh.

—Continued on Inside Back Cover

On the Naval Research Reserve

NRRC 1-1 Held a Three Day Seminar on International Relations

A three day "Seminar on International Relations," sponsored by the Naval Reserve Research Co. 1-1 of Boston, was held at the new Bentley College campus in Waltham, Mass. November 15-17, 1968.

Participating in the series of lectures were Wilbert K. Carter, associate professor of sociology at Tufts University and a CDR, in NRRC 1-1, Dr. Robert Delaney, director of the Edward R. Murrow Center of Public Diplomacy, COL Thomas Dutton, USMC, faculty member of the U.S. Naval War College, Dr. Moses Steiner, professor of Near Eastern Civilization, Hebrew Teachers College, and Charles B. Vetta of the U.S. State Department.

The seminar concluded with a panel discussion, "Soviet Foreign Policy in the 1960's," moderated by Alexander Zamperion, assistant professor of economics at Bentley. Members of the panel included Allen Cameron, currently doing research at the Fletcher School of Law and Diplomacy, and who is compiling a two-volume collection of documents on Vietnam; Dr. Robert Legvold, assistant professor of government at Tufts University and author of a forthcoming book on Soviet policy in Africa; and Herbert L. Sawyer, assistant professor of government and chairman of the Government Department at Bentley College.

Dr. Benjamin M. Perles, professor of economics and chairman of the Economics Department at the host college and CAPT, USNR-R, NRRC 1-1 was chairman of the three-day program. LCDR Arthur H. Post, USNR-R, NRRC, was the coordinator and CDR Charles F. Davis, Jr., USNR-R, is CO of NRRC 1-1.

NRRC 3-9 Hosts Meeting

NRRC 3-9 recently hosted a Group Commander's meeting. COs, XOs and Group Staff Officers of Naval Reserve Group 3-10(S) attended. Units represented included several surface divisions, military training division, CBs, NROS, Dental Company and the Research Company, and geographically are drawn from the eastern end of Long Island. CDR S. J. Tassinari USNR, the Group Commander (a former CO of the Research Company) presided at the meeting and reviewed major points of common interest. CAPT B. L. Tanner, who recently reported to COM 3 as Assistant Chief of Staff for Naval Reserve and Training addressed the group and answered questions concerning overall policy and recent directives.

The Group Commander of 3-10(S), CDR S. J. Tassinari USNR-R, (not shown) received the undivided attention of (l. to r.) CDR L. A. Baker, X. O. of NRRC 3-9, CAPT B. L. Tanner, ACOS to Com3 for Reserve Training, CAPT V. P. Bond, C.O. of NRRC 3-9, CAPT B. B. Osthues, CNRG 3-19(M), and CAPT R. Zenneck, C.O. of NROS 3-6.

NRRC 9-6 Wins National Competition

This year's winner of the Research Reserve *Award for General Excellence*—was the Naval Reserve Research Company 9-6, Minneapolis, Minnesota.

Nominations for the award, which is given to the most outstanding Research Reserve company, were submitted by Commandants of the Naval Districts. LCDR Theodore E. Molitor, USNR, was in command of NRRC 9-6 during Fiscal Year 1968. Presentation of the award is planned for early 1969.

Among the accomplishments of the 21-member Research Reserve company for Fiscal Year 1969 were the following:

Inspection Grade	3.83
Ready Reserve Status	100%
Drill Attendance	92%
ACDUTRA Participation	81%
Correspondence Course Completion	23.8
Training Grade	3.68
Membership, Net Increase	+2

Also the unit planned and conducted the First Upper Midwest Research Reserve Seminar which was held 10 June to 21 June 1968.

After panel reviewed the records, inspection marks, and other award criteria it recommends the winning company. The panel was composed of the following officers: CAPT N. Mikhalevsky, USN, Director, Naval Applications and Analysis Division, Office of Naval Research; CAPT R. J. Stankowski, USNR, Director, Naval Reserve Programs Division, Bureau of Naval Personnel; CAPT W. B. Thompson, USNR, Head, Logistics Support Branch (Naval Reserve), Bureau of Naval Personnel.

NRRC 5-10, Bethesda; Maryland Wins Award

The Commandant's award was presented to Naval Research Reserve Company 5-10 for the outstanding non-pay reserve company in fiscal 1968 in the Fifth Naval District. Rear Admiral A. Atley Peterson, representing the Commandant of the Fifth Naval District, presented the award to Lieutenant Commander Alexander Barton, the former C.O. of 5-10. Commander Sherman Ross, the present C.O., and Rear Admiral R.O. Canada, C.O. of National Naval Medical Center, Bethesda, Maryland also participated in the ceremony.

The Naval Reserve Company which meets at the Naval Medical Research Institute Auditorium, Bethesda, Maryland is comprised of physicians, psychologists, and scientists who are in various fields of research. The average member in the company has 2.2 university degrees.

Parasitic Insects Studied by NRRC 11-7 Tucson

On the outskirts of Tucson, Arizona, the U.S. Dept. of Agriculture maintains a laboratory whose personnel concentrate on biological and ecological control of insects.

Parasitic insects from three continents are reared in order to study the potential effect of a massive release of these insects for controlling some of the most destructive caterpillar species in the world. Two parasitic flies and one parasitic wasp have been imported from India and one wasp from Africa for their potential use in non-chemical

LT Lin (NRRC 3-1) is viewing stages of a parasitic insect life cycle under the direction of CDR D. E. Bryan (NRRC 11-7). Other members of NRRC 11-7 on the left are LCDR R. L. Voigt and LCDR D. M. McEligot.

control programs. Seven parasite species indigenous to the U.S. are also under consideration because of their environmental adaptation.

In another section of the facility host material for parasite and predator culture is produced on diets synthesized within the laboratory. At peak output as many as 50,000 host insects may be reared per week.

NRRC 11-7 recently toured the laboratory guided by Dr. D. E. Bryan who is responsible for the work with parasites. Dr. Bryan, a CDR, MSC USNR-R is a member and former CO of Arizona's only Research Reserve unit.

Geomagnetic Investigations of the Arctic Basin

During the period 1961-1964 nearly 150,000 km of aeromagnetic tracks were flown in a survey of the Arctic Basin. A digital recording, proton precession magnetometer was designed and built for these surveys, automated data processing and display techniques developed and computer analysis methods devised. This was the first such automated system ever put into field operation and made the University of Wisconsin the first school with aeromagnetic capability. The system has been used in aircraft, ships, and vehicles and provides better that 95% reliability. It has been used by three universities and the U.S. Geological Survey.

One of the more significant findings indicates that large areas of the Arctic Basin are so magnetically disturbed that use of existing equipment for submarine detection would be difficult if not impossible. Anomalies in excess of 1000 gammas were common in these regions and magnetic gradients as steep as 700 gammas over 200 meters observed.

Selected Contract Research Reports

The contract research reports listed below have been extracted from U.S. Government Research & Development Report 68, No. 19 of 10 October 1968, No. 20 of 25 October 1968 and No. 21 of 10 November 1968. Government agencies and their contractors who are registered with the Defense Documentation Center of the Defense Supply Agency may obtain copies from the Center at Cameron Station, Alexandria, Virginia 22314. Abstracts of the reports are found in USGRDR 68, Nos. 19, 20 and 21.

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1969 International Conference on Photoconductivity to be held in the Department of Materials Science, Stanford University, Stanford, California, August 12-15, 1969. Additional information may be obtained from Prof. R. H. Bube, Local Arrangements Chairman, Department of Materials Science, Stanford University, Stanford, California 94305. Phone: Area Code 415-321-2300. Co-sponsored by the Office of Naval Research's Physic Branch and the Department of Materials Science, Stanford University.

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Down to the Seas in Concrete—Continued from Page 29

On one occasion a 34-foot concrete-hulled cabin cruiser was struck amidships by a 3-1/2-ton sloop traveling at 10 knots. The concrete cabin cruiser was able to proceed under her own power for repairs which took 21 man hours to complete. Damage consisted of deflection of the hull from true over an area of seven feet long and three feet wide. At the point of impact the hull was pushed in 3-1/2 inches. It was repaired by hammering the reinforcement back into position cutting away the damaged surface which was then filled, sanded and brought back to as-new appearance. In the view of the marine surveyor a similar craft with a timber hull would have been sunk.

In another case a boat was lifted up by a wave and deposited down on the upper end of a pile which produced a considerable impression in the hull and opened it to leakage. Pumps were able to keep the boat from sinking while a repair man went over the side and forced in concrete mix (in the presence of sea water) until the leak was fully controlled.

Although information on construction techniques is somewhat limited for proprietary reasons, it is understood that the hull is laid up on a frame of metal tubing which support layers of several different sizes of steel mesh. All methods of concrete construction are used in different portions of the craft. Guns may be used to spray the concrete; also ordinary trowelling as well as casting techniques are applied in certain areas. Many special tools have been developed by the shipyard for these purposes.

The thickness of the hull may vary from as little as 5/8 inch to as much as one foot. This latter thickness was used in the bow portions of a tug boat, where severe impacts would be expected. Because it is not practical to make the concrete much thinner than 1/2-inch thick, this material is a little heavy for small pleasure boats. At lengths greater than 30 feet, concrete begins to show an advantage over other methods of construction in that the stiffness of the hull obviates the necessity for the interior framing required by more conventional construction techniques.

The question that remains now is whether this will be a widely exploited construction technique or will be used in only a limited area of specialty.

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An Ammi barge carrying the TEKTITE I habitat is being towed out of the Philadelphia Naval Shipyard to be floated onto the well deck of the USS HERMITAGE (LSD-34) for its trip to the TEKTITE site off St. John, Virgin Islands. *See page 1.*

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