AVAL RESEARCH

REVIEWS

JULY 1969

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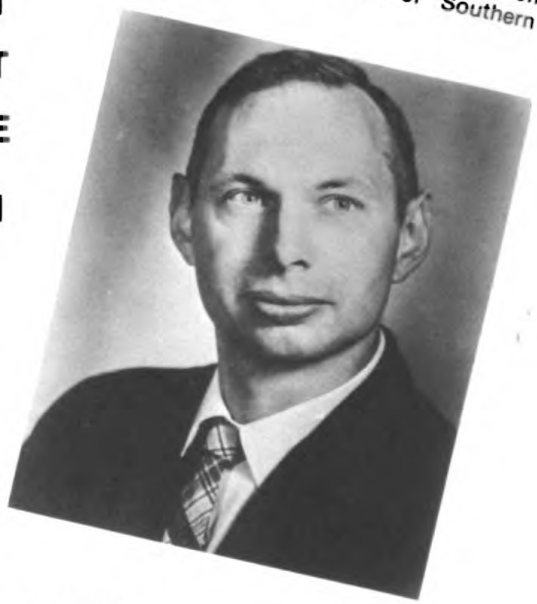
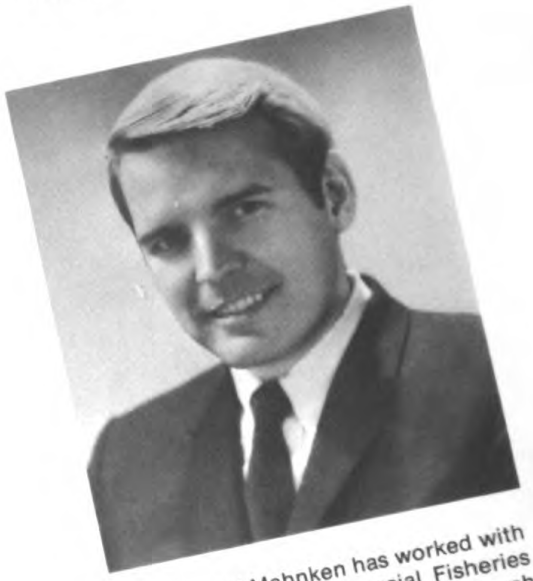
Mr. Richard A. Waller has been with the Bureau of Commercial Fisheries since 1961 and has worked in various research positions with the Bureau's marine programs. Currently, he is attached to the Bureau Central Office staff in Washington, D.C. He is Project Manager for Interior's part of the Tektite Project and served as crew chief during the operation.

Dr. Edward Clifton has worked with the Geological Survey since 1963, assigned to the Marine Geology Laboratory in Menlo Park, California. For the past year, his research efforts have been directed toward investigations of the origin and economic potential of black sand deposits on the continental shelf of Southern Oregon.



AQUANAUTS

Mr. John Van Derwalker has been with the Bureau of Commercial Fisheries since 1958 and has worked at various of the Bureau's field laboratories. He is presently assigned to the Bureau of Commercial Fisheries Biological Laboratory in Seattle, Washington, where he has been doing research on the migration patterns of chinook salmon.



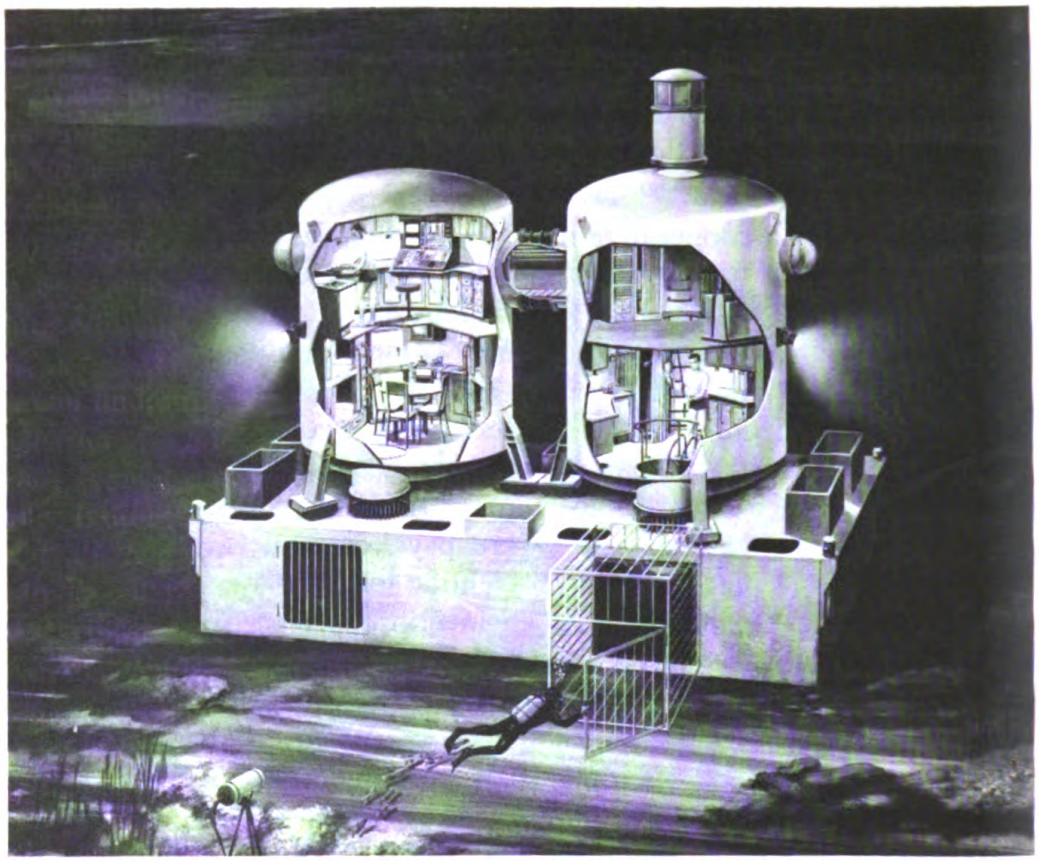
Mr. Conrad Mahnken has worked with the Bureau of Commercial Fisheries since 1963. His principal research efforts have been in marine zooplankton studies, and he is currently working on a marine aquaculture project at the Bureau's Biological Laboratory in Seattle, Washington.

The Nature and Significance of Project Tektite

Tektite 1 was a cooperative multi-agency/industry/university program designed to place four marine scientists, under saturated diving conditions, on the ocean floor for 60 continuous days. It involved the Departments of the Navy and Interior, the National Aeronautics and Space Administration, and the General Electric Company with assistance from the Coast Guard, the University of Pennsylvania, and other government, industry, and academic organizations. It was under the overall cognizance and management of the Chief of Naval Research. Among its principal objectives were psychological and physiological studies of crew behavior, marine scientific investigations, and advancement in undersea technology and engineering.

The Tektite 1 mission was conducted at a carefully selected isolated site near St. John, Virgin Islands, from 15 February to 15 April 1969. This was the longest period for human beings to live under saturated diving conditions, and the only such experiment which has utilized a controlled nitrogen/oxygen mixture in its atmosphere. During the experiment data was obtained daily from each aquanaut including blood and microbiological samples. These samples along with pre- and post-dive measures provided the basis for the biomedical studies. Sleep patterns and other behavioral data were monitored continuously from the surface. The aquanauts engaged in scientific activities, involving marine biology and geology, ranging up to 1000 yards away from the habitat for several hours daily. From both scientific and safety points of view, it was essential to monitor the entire living space of the habitat and each of the aquanauts when he was out in the water. The habitat atmosphere monitoring and replenishment system was particularly critical and was accordingly complex and designed with extraordinary back-up capabilities. The instrumentation provided for continuous television monitoring of the habitat by medical doctors and psychologists experienced in diving, and included mass spectrometers, gas chromatographs, carbon dioxide scrubbers, an air replenishment system, water, power, and communications from the top-side support van. To provide for decompression in event of emergency and for eventual ascent from the habitat, complete decompression facilities were maintained and manned by trained teams for the duration of the experiment.

The facilities for the experiment were constructed and installed precisely on schedule from October 1968 to the start of the experiment in February 1969. The experiment was completed with a perfect safety record within three minutes of a time scheduled many months previously.



On April 15, 1969, four aquanaut-scientists successfully completed a 60-day mission in this four chamber habitat at a depth of 50 feet off Greater Lameshur Bay, St. John Island, in the Virgin Islands. Each of the two vertical structures is 12.5 feet in diameter by 18.1 feet high. They are joined by a four and a half-foot diameter tunnel. The lower right compartment (wet laboratory) is primarily a wet work area and will be open to the sea at all times. The upper right compartment (engine room) is prime storage area for the food and houses the environmental control system as well. Upper left compartment (bridge) serves as the major laboratory center and the lower left compartment (crew quarters) is the living quarters for the four-man crew. The habitat was designed, built and furnished by General Electric Company's Missile and Space Division, which was also a sponsor of Tektite 1, along with the U.S. Navy, the U.S. Department of Interior and the National Aeronautics and Space Administration.

The interest of the National Aeronautics and Space Administration in Tektite 1 is related to their requirements to man space stations for long periods. The Department of the Interior has a primary interest in exploiting the marine resources of the ocean floor. The Office of Naval Research has broad interests including medical and behavioral aspects of ocean floor habitation and undersea technology and engineering. In common with many other agencies and the civilian community, the Office of Naval Research is interested in the straight-forward question as to whether this kind of habitat has promise to enhance man's capabilities to work or do research on the ocean floor.

Tektite 1 has, without question, represented a major step forward in the study of man-in-the-sea. Some of its major contributions are:

- An example of how several government agencies can combine efforts with industry and the academic community into a single pioneering undersea program of national significance.
- The first application of saturation diving technology to the civilian scientific oceanographic community.
- The execution of a marine science program, while inhabiting the ocean floor, which by its very nature demonstrated the advantages and flexibility gained by living in the sea.
- The development and implementation of the most sophisticated program for studying human behavior ever attempted in any operational environment.
- The development and implementation of a physiological program which demonstrated clearly the feasibility of men living for prolonged periods on the ocean floor while breathing a controlled mixture of nitrogen and oxygen.
- The development of nitrogen-oxygen saturation decompression tables for both routine and emergency purposes.
- The longest horizontal excursion dives ever attempted by divers living in a habitat under saturated conditions.
- The utilization of operational and developmental equipment in unique applications to undersea technology and engineering. Such techniques were used in particular during the lowering and emplacement of the habitat.
- The training and utilization of Navy Construction Battalion divers for underwater construction projects employing advanced technology.
- The design, fabrication, and utilization of a prototype undersea habitat.

The successful conclusion of Tektite 1 demonstrated, not only that men can get along together and perform safely and effectively on the ocean floor for extended periods, but has provided specific psychological, physiological, and marine scientific results can be applied to the nations space and undersea programs.

The National Aeronautics and Space Administration, the Smithsonian Institution, National Council on Marine Resources and Engineering Development, and a large segment of the remaining scientific community have expressed keen interest in the further exploitation of the unique facilities, experiences, and knowledge gained by Tektite 1.

Left to right: Aquanauts Van Derwalker, Mahnken, Clifton, and Waller being congratulated by Vice President Agnew

MESSAGES TO THE AQUANAUTS

At the end of the project, as well as during the mission when they broke the existing record for the longest continuous stay underwater, the aquanauts received congratulatory messages from the nation's leaders. Some of these messages are shown below:

Message to Tektite 1
From the President of the United States
(April 16, 1969)

Your record breaking venture into inner space is another milestone in human achievements. The aquanauts joined the astronauts as space pioneers. CONGRATULATIONS!

Message to Tektite 1
From the Vice-President of the United States
(March 17, 1969)

As Chairman of the National Council of Marine Resources and Engineering Development, I have been keeping abreast of your progress in the Tektite mission. This project is a significant landmark in man's continuing efforts to understand the vast undersea world and to work and live in this new and challenging environment. Your scientific competence, courage and pioneering spirit are the key ingredients which will ultimately spell success and a source of inspiration to all of us.

Congratulations on reaching your goals at the halfway mark on your 60-day mission. On behalf of the Council and the Nation I

wish all of you good health and God speed for the remainder of your undersea venture.

Message to Tektite 1
From the Secretary of the Navy
(April 17, 1969)

I congratulate the Project Tektite 1 team, the aquanauts and supporting participants from or working with NASA, Dept. of Interior, Navy, and General Electric Company on their outstanding accomplishment upon bringing Tektite 1 to a successful conclusion. This record experiment under saturation diving conditions was marked by a perfect safety record, was executed on schedule in all respects, and is a monument to a team effort directed toward broad scientific interests in the environment of the sea. Well Done.

Message to Tektite 1
From the Secretary of Interior
(March 17, 1969)

Congratulations as you pass the halfway mark in your mission. You have already exceeded the duration record for a dive of this type, and we are confident your work will open new avenues to a better understanding of man and the ocean.

Message to Tektite 1
From Commandant of the Coast Guard
(April 19, 1969)

I commend you and all who contributed to the success of project Tektite 1 and note with particular pleasure the outstanding safety record achieved in this pioneer underwater mission.

Message to Tektite 1
From the Chief of Naval Material
(April 18, 1969)

Warm congratulations on a highly successful completion of project Tektite and extension of diving knowledge and demonstrated capabilities. Noteworthy planning and execution of the experiment are sources of pride to the diving community. Achievements of aquanauts Waller, Clifton, Mahnken, and Van Derwalker greatly admired.

Tektite Press Conference

The Tektite project combined the management and technical skills of the U.S. Government and American Industry. The Federal Agencies participating in the project were the United States Navy, which directed the project; the Department of the Interior, which provided the aquanauts; and the National Aeronautics and Space Administration (NASA), which used the habitat as a means of testing how a space crew might perform on an extended mission. Industry was represented by the General Electric Company, which designed, built and furnished the undersea habitat to the project.

Tektite I began on February 15 when the four men entered their undersea habitat lying in 50 feet of water off the Virgin Islands and ended when they surfaced on April 15.

The aquanauts demonstrated that marine scientists living on the ocean bottom for long periods of time rather than periodically diving from the surface can considerably speed up studies of fish life leading to an increased food supply from the ocean. The Tektite I project also proved that ocean-bottom living in a pressurized undersea habitat for many weeks can be achieved in comfort and safety with no undue strain on the men.

The four aquanauts were constantly monitored by psychologists via closed-circuit television and open microphones, and a biomedical team checked the four men regularly throughout the operation. During the two-month period, the aquanauts stayed in excellent physical condition, except for an occasional ear infection known as "swimmer's ear," and consistently displayed good spirits.

During their two-month stay on the ocean bottom, the aquanauts spent 434 hours engaged in scientific studies in the water outside their habitat. One of their studies was to observe closely the habits of spiny lobsters, a source for the delicacy known as "lobster tails," and other marine animals. The geologist made maps of the ocean floor.

Another objective achieved by the Tektite project was the longest and most carefully observed period of saturation diving using nitrogen and oxygen as the breathing mixture. The Navy's Sealab series, which is concerned with deeper dives and military tasks, uses helium as the major breathing gas.

On April 18, 1969, a press conference was held at St. Thomas, Virgin Islands. Answering the questions from the press were the aquanauts: Mr. Richard Waller, Mr. Conrad Mahnken, Mr. John Van Derwalker, and Dr. Edward Clifton. Other members of the panel were Dr. Miller, Office of Naval Research, Scientific Coordinator for the Tektite Program; Mr. Pauli, ONR Project Manager; CDR Markham, Naval Medical Submarine Center, New London, Connecticut; Mr. Thompson,

Tektite Program Manager for General Electric; and Mr. Burcher, Tektite Program Manager for NASA.

Q. Did anything go wrong with the mission?

DR. MILLER: The mission went very well. It was conducted as planned. The only medical problem we faced was the ear infections* which, I believe you are aware of. We didn't have any serious problem with the conduct of the mission. The scientific programs were conducted as scheduled. The data will be available as soon as the analysis permits.

Q. I have been interviewing and talking to psychologists the last couple of days. And everyone I spoke to said they expected no problem during the mission. I am wondering how you justify a mission in which you do not expect any problems?

DR. MILLER: It depends on what kind of problems you are referring to. If you are referring to behavioral problems—we didn't anticipate any because our experience in missions of this kind indicates that people are so highly desirous of completing the mission successfully that they tend to hold down any differences that might jeopardize the success of the mission; this is both topside and bottomside.

From a medical standpoint it is the first time we've had nitrogen saturation for a long period of time. We didn't expect problems, but it was a completely unknown area. And the fact that we didn't have problems didn't mean that there couldn't have been. The decompression tables were developed for this program. They were successful, but they could have caused problems.

The fact that we were fortunate enough to have a smoothly operating mission in retrospect makes it look easy and people wonder why we did it at all. But I think we are very fortunate in that the planning was carried out successfully.

Q. Did you find anything of relevance in the debriefing of the aquanauts after the mission?

DR. MILLER: CDR Markham, would you care to comment on the tentative findings or any conclusions you might draw with regard to the biomedical debriefing?

CDR MARKHAM: As for the data that we have and what has been analyzed to this point, we can say that this has been a very safe operation.

Q. I remember you said at the beginning of the mission that one of the things that you expected to happen [to the aquanauts] was defatting of the tissues. Did that bear out?

CDR MARKHAM: That did not bear up. I didn't believe the engineering system could maintain the relative humidity at the level

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* During the mission all four aquanauts were plagued, some of them recurrently, by "swimmer's ear," an ear infection common to swimmers and divers, especially in warm waters.

On April 15 between 12:15 and 12:45 AM the aquanauts surfaced. The personnel transfer capsule brought the aquanauts from the Tektite habitat to the decompression chamber in groups of two.

it did. It did so well that they were better off down there than we were topside. And I have to take my hat off to the GE engineers for that. I didn't believe they could do it and they did it. It eliminated a problem that we had anticipated.

Q. Dr. Miller, could we now turn to the behavioral aspects of the experiment?

DR. MILLER: Dr. Radloff, would you care to comment, generally speaking, on what you consider appropriate for the behavioral program? I should say that Dr. Radloff has been responsible for the development and principally for the execution of the behavioral observation program, and is from the Naval Medical Research Institute.

DR. RADLOFF: I think that if we did anticipate some really serious problems, we would be well advised not to try to carry out a mission of this type, and the purpose is to document in a great deal of detail so that we can look at the interaction patterns of the men with each other, with the environment, and to get a fix on some data points so we can know in detail what to expect in future missions.

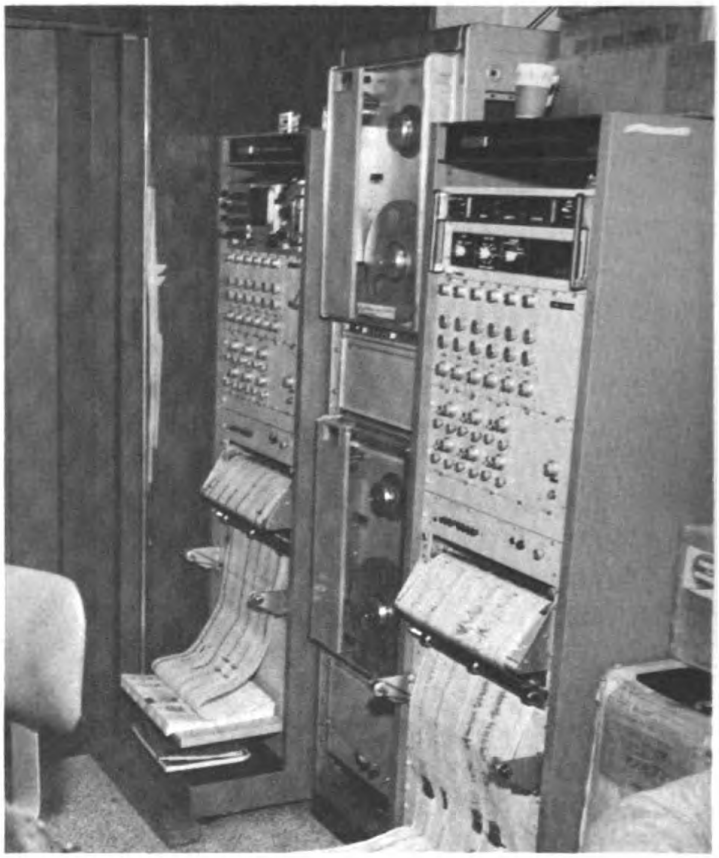
We gathered a tremendous amount of data; the analysis of it has only begun. But, we can chart such things as the moods of the men. When

Television monitors on the surface. One of the principal methods of collecting behavioral information was by closed circuit television, which allowed objective recording of observed behavior by personnel on the surface. One camera was located in each of the four habitat rooms. Two portable waterproof TV cameras with remotely controlled pan, tilt, zoom, and lens adjustment were 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 were set up in the control van. In addition, a video tape recorder and playback were installed.

they were down with ear infections, for instance, they were not able to work. We can look at the development of their work as they got accustomed to the habitat. It took some time for them to get accustomed to the environment.

But, in the behavioral area, I expected that these men would have a ball, would get along extremely well together because they were part of a situation in which they were very highly motivated. I am sure they would echo the comments of a Sealab II diver who said, "Why is everybody treating me as a hero. I didn't do anything that ten thousand other Navy divers wouldn't have given their right arm to do!" And given an opportunity like this, they rose to the occasion and performed extremely well. And as could be expected, got along probably better than they would have on the surface, in a mountain cabin for 60 days, where they wouldn't have had their primary interest to hold them there and to weld them into a group. So that I think this is probably the extend of what I can give now on the behavioral program.

Q. Can you tell us some specifics about the moods of the aquanauts when they could not work? How long it took to become used to the habitat?



Recorder used for obtaining electroencephalographic records (brain waves) from two aquanauts. The recorder was located on the surface support van.

DR. RADLOFF: I can't because these data are all in the great maw of the IBM machines or soon will be.

Q. Since you're experienced with Sealab II perhaps you can compare the two projects.

DR. RADLOFF: Well, the time period was much longer for Tektite. The working conditions were a great deal different. For Sealab II the water was dark and cold; visibility was poor because of the silt, just the opposite of the water conditions here. The men in Sealab II felt that they were very cramped and crowded, and that it was difficult for them to get out of the water. The four men on this team put in almost exactly the same amount of diving time as the ten men on Sealab II. In any pioneering program you are going to have this exhilaration of accomplishing unique and unusual things. And this is characteristic of both of the programs and I find the reactions remarkably similar, despite the dissimilarities in the environment.

Q. How did the habitat hold up?

DR. MILLER: I don't want to answer for General Electric. The men seemed to be very happy in it.

The four aquanauts are in the crew quarters. The crew quarters contain a small galley, bunks, storage space for personal equipment, and radio and television facilities.

Q. Let us go on to the four aquanauts. Did you eat any food that you got yourselves on the bottom: lobsters, fish, periwinkles? The diet might have gotten a little arduous after a few weeks. Did you catch anything outside the habitat?

MR. WALLER: I'd like to refer that question to Dr. Clifton. I think he was the one most frustrated by the diet.

DR. CLIFTON: I very much like sea food and the first thing I was told when I got down there is that there is a toxicity factor in the fish—*Salmonella*—which prohibits your eating a great many of the fish. And since no one seems to really know which fish these were, we didn't eat any fish.

I was very much interested in obtaining lobster because there is enough experience to know that you won't get sick from the lobsters. However, rather unfortunately, we had a lobster expert [John Van Derwalker] down there who was studying the lobsters. And he wasn't about to let anyone get to his pets.

In terms of the diet that we had, I think that we kept it varied enough. We had a pretty wide variety of food in the habitat. We were able to get fresh produce—milk, eggs, things like this—from the surface and, with a little bit of imagination you can take canned food and make it taste pretty good. And actually it was enough of a challenge that I think we enjoyed doing it.

Q. You didn't even eat one lobster?

MR. VAN DERWALKER: I think I'd better answer that one. I really had a hard time keeping Ed off the lobsters and so I bribed him by saying that when the mission was over we'd go out and get some lobsters. So, the next to the last day I took Ed as far away out of the study areas as I could get and still have enough air to get back to the habitat. And then I snared only immature males because I didn't want to interfere with the breeding that was going on at the time, and I didn't want to reduce the females because I wanted to keep the eggs going. So, we had four immature male lobster tails before the end of the mission.

Q. Continuing on food, I understand that there was an Easter Egg plant at Easter time, is that correct?

DR. MILLER: Would one of you care to comment on that?

MR. CLIFTON: Yes. On Easter morning, John and I planned to make an early dive and we got down to the wet room and there were little nests of grass here and there with jelly beans in them and a note from the Great Bunny who had apparently slipped down there in the predawn hours and left us some Easter eggs. It seems to me, recollecting on this, I could hear his regulator. But I wasn't wide enough awake really to know what it was.

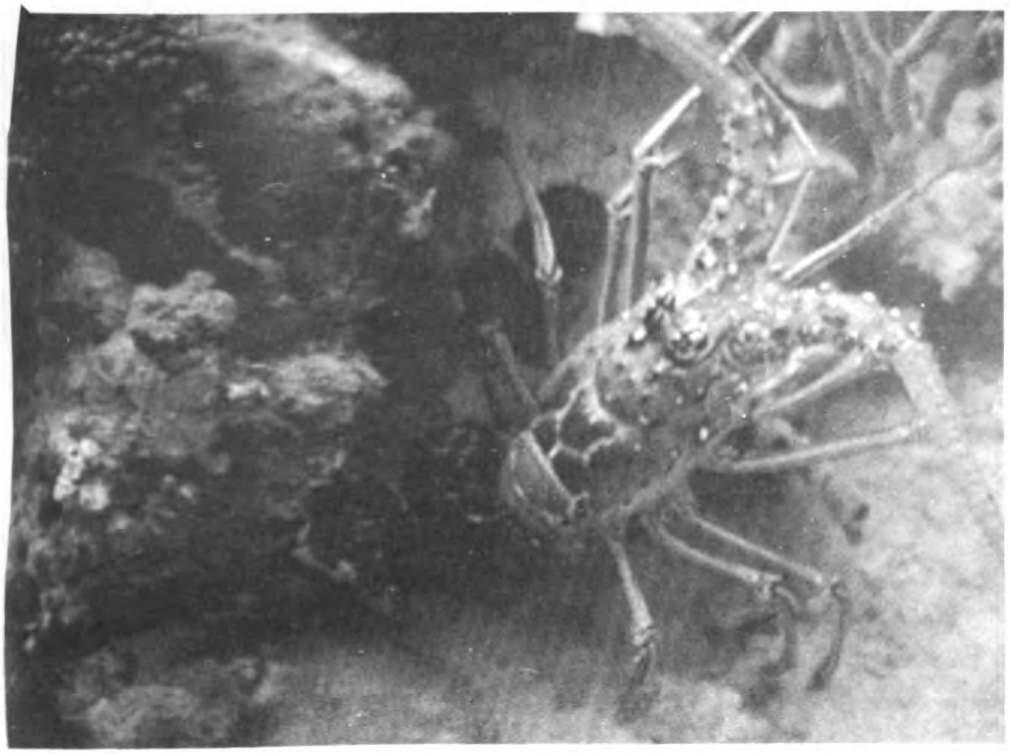
Q. I understand that the aquanauts lost about 11 percent of their total diving time because of ear infections, and I would like to ask them whether they feel generally satisfied with their projects. What they didn't get done? What they wanted to get done? And how they feel about their own work?

DR. MILLER: Rick, would you care to comment on that?

MR. WALLER: Yes. We've discussed this many times. Knowing that we had a specific amount of time to spend on the bottom there was some distress that we did lose this time with our swimmer's ear. However, we could have stayed down I guess another 600 days and still not finish all the things that really presented themselves to do. Things that were worthwhile doing and should have been done down there from that habitat.

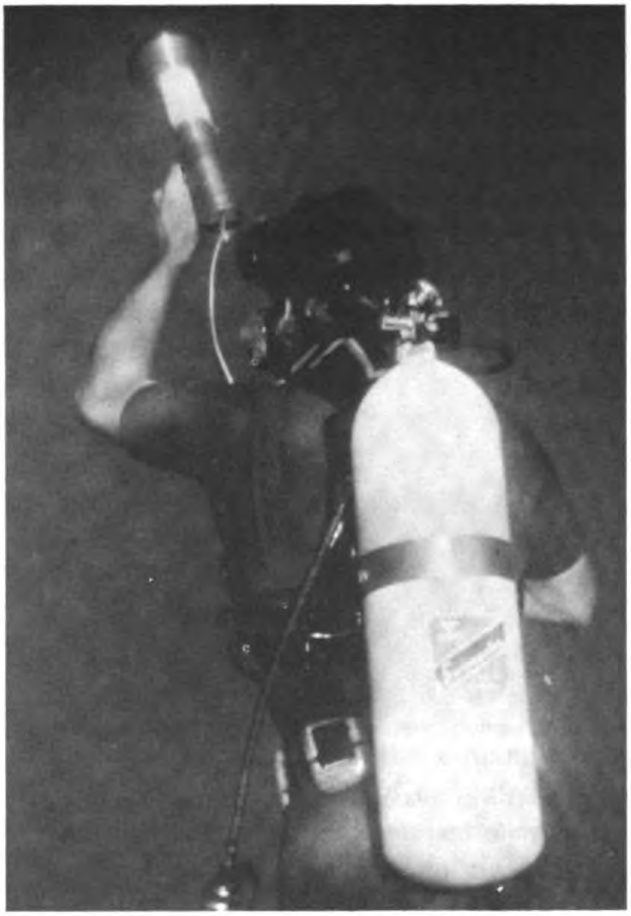
Q. What success did you have with the transistors in order to locate and track the lobsters?

MR. WALLER: Well, I don't know if everyone knows that we have a small transistorized tag that we could attach to the back of the lobster, and we have an underwater receiver with a hearing aid type ear phone that permitted us to hear the signal from a lobster. We attached these to several lobsters; and at night when they came out of their burrows, we could find them several hundred feet away. In fact, I think probably at night we could find them as far away as we could swim. But during the daytime when they went into the burrows, the signal was attenuated and we had to be within just a few feet, maybe 50 feet, to find one. But the lobsters tended to move back in the same burrow each night after they had gone out, or some nearby area. So when we had tagged



One of Van Derwalker's assignments was to study the habits of the Spiny Lobster. His studies have uncovered many breeding and migration characteristics of the lobster.

Coral gardens like this were seen near the Tektite site



Aquanaut using sonar gun to locate lobsters which had been tagged. Because of the tag the sonar could pick up the lobster thus supplying data for studying his movements.

lobsters we could usually find them either by going to the burrow they had occupied before or looking around the area in the vicinity of that burrow

Q. Could the results of any of your work be applied to commercial fisheries?

MR. WALLER: I think it could be applied not in fishing, but perhaps in management. I can't say because I haven't had enough time to really go through the data.

Q. Did the aquanauts say what they liked best, and what changes they would like to see made?

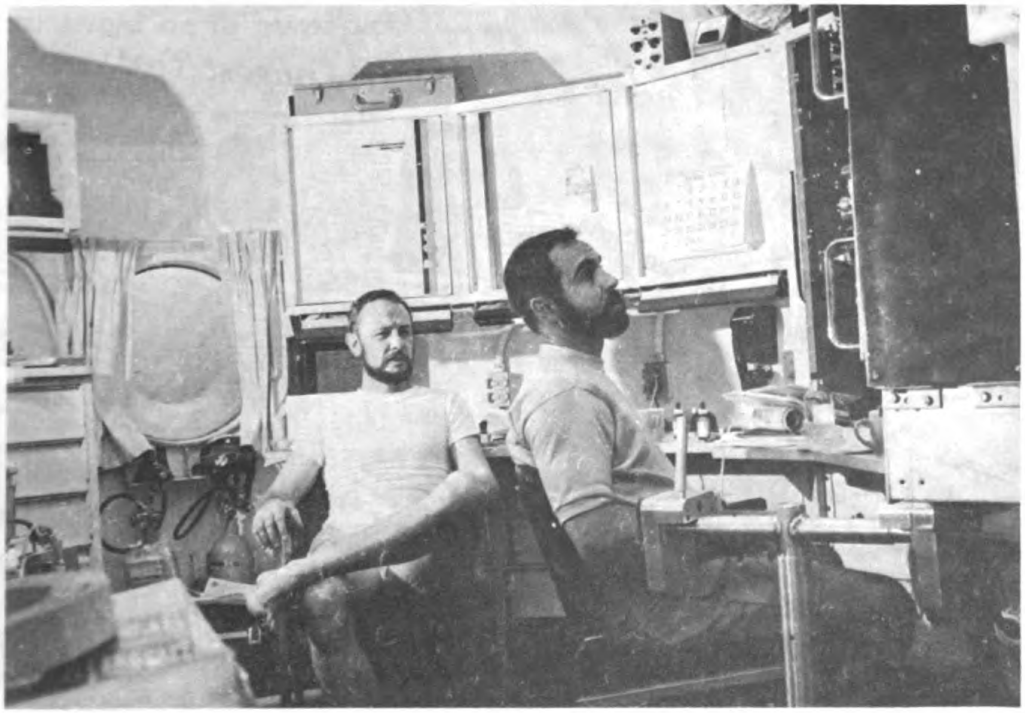
MR. WALLER: I think the largest change we've all agreed on would be in items of equipment: swimmer equipment, that we badly needed, and navigational equipment. When I say, swimmer equipment I mean breathing equipment that will effectively extend your range and time away from the habitat. The habitat itself performed very well. It was quite a tribute to a lot of engineers of the GE company. There may be some modifications that you can make for different type missions. But, overall I think the habitat itself provided a very fine prototype house for our use.

Q. What did you fellows argue about? Several times you shut off the mike in your engine rooms.

MR. WALLER: Because we shut off the mikes didn't mean we were arguing necessarily. We were responsible, primarily, for running the habitat. We were concerned about safety and many other things down there. A lot of people on the surface were concerned about these same things—our safety and supporting us. And on some instances we simply felt the need to discuss our operational techniques and come to some agreement amongst ourselves before we advised the surface on how we would best like to proceed on a given point.

Anytime you get into programs you are dealing with people. And people, you know, are quite different. We had just a few problems in the beginning establishing an operational routine, you might say. We had agreed to have open mikes and close-circuit television in the habitat explicitly, or primarily, for the behavioral program. We weren't really too concerned with being viewed and overheard all the time; but when we found out on one occasion that a slight difference of opinion with one of the watch officers up above had been monitored while we were discussing it, we decided that we could most forcibly show our displeasure with the open microphone being used in this fashion by turning it off for a few hours.

DR. MILLER: I would like to comment on that—not the incident but the idea. In Cousteau's early programs and others it was found that surface or earth-based outsiders initiated too much communication. In other words, in Cousteau's program there were so many people calling



Van Derwalker and Waller checking habitat environmental monitoring equipment in the bridge

a Giant Step in Conquest of Sea

Undersea projects
Hold much promise

ZESTIG DAGEN NAAR DE BODEM VAN DE OCEAAN

4 Aquanauts Surfacing

THE NEW YORK TIMES

Tektite Project Points Way Toward Man's Eventual Control of Ocean Deeps

But New Techniques Are Needed and Will Be Costly

Aquanauts Set To End Tests In Virgin Isles

Unlocking Secrets of the Sea

Men Work 4 Hours Daily Outside Lab

...I've just been waiting for it.
—Rick Waller

locada en el fondo del Caribe,
hará dar grandes pasos
n beneficio de la humanidad

ale Reported High
ng Four Aquanauts
ersed Since Feb. 15

Aquanauts Begin Training For Two-Month Sea Project

Aquanauts Describe 'Near-Perfect' Feat

By DONALD DRAKE
Of The Inquirer Staff

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After a Record Stay In 'Beehive,' Aquanauts Come Up for Air

s Say 60-Day Sea Stay asier After Experience

Half-way Mark for Aquanauts

Underwater Pioneers

17

up the aquanauts saying, "How are things going? What's new? Hello George!" and so on that finally Cousteau had to seriously restrict the communications being initiated by topside.

For operational reasons there are occasions when you simply must shut the mikes off. But our plan in Tektite was to minimize, as much as possible, topside initiated communications. There was a great deal of topside-initiated communication the first ten days when we were having equipment problems. Later on it got to be a more satisfactory situation.

A basic problem in isolation studies is how much communication is considered desirable by the people in an isolated state. Generally speaking it seems as though the people who are isolated should initiate most of the communications except for obvious emergencies. I think the mikes were off something on the order of three hours, at which point they were turned back on and the relationship was picked up and ran smoothly from that point on. There were other occasions when the microphones were turned off so that they could discuss plans, operations, and so on. There was no fuss made on these occasions and we don't think we had a serious problem.

MR. MAHNKEN: I'd like to make a comment on that. We were told at the beginning of the mission that we would be able to turn the open mikes off whenever we had something personal to discuss, which we did. And one other point to make is that we very much appreciated topside leaving us alone to do our work. There were many hours spent in transposing data and filling in our logs. And it was very helpful not to be bothered at this time, especially on the bridge where we were doing most of this work. So, with the exception of this one incident, which was really a minor incident, things went very smoothly with topside. We knew most of the watch officers before we went down and we considered them our friends; and that friendly relationship grew throughout the mission.

Q. Aside from the moray eel which you had to face at one time, was there any other marine encounter?

MR. MAHNKEN: I'd like to make another comment here. I have been credited for sixty days for killing the moray eel. I did not kill that eel. Mr. Van Derwalker and Dr. Clifton were the ones who dispatched the moray eel. So I decline any credit.

Q. Did you think there were any perils other than the eel?

A. No sir.

Q. What was the average number of gallons of fresh water used by each aquanaut each day? Is it comparable to what you would use on surface?

MR. THOMPSON: Its slightly more. I don't have the exact amount: I would have to go back to the data but I think it was of the order of about something in excess of 200 gallons per man. I would have to check to see.

Aerial view of Greater Lameshur Bay, the Tektite site, off St. John Island in Virgin Islands National Park

Q. If you were to go down again at what depth would you set the habitat?

DR. MILLER: This is really a hard question to answer. Various programs are designed to test different depths. Our primary interest in Tektite was not to test a specific depth but to pick a depth suitable to do a prototype mission. This is the first mission such as this that is designed primarily for marine research purposes. And it could well be that Ed Clifton might have some very interesting geological research off Oregon he might like to do in one hundred feet of water. Unfortunately, we can't apply all of the valuable data we've gotten at 50 feet to that. We've got to start over again. But, as far as I am concerned, the habitat could stay right there in Lameshur Bay for the next five years. A steady succession of marine scientists could go in and out and continue to accomplish very productive work.

The problem on depth is that when you exceed approximately 100 feet you begin to run into the problems of nitrogen narcosis. So, generally speaking, if the habitat or another habitat were to be used in a similar mission as this, a guess would be between 50 and 100 feet. When you start going beyond you begin running into a problem with narcosis. There you have to consider using other breathing mixtures.

Q. Did the aquanauts under storm conditions feel a surge on the bottom, or any noticeable feeling? What effect did it have? Could you tell whether it was raining, or sunny?

MR. MAHNKEN: The weather on the surface was very easy to monitor from below with the exception of rain. We could tell whether it was cloudy; we could tell whether it was sunny; we could tell to some degree the wave action at the surface but most of all we were aware of the surge. We could feel the surge due to the wave action from which we speculated on weather conditions at the surface.

Q. How did you feel the surge?

MR. MAHNKEN: You could feel it in your ear—the pressure changes in your ears.

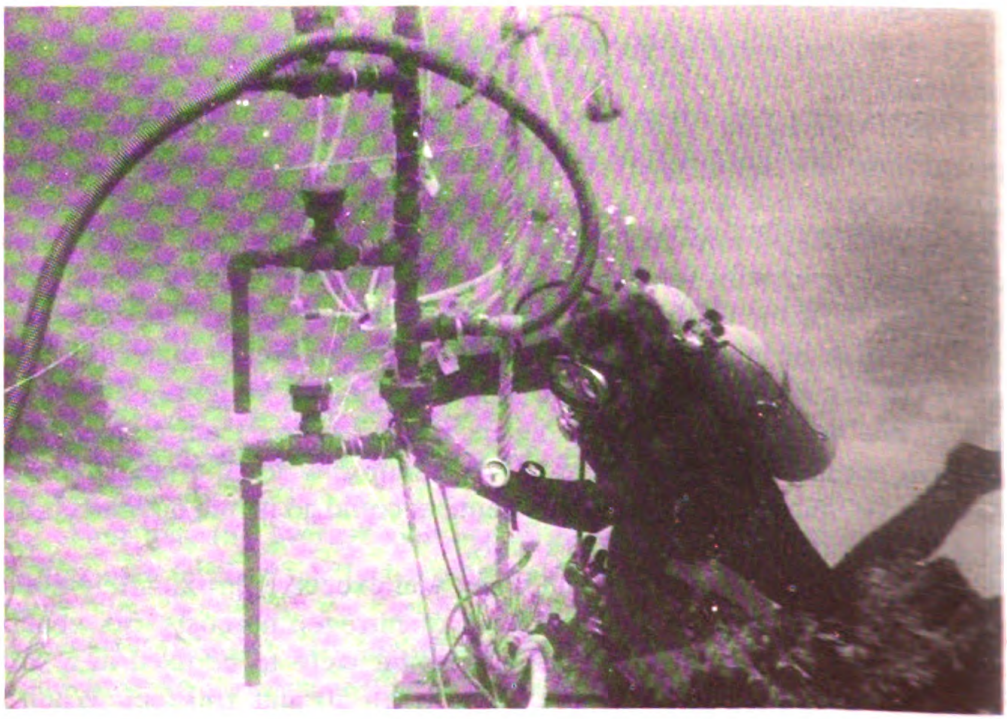
Q. What was the size of the eel and why did you kill it?

DR. CLIFTON: Mr. Waller went down and started putting on swim fins, and the eel decided to give him a little competition for the fins. So Waller tried to get him to go out in the shark cage where he had entered. He pushed him out of the hatch, but the eel got mad and swallowed one of the lobster snares, and swam out into the rocks. When he was in that condition, we did not want to be swimming around him, so we went out and did him in.

Q. How big was he?

MR. MAHNKEN: About three-and-a-half feet.

DR. CLIFTON: He was a lot smaller dead than he was alive!



A diver is assemblying the plankton standpipe. This equipment pumps water from various levels directly into the habitat for plankton analysis.

Q. How close to large marine life did you work?

MR. WALLER: We met a nice large porpoise one day swimming with us.

Q. Was he playing?

MR. WALLER: No, he stayed about 20 or 30 feet off; he was quite interested in us. He swam around us, but we didn't seem to be able to attract him any closer.

Q. Was he a behavioral scientist?

A. He could have been in disguise.

Q. How far did you go away—or did anyone go away from the habitat? Did you drop to any depth below 50 feet?

MR. WALLER: About the deepest we went down was something of the order of 70 to 75 feet unless I'm wrong. There simply wasn't any reason to go deeper because so many experiments were set up right around the reef area. We did this at one other nearby reef in the bay system that was probably on the order of 1800 feet away. And it seemed like quite a long swim at the time.

Q. What was the maximum radius of operation?

MR. WALLER: I think that's about as far as we went. We did routine swims up to 12 to 1500 feet away, and it got to be old hat after awhile.

Q. Could you tell us what was the factor limiting work outside the habitat? What limited the amount of time you spent in the water?

MR. WALLER: The limiting factor was in our breathing equipment. We, of course, can't say at what point we might have been limited by the need of thermal protection. It does get cool at times you know yourself, down there, when you are exposed a long time. There is a very definite need for improvement in this regard. To have to be limited to 45-minute dives and restricted in the range of operation is quite frustrating. You spend too much travel time and recharging time.

DR. MILLER: Rick, I wonder if you or one of the other fellows would describe what you would consider a typical day, starting with when you get up.

MR. MAHNKEN: Just one minute. I would like to make one more comment on this last fact. I think that Rick is very right here. The back pack* would have made the operation, in terms of the amount of time spent in the water not more successful, but it would have allowed us to stay in longer and range perhaps further from the habitat. In addition to the amount of time we could spend in the water a closed system is good from a marine behavioral point of view in observing a fish because you can go up to a fish and you don't have a stream of bubbles coming from your breathing apparatus to disturb the fish.

*A closed circuit breathing apparatus which filters out carbon dioxide and regulates breathing gas for several hours.

Q. With your present knowledge, and equipment, can a mission of this type be successfully run in the Arctic area?

MR. THOMPSON: We have a great problem in the thermal area of protecting man for a long time. There has been diving in the Arctic waters. People have for short intervals of time gone into them, but not for any extended period such as what we're talking about here.

The habitat as designed is a warm water habitat. In fact, our primary problem is cooling rather than heating. This is the reverse of the problem of Sealab and some of the other habitats that we know of. We had to worry about the heat problem and cool it down. Essentially, it is the lack of any thermal lagging; and as a result you could not use this habitat in waters that got very much lower than about 65 degrees or so without considerable modification.

Q. Would you compare helium-oxygen breathing mixture with the nitrogen-oxygen mixture used in Tektite?

DR. MILLER: Compare it in what way?

Q. I would be interested to know which mixture is better?

DR. MILLER: It's for two entirely different purposes. When you go beyond approximately one hundred feet you suffer from narcosis which is due to the nitrogen acting as an anesthetic. This is the reason for helium being added to a system for deep diving. It's not that it's better, but you simply cannot do deep diving under these conditions with nitrogen.

Now, the advantage in using nitrogen in shallow water is that you don't have the added expense of the gas itself, and the special equipment

Mahnken and Clifton using mass spectrometer which monitors the atmosphere of the habitat. A similar spectrometer was located in the surface support van.

that is required. Also you don't have this Donald Duck voice which complicates your communication. So there are a lot of advantages in shallow water to using the nitrogen-oxygen system.

Q. You knew in advance that you shouldn't attempt to go beyond 75 feet?

DR. MILLER: That's correct, yes.

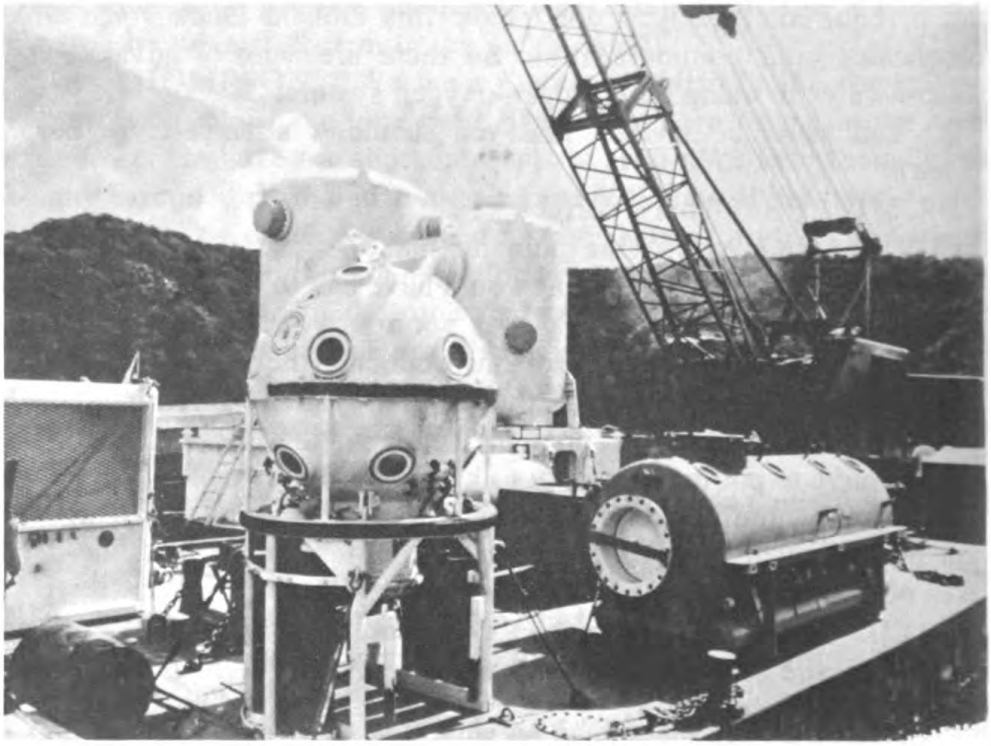
CDR MARKHAM: One point to make is that if helium were to be used, the design of the habitat would have had to be changed because of the cooling effect of this gas. As soon as you get helium into the atmosphere, you avoid the effect on producing the narcosis but at the same time the conductivity of the air that you are breathing in the water or in the habitat goes up significantly so that the amount of heat that you have to put in the habitat to keep man comfortable—the comfort zone, actually, the temperature—has to be up to about 85 degrees for man to feel even comfortable because of the amount of heat that is taken off the body.

Q. CDR Markham, you've had experience with both of these kinds of gases. Do you have any comments on the subjective feelings with breathing helium versus nitrogen?

CDR MARKHAM: I don't think that it's much different subjectively with breathing them. But probably the nitrogen atmosphere is more desirable for the facts that we've just discussed here—the thermo comfort and particularly communication. In other words, it's just impossible, as Dr. Miller said to use a nitrogen atmosphere probably around a hundred feet or below and that is something that still is a little bit in the grey zone of the unknown. Before somebody or anyone jumps off in one hundred feet of water they are going to have to find out, under controlled conditions, if it's possible to do it. We weren't even sure when we started this venture if we would see a narcosis effect at the depth we're in now. We tried it in chamber and found out that we did not have any effect; we really didn't think we were going to but we weren't certain—no one had done it.

Q. What do you think habitats like this will be used for in the near future?

MR. WALLER: I think the most immediate use of undersea habitats, and I'm quite biased, of course, is going to be for scientific purposes. Several other systems have already been developed for oil exploration that are more appropriate to specific needs of the oil industry. Manned habitats, I think, are going to have more use in scientific missions than any other type of undersea work. At least for the next several years. We, of course, don't know what decisions are finally going to be reached on questions of the sea bed and how military or non-military uses of the sea bed could be made between several powers. This may or may not restrict the military use of habitats; it's too far in the future to say right now but I think that several habitats could be operated very productively in various areas of our continental shelves.



Pictured here are the personnel transfer capsule (foreground), the decompression chamber (right) and the habitat in the background. The equipment is being carried on the surface support barge to the Tektite site.

Q. What are you going to recommend for the length of future dives? Are 60 days too long, long enough, or too short?

MR. WALLER: This is something I think that each individual is going to have to answer. I think, if you want to get maximum utilization out of one particular project as we did with Tektite by combining the behavioral experiment, biomedical experiment, along with our own specific marine scientific experiments, 60 days seemed to be the order of time needed. It could be that 30-day behavioral missions might benefit some agencies, and we could couple up.

As for the scientific use, my feeling is that a habitat should be left in an area where there are many interested people continually using it. Some groups could probably complete their studies in one week and would consider that well worth the price of such a relatively short decompression. Other people might like to stay for a much longer period. Others might like to be down a week and up a week. It would depend on each individual.

Q. How much longer could you have stayed down?

MR. WALLER: Well, I don't think any of us really know but I would say that we certainly could have stayed down a lot longer than we did.

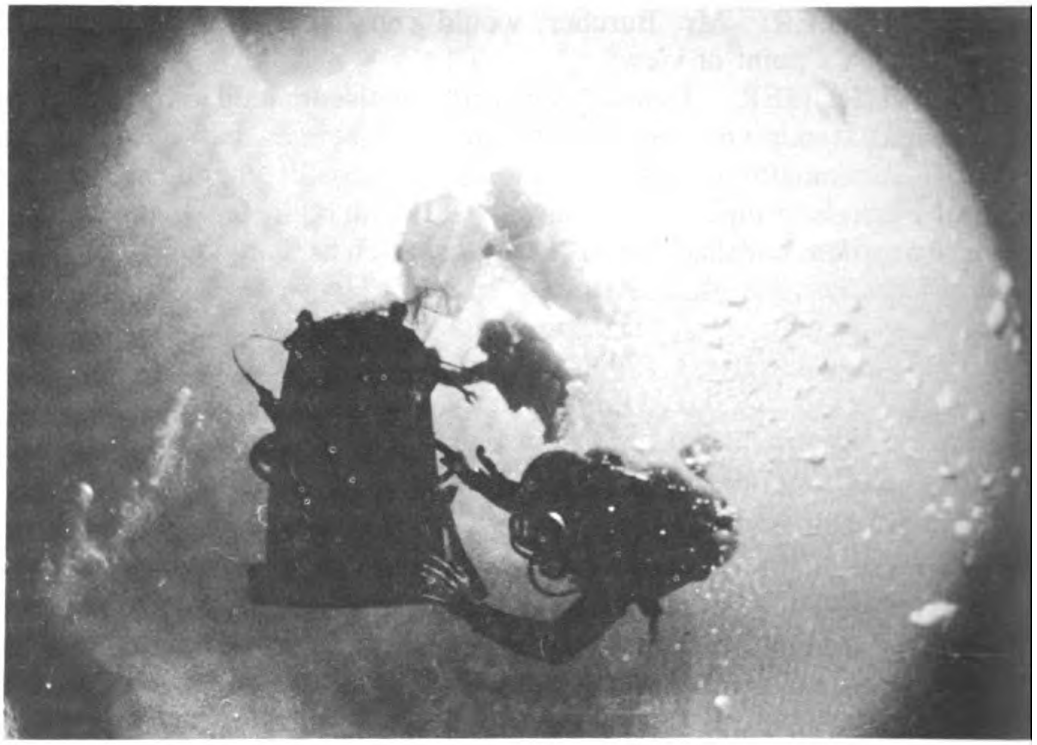
DR. MILLER: Mr. Burcher, would you like to comment on this from NASA's point of view?

MR. BURCHER: I think I can pretty much sum it up in that from the behavioral standpoint; we have found out that men can live together and do meaningful scientific work under stressful conditions for extended periods of time up to 60 days. We did not really feel that we would have a problem but this gives us assurance such as Tom [Dr. Markham] said of the oxygen-nitrogen mixture, "It's a data point." I think also, from the standpoint of the biomedical aspects, we had a number of biomedical experiments and hemotology tests. Not that they showed anything significant but I think that it was just the reverse: they did not show any great chances under these particular conditions, or under this particular environment.

Q. Can you tell me who originated the Tektite idea?

DR. MILLER: Two-and-a-half years ago, NASA and ONR got together and did some preliminary skull sessions so to speak on making

The aquanauts used transfer pots as pictured here to receive and send equipment to the surface



A big dumb waiter, which was used for transferring large equipment to and from the surface, is seen here being moved with the aid of an inflated bag. The dumb waiter was hoisted and lowered by a cable.

an anology between the ocean environment and the space environment: how similar they were, and how NASA could get some data out of the ocean environment at a much less cost than it would from a preliminary space mission. Then there were several studies: one with GE and one with another organization. As a result of this study effort which was funded and managed by NASA with help from the Office of Naval Research came the Tektite program as proposed by GE.

The initial discussions led to the study contract which concluded that the data gained on people working in the sea on meaningful tasks where the missions were real, could in fact be extrapolated to space where they had crews on meaningful tasks where the missions were real. GE proposed to the agencies the possibility of conducting this program. Shortly after, we contacted Mr. Waller of the Interior Dept. because of his involvement in Sealab to see whether he could develop some interest in this kind of a program in the Department of Interior. He was able to do this which brought in the third major government agency and added the fourth major partner. And that's sort of how the program got started.

DR. CLIFTON: I would like to raise one point about the significance of Tektite that seems to have been generally overlooked. And that is: what was done in acquiring knowledge working in an underwater

habitat toward scientific research. For example, when I went into this service, as a geologist I was not at all certain that I would be able to conduct a favorable research program on the ocean floor while living on the ocean floor. I didn't know, for example, what the constraints would be towards conducting research. I think one of the most important things was finding out how limiting any such constraints would be. As a result of the experiment, I am confident that a great deal can be done. There is a tremendous amount that can be accomplished from an underwater habitat by a scientist. And with the proper research problems success doesn't really depend upon water depth. Give us the hardware, and the time that is required to complete the job and we can do it. And I think this is the one thing Tektite has proved; that the underwater habitat is a good base for conducting scientific research.

Q. Do you think that you collected more data than you could by diving from the surface?

DR. CLIFTON: Absolutely. I could have collected probably twice as much under the proper conditions; that is with the proper equipment and if my diving time was devoted entirely to geological work, rather than to split half-and-half between geological and biological. Each one of us had to devote about half of his time to assisting on other people's programs. If instead of four programs down there we had two programs, we would have been able to accomplish twice as much. It would not be at all different to get in six to eight hours of research time on the ocean floor from the habitat each day as compared probably with three hours of diving from the surface because of the decompression problem.

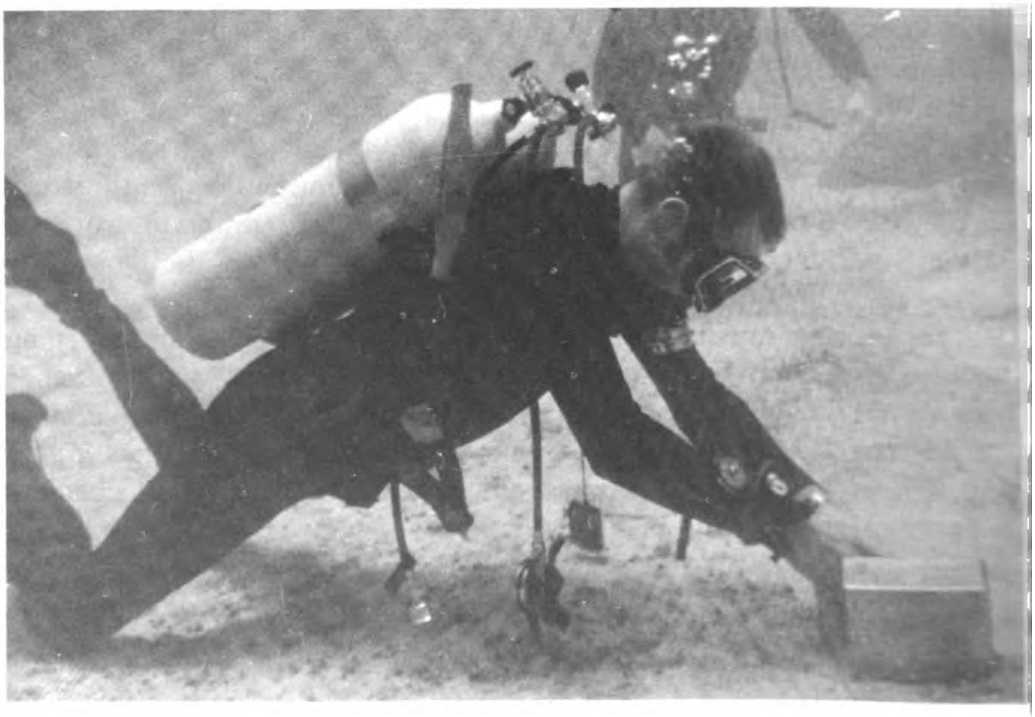
Q. Was not your average time in the water much less than six or eight hours?

MR. WALLER: Well, sometimes there are evils in using averages. We lost a lot of time with the ear infection. We had several minor problems to which we had to devote our entire attention. We had lots and lots of other programs separate and distinct and different from the Marine Sciences Program. There was a major thrust in the biomedical effort here. All of these things cut into our time.

We're talking about four people here: We'd get up in the morning. Somebody had to fix breakfast. Somebody had to wash the dishes. There wasn't enough room to leave things out. Two other people might start getting ready to go out which involves getting their equipment ready. Then the other two had to spend quite a bit of time simply checking the system over and making sure everything was right. We had to spend quite a bit of time changing the baralyme to keep the carbon dioxide levels down at the appropriate level. When I was communicating with the surface, my partner had to wait for me and I was keeping him from his job outside.

Each dive had to be interrupted about every 45 minutes with a 45-minute break for recharging—not counting travel time. And then there

Clifton examining a geological specimen



An aquanaut is seen here with a box used for geological experiments

were two more meals that day, more baralyme changes. I think we're pretty well agreed that a four-man crew is just a little too small; that we ought to consider having a five-man crew. And then maybe work into a six-man crew.

I think that we've learned a lot on the engineering side of the house. We've really looked hard at a lot of equipment problems that we had, and I think we can overcome them now. Even if we hadn't come out of the project with any meaningful scientific data, I think the project would have been worthwhile. The most amazing thing to me, and to the others that are familiar with the project is that in several aspects of the research down there we've done some of the most productive work that I've ever seen in such a short time. I think that this 60 days, in some areas, might compare to a year in another normal program.

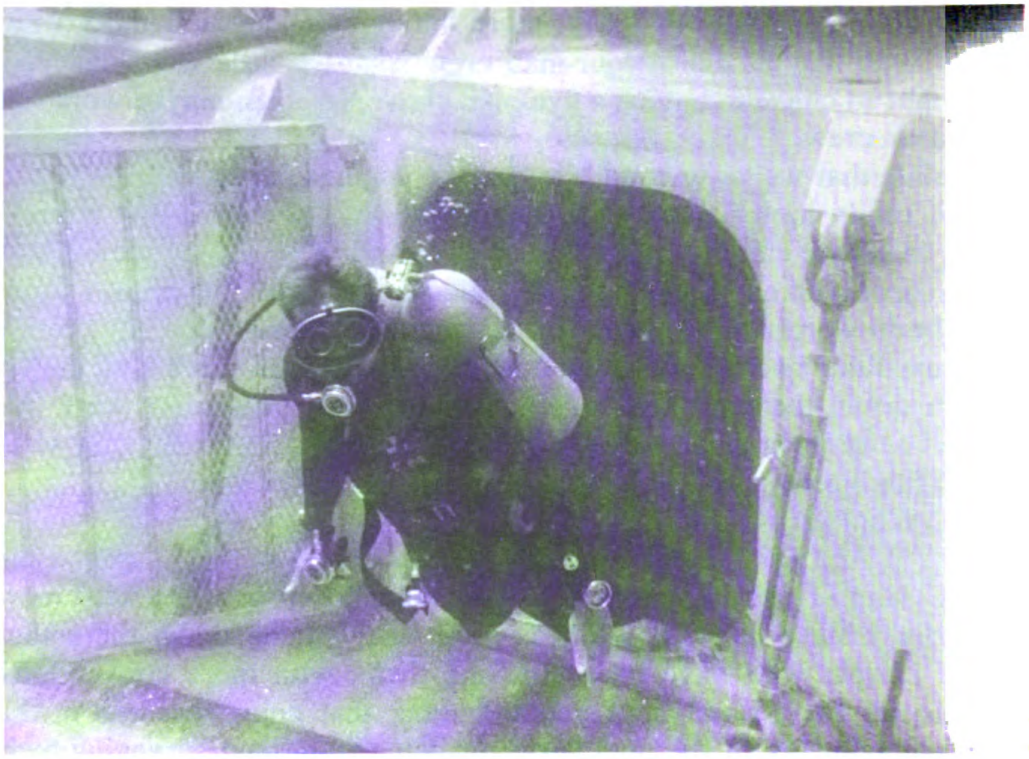
Q. What areas?

MR. WALLER: Well, the most specific thing I can get to right away is Mr. Van Derwalker's lobster study. I think that he has gotten more valuable insight into what lobsters are really doing down there than many people who have been studying them, with more conventional techniques for a number of years. I think that doing research in this way is analogous to the land surveyor going from land surveying techniques to aerial surveying techniques. Your equipment gets more complex, more expensive, but you can sure see a lot more.

DR. MILLER: I think there are two other points here: one, although the surface aquanaut average diving time was very close to the aquanaut living in a habitat, their average depth was about 30 feet less. And we might consider also the fact that Tektite is the first shot; if you go down 75 or 90 feet, your bottom time from the surface is very short—both in a single dive and in a repetitive dive the same day.

Secondly, a point which hasn't been made is the tremendous flexibility which a program of living on the bottom has. There were some significant changes in the direction of research as a result of exposure to the bottom. For example, Mr. Mahnken shifted a substantial portion of his time from one study to another because of his ability down there of conducting research on something which he didn't know ahead of time. Would you care to comment on that?

MR. MAHNKEN: Well, yes. When we first decided we were going to participate in Tektite we wanted to design some instrumentation which would be unique to an underwater habitat of this sort. Then inspecting the prototype pieces of equipment, we come up with problems. One of the problems was with my plankton standpipe; we found when we got into the habitat the pump had been burned out and we attempted to replace it as fast as possible. We purposely designed our research programs so that we had more work than we could possibly do on the bottom in case our planned activities did not work out. I found that one of the most valuable aspects of operating from a habitat of this



An aquanaut leaving the habitat from one of the four openings at its base

sort was that you could get outside of the habitat. That's how I designed my research program; prior to the equipment breakdown, I was spending a lot of time in the habitat.

I found an interesting situation on the reef concerning a group of small quinnat shrimps that lived on anemones. The pharmaceutical industry, and especially toxicologists have been interested in these organisms because they are immune to these anemones. These shrimp live on the anemones for a specific purpose: their light blue bodies contrast against the dark background of the anemones and by clicking their antennae they can attract fish. When these fish come into the anemones, the shrimp jump off onto the fish and eat external parasites from the fish.

It was my feeling that anything that I could learn about the behavior and the ecology of these shrimp would aid in toxicological or pharmacological studies. I spent most of my water time that was allotted to me studying these shrimps. In approximately 40 days I completed what I feel is a very good study. To me this is really icing on the cake. As we picked up new ideas swimming across the reef, we were able to modify our research plans so that these problems were studied.

My feeling is that we went down with some good questions, and we came back with some good answers. But we came back with some real good questions too that we discovered while we were working down there.

Q. Dr. Clifton, did you learn anything that can be applied to offshore oil drilling operations?

DR. CLIFTON: I think probably so when we get all the data put together. We have quite a bit of data on a reef and on the reef assemblage; coral reefs are known producers and reservoirs of petroleum. We have a lot of data and samples that have yet to be processed. But we've got them all tied into a geological framework now. And using this, we can tell a great deal about the pattern of sedimentation on a contemporary reef that can be extrapolated to ancient reefs that are found in the rocks.

Q. Rick, did I understand that you feel it is possible to remain under sea for as long as a year?

MR. WALLER: Well, I don't see any reason why that habitat itself down there wouldn't stay and operate well for a year. I don't know if anyone has or is going to want to stay down for a year.

DR. MILLER: Well, there are many cases where people are isolated in various conditions such as lighthouses and wintering over in the Antarctic. There are a number of instances in which people have survived alone or in small groups for much longer.

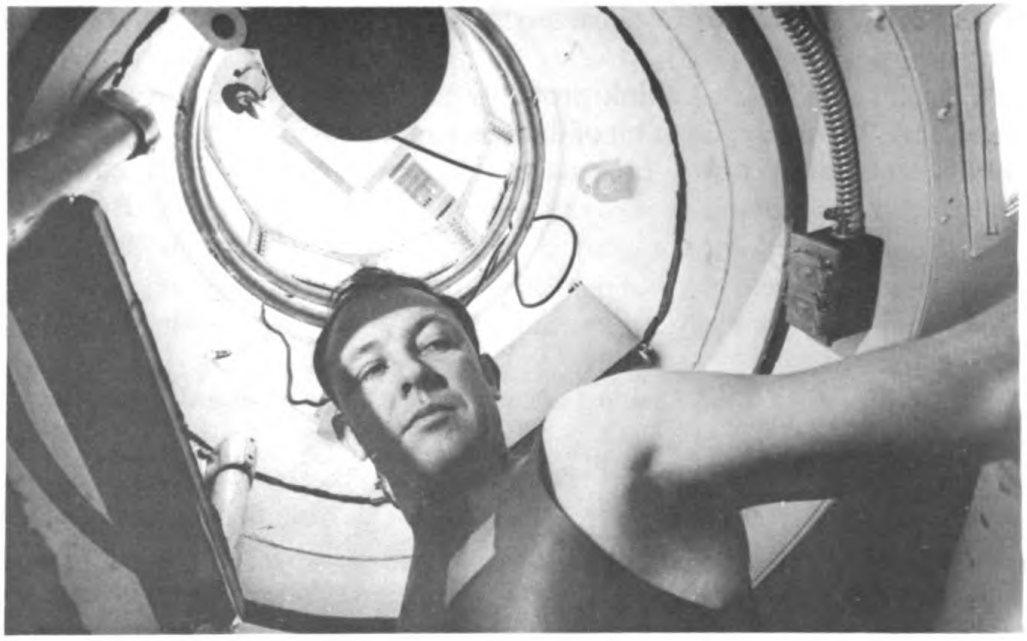
The engineering problems and maintenance of a habitat where your equipment is not designed necessarily to run for a full year might be a limiting factor. Mr. Thompson, would you care to comment on that?

MR. THOMPSON: The majority of the failures were minor and none of them were what we call "mission critical." To have continued for another 30 days would have made me a little more nervous. I would limit a continuous running of this particular habitat to about 90 days or four months at the most.

MR. BURCHER: One of the aspects that we may be looking into is the rotation of crews for extended earth orbital missions such as the rotating of crews on a 30-, 60- and 90-day basis. A habitat like this could possibly give us some additional data on this particular point.

Q. Would you compare conducting research while living on the bottom versus operating from the surface?

DR. CLIFTON: Yes, I think that there were certain aspects of the geological program that could be conducted much more favorably from the surface than they were from beneath. Larry Phillips, the backup geological aquanaut, was working throughout the project mapping on a more or less regional basis where I was mapping on a very detailed base. Without the capability of a wide range, which of course the surface people have, but which we did not have, I could not put together a regional picture of the whole pattern of sedimentology and bottom facies distinctions that Larry was able to put together. I think most programs were dependent on how much time you spent in the water. There was relatively close-in, very detailed mapping, and sampling, for which the habitat gave you the real potential of having more time on bottom than working from the surface.



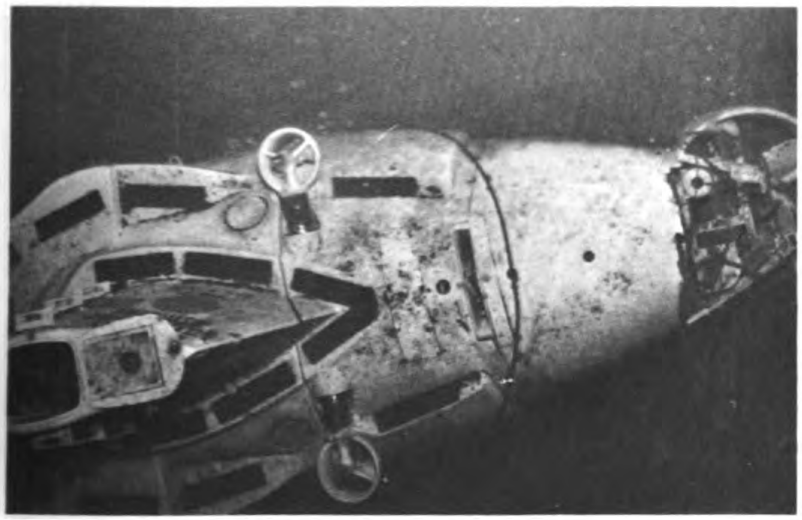
Van Derwalker climbing into the observation cupola which was on top of the engine room

MR. VAN DERWALKER: I wonder if I can made a comment to one of the questions about diver time in the water. I think we should make it clear that the people are not the limiting factor in the amount of time spent in the water at this time; it is technology. I think that as technology advances, the human is going to spend the time in the water. I don't think we had any heat problems. And I think we could have spent a lot more time in the water if there weren't tasks somewhere else that needed to be done. I wouldn't want anyone to go away thinking that we couldn't have spent more time in the water if we hadn't had the responsibilities in other places.

DR. MILLER: I would like to add that the total diving time of this program by the aquanauts on the ocean floor was 434 hours. You start averaging this out and it turns out to be around two hours per day per man. That is overall, including days when they were suffering from ear infection, fixing equipment, and so on. There were many days where the diving time of a given man could reach as high as five hours. If we change a crew composition so that perhaps future crews don't have to spend so much time on maintenance and things of this sort, there is no reason even with existing equipment why it shouldn't go up significantly. With the additional sophistication that we expect, in the very near future, it can certainly go up. And as you go deeper, even with the same amount of diving time you can no longer begin to compare it with work from the surface.

U.S. GOVERNMENT PRINTING OFFICE : 1969 O - 357-075

MIZAR PHOTOGRAPHS ALVIN



The Navy's deep-diving research submarine ALVIN, resting on the ocean bottom in 5000 feet of water 120 miles south of Cape Cod, has been successfully photographed by the USNS MIZAR, the Naval Research Laboratory's oceanographic research ship.

ALVIN, which has a depth capability of 6000 feet, sank on Octover 16, 1968 as the result of an accident while it was being prepared for launching. No lives were lost. ALVIN was operated by the Woods Hole Oceanographic Institution for the Office of Naval Research.

The MIZAR photographed ALVIN during the seventh pass over the general area where it sank. It was actually found to be located about 300 yards from the position previously established when it went down.

The initial photographs show the 15-ton submersible to be in an upright position sitting in two or three feet of mud. They show the shrouded propeller, which broke off during the accident, still connected to the rest of the hull by hydraulic hoses.

It cannot be determined from these first photographs what further damage may have been caused when ALVIN plunged to the bottom. Any final decision on attempts to salvage ALVIN must await a study of the photographs and estimates of cost of salvage *versus* the salvage value of the submersible.

The MIZAR, which located and photographed the remains of the submarine SCORPION off the Azores last fall, uses equipment especially developed by NRL for deep sea search and inspection. The 22-foot research submarine is the smallest underwater object to be a search target for the NRL oceanographic ship, which is owned and operated by the Military Sea Transportation Service.

AVAL RESEARCH REVIEWS publishes highlights of research conducted by Navy laboratories and contractors and describes important Naval experimental facilities. Manuscripts submitted for publication, correspondence concerning prospective articles, and changes of address, should be directed to Code 109, Office of Naval Research, Washington, D.C., 20360. The magazine is listed for sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C., 20402. Subscription price: $1.75 per year in the U.S. and Canada; $2.25 per year, foreign; $0.20 per individual copy. The issuance of this periodical approved in accordance with Dept. of the Navy publications and printing regulations.

NAVSO P-510

IN THIS ISSUE

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Tektite I was a cooperative multi-agency/industry/university program designed to place four marine scientists, under saturated diving conditions, on the ocean floor for 60 continuous days. It involved the Departments of the Navy and Interior, the National Aeronautics and Space Administration, and the General Electric Company with assistance from the Coast Guard, the University of Pennsylvania, and other government, industry, and academic organizations. It was under the overall cognizance and management of the Chief of Naval Research. Among its principal objectives were psychological and physiological studies of crew behavior, marine scientific investigations, and advancement in undersea technology and engineering.

On April 15 about 8:00 PM the aquanauts left the deck decompression chamber, which is seen at the right, to be greeted by their families. After the aquanauts surfaced they had to remain in the decompression chamber 19 hours.

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