Australia. This unique service uses transportable recompression chambers and includes the necessary personnel and aircraft. It solves the problems caused by the distance between individual hyperbaric facilities. In addition, the service is provided to the South Pacific region.

It is important to emphasise that the DES cannot task the NSCA directly, and that this will always be the responsibility of regional ambulance organisations. The overall service available to Australian diving casualties consists of: the DES as an emergency advisory body; the various ambulance organisations which will control and co-ordinate the retrievals; the NSCA hyperbaric retrieval service acting at the direction of the ambulance organisations; and the various hyperbaric units capable of definitive treatment.

These combined resources will significantly reduce the morbidity and mortality arising from diving accidents, and will produce considerable cost savings to State and Federal budgets. This is illustrated by a recent hyperbaric retrieval of an abalone diver with arterial gas embolism from Portland, Victoria, to Royal Adelaide Hospital. In the absence of this retrieval, which involved a transportable recompression chamber, the delay before treatment would have made survival without major handicap impossible. The cost to the community arising from such morbidity would include that of maintaining a handicapped individual and his family, in addition to the loss of taxation revenue from his former earnings. Given that the diver has returned to work without disability, the cost-savings calculated from this retrieval are sufficient to operate the retrieval system throughout Australia for many years.

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THE UNIVERSITY OF SOUTHERN CALIFORNIA CATALINA ISLAND MARINE SCIENCE CENTER, AND SOME RECENT PROJECTS

Andrew Pilmanis

CATALINA ISLAND

The University of Southern California (USC) is not State supported. USC is a private institution. Although it is Los Angeles it is in no way associated with UCLA except as a rival.

Catalina Island is 20 miles off-shore. It is about 25 miles long. The Institute for Marine and Coastal Studies is located at the west end at Two Harbours or the Isthmus. The Marine Science Centre (MSC) is in a small cove called Fisherman's Cove which has some unique features which is the reason it was placed there.

It was originally to be run by a consortium of universities in Southern California, however the other universities backed out and left the USC with it. It was a financial drain and so a problem in that respect. The plus is that it has been in operation since 1967 and we have had some fascinating projects there.

The Fisherman's Cove area has similar water conditions to Cooks Bay in Moorea except it is somewhat cooler. It is on the east side of the Catalina Island and there is excellent diving. Our average visibility is about 15m but at times it gets to over 30m visibility. The kelp, macrocystus, is the primary attraction. Unfortunately the warm water conditions of El Nino a few years ago totally wiped out the kelp at Catalina. It is just starting to grow back now that the water has cooled off. Kelp requires cool water and we have had almost a 10°C increase, on the average, during the El Nino, which brought warm water up from the South American coast. The warm water conditions lasted about three years. We had actually tropical fish around Catalina.

In the summer the area becomes the local watering hole for the yachting community. There are an enormous number of pleasure yachts in Southern California. Most of these leave their marina once or twice a year and come over to Catalina. The owners go to the bar for a drink or two then go back on the boat and back to the marina on the mainland. It is a yearly ritual.

Movie companies have had a lot to do with the ecology of Catalina Island. For the filming of "The Vanishing Herd" buffalo were brought to the island and 15 buffalo were left on the island. Now there are over 600. They are not very intelligent beasts, they tend to stomp on everything. They are not a hazard but they leave their calling cards on your front door. They have been known to walk up and down the halls of the dormitories which upsets the students. The Isthmus area was used for the filming of the original "Mutiny on the Bounty" in the 1930s with Charles Laughton. The movie company planted exotic trees including many coconut palms for the movie, and they still flourish.

MARINE SCIENCE CENTER

The Marine Science Center was built in 1967. It consists of a laboratory building, dormitory housing and on the waterfront there is a pier, a heliport and the chamber in a large building. There is a marine railway leading to the large building where the chamber is (Figures 1, 2 and 3).

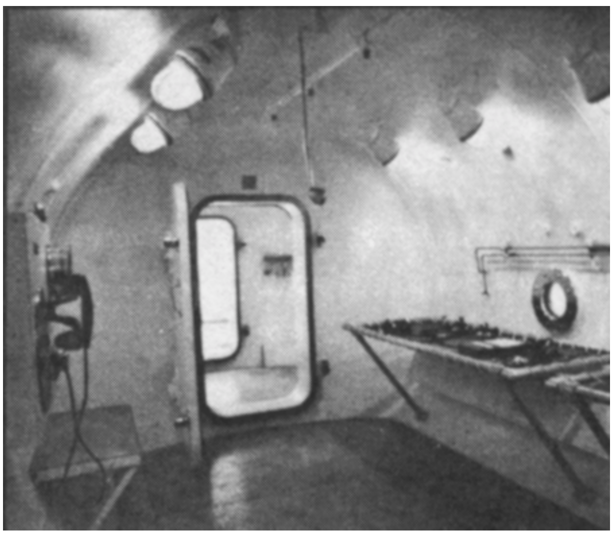


Figure 1. Inside the chamber.

The heliport pad was put in because of the chamber. For every chamber case that we receive, we have three or four helicopter landings, bringing the patient in and taking the patient out, bringing the physician in and out.

Figure 2. Aerial view of the Marine Science Center, Catalina Island.

The marine railway is a very inexpensive way to launch and retrieve submersibles. The greatest cost when using a submersible is the support vessel, not the submersible itself. The marine railway bypasses the support vessel and allows us to launch and retrieve at will. We have had six or seven different submersibles utilise the facility. At times we have been down to a thousand feet chasing crabs with manipulators on submersibles.

The Marine Science Center is used because there is easy access to very calm, clear waters for a variety of marine science subjects and research and teaching. It is an unpolluted area.

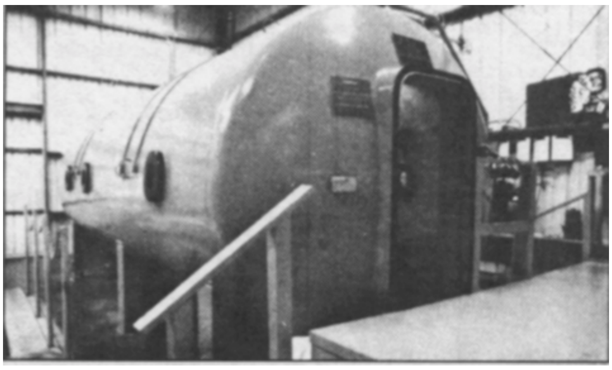


Figure 3. The Catalina hyperbaric chamber

We get marine mammals at Catalina Island including grey whales about 50 or 60 feet long. Sharks are also seen, although up the coast in the San Francisco area we get a fair number of great whites. During the El Nino condition there were 6 or 8 very serious attacks in the San Francisco area. As a result almost nobody went in the water. You could go out in the boat almost any day and find a great white.

Most of our diving is done from small vessels. The University does run large oceanographic vessels which tend to stay away from shore. We have had a number of rather interesting visitors to the Marine Science Center. The Cousteau team did their first TV special on squid at Catalina. The Cove is a squid breeding ground. Cousteau took the Calypso in there and the ship's water intakes got plugged with squid, and everything was over-heating. So they jumped overboard to clear the intakes, found the squid mating and made a TV special out of it.

PHYSIOLOGICAL STUDIES

We will now talk about the specific medical physiological problems that our programs have been associated with over the years. I started off in the space program studying cardiovascular dynamics associated with weightlessness which occurs acutely both in space and underwater. The space program also has chronic problems associated with weightlessness.

Then I went into breathhold diving physiology. We did central venous catheterization on people who then did breathhold dives. The central venous pressure goes up and the heart rate goes down. The bradycardia associated with breathhold diving can reach 4.5 seconds between beats. Inspite of the dramatic bradycardia there was no noticeable effect on the individual during the dive.

Similar cardiovascular changes during breathhold diving occur in marine mammals. We trained a Californian Sea Lion to dive on command therefore it was a voluntary dive in the ocean. Most of the work before that had been done by strapping a sea lion to a board and shoving his head underwater and reporting the various responses. The results of both techniques were very similar in the shifting fluids, the bradycardia, the tremendous vasoconstriction that occurs with the diving reflex. There really was not much difference between the voluntary and the forced immersion.

We got interested in people again and in deeper diving. We did deep dives and studied the cardiovascular responses. I would have to say I would not repeat those dives knowing what I know now but it was interesting at the time. We had underwater ergometers to measure work done underwater. A series of underwater reporting devices were strapped onto the divers for measuring a variety of parameters. We could measure anything we wanted, however primarily we were interested in cardio-vascular responses. We got into respiratory gas sampling during different types of diving and different levels of exercise. We could take at least six gas samples during a dive.

Some of our data is pertinent to sport diving. CO2 retention does occur with scuba diving. Most people feel that since it is an open circuit device that one should not get any CO_2 retention. Well we did. There are three factors that affect the PCO_2 of a scuba diver, the depth which of course governs the density of the gas, the level of exercise and the level of resistance in the regulator. There is often a tremendous amount of resistance in the regulator. The mouthpiece opening that one breathes through is only small so divers at depth, working hard do retain CO_2. At times it was to levels that were of concern to us. We usually found an increase in PCO_2 with depth but we also found a decrease in work capacity with depth. The maximum work that the diver could accomplish, decreases and CO_2 levels rise leading to not very productive diving. We attempted to go deeper than 30 metres and found that we just could not, with good conscience, make those experimental working dives. They were becoming dangerous from the risk of the subjects passing out from CO_2 retention. A tight fitting wet suit is one of the factors that affects respiration, but the density of the gas, the resistance of the regulator and the level of work predominate.

Another thing that had been found a number of times before, in the US Navy, in the Israeli Navy and other places, is that experienced divers tend to have a very low sensitivity to CO_2. The increase in minute volume with rising inspired CO_2 is a measure of CO_2 sensitivity. Normal people do not retain CO_2 when inspiring a raised CO_2. They increase their minute volume, to maintain a normal PCO_2. Some experienced divers do not increase their minute volume as much, in other words they are less sensitive to CO_2 , and they retain CO_2 raising their PCO_2 . CO_2 retention can send you unconscious and the problem is, that you get no warning. One moment you are conscious and then you are unconscious with nothing in between. It is a hazardous situation. I know of two deaths of extremely experienced divers in deeper depths working hard where they simply passed out for no known reason. There was no struggle. There was plenty of air in the tank. No cause other than CO_2 retention could be found. Of course CO_2 diffuses out so fast you cannot prove that it had occurred, but it is very tempting to point the finger at those two deaths as CO_2 retention. With our subjects at high levels of CO_2 they routinely got headaches. The headaches typically would occur either underwater or immediately after the dive and would last either a few minutes or an hour or two. High PCO_2 was always associated with headaches. We still do not know why some divers retain CO_2. The last paper from the Israeli Navy more or less left it hanging. It is either a natural selection process, because we only had very experienced divers down, they were not recruits. Or it is an adaptation of some sort. These people are insensitive to CO_2 on the surface as well as underwater.

The resistance in the regulators is a very important aspect. We bench tested every regulator for every dive before and after, and they varied tremendously. In the end we used US Divers Conshelf regulators. We found them to have the least resistance. These had only a few cm of water inhalation and exhalation resistance. The normal regulator would be double, triple or quadruple these numbers. I would be extremely surprised if any of the audience's regulators were in the range we used. It is very difficult to obtain such low resistances. Our data was collected using the low resistance regulators. If one doubles or triples the resistance it makes the situation that much worse.

The divers definitely did hypoventilate relative to their topside respiration. Whether it is the result of using a regulator or is physiological, I cannot say but it was a constant finding.

We are now interested in thermal aspects in divers and in thermal protection. There is a gadget on the market called a heat flow disc. Put a number of discs in strategic areas on the body and you can measure the flow of heat across those discs and then we can come up with total body heat loss, or gain. This is a much better measure of what is really going on in thermal stress than rectal temperature which has been the usual measurement. Using heat flow discs you can obtain information on the actual heat loss. If you just measure rectal temperature on a dive there is a lag before any temperature drop occurs, so although heat loss is occurring it is not being recorded at first. What is much more interesting is the whole body heat loss in watts per metre.[2] We studied this in a variety of different wetsuits. As one would expect there was greater heat loss when wearing the thinner wetsuits than the thicker. We found that there is an immediate heat loss reading when the diver first jumps into the water and then heat loss generally stabilizes at some level, particularly with the thicker suits. In the thin suits the subjects simply did not last long enough to stabilise as they aborted the dive because they were cold. With rectal temperature, skin temperature, heat flow and water temperature, one can obtain total body heat loss which is what we are interested in. One can calculate the insulation of the wet suit according to the depth, taking into account the changing water temperature (thermoclines) during the dive.

Another project that lasted about four years was with the Doppler bubble detector, for detecting bubbles after a dive or during a dive. An ultrasound transmitter and sensor is focussed on the right heart. It works quite well. I think it is probably responsible for the shift in the last 15 years in how we view decompression sickness, decompression tables and treatment, etc. It is very easy to use. It is not so easy to interpret. One gets a variety of sounds coming out of the right heart. If there is extensive bubbling anybody can pick it listening through the head set. It is the minor to small amounts of bubbling that become a problem. Of course that is generally the area we are most interested in. If somebody comes up with decompression sickness we put a Doppler on immediately, we hear an almost continuous flow of air through the right heart. We cannot hear any of the other heart sounds. The use of Doppler monitoring was started back in the early 1970s by Merryl Spencer in Seattle. He classified the bubble detection as grade 1, 2, 3 and 4, each with increasing numbers of bubbles. It is not very useful because the person listening is the key factor. I remember one of Merryl's number one bubble listeners coming down and listening to one of our subjects. I listened to the Doppler and he listened to it. We came to totally opposite conclusions. At that time I had had four years of Doppler monitoring so there is a tremendous amount of individual interpretation. I think its value is very limited and that people often make too much of the data from Doppler studies. It is useful so long as you realise that who interprets the data is extremely important.

We went through a series of electronic developments in the early 1970s trying to get an electronic signature of a bubble. Unfortunately frequency alone will not do it. One needs several parameters and our laboratory could not develop a satisfactory instrument. We used frequencies, the problem is that each individual and each location has different frequencies. Doppler monitoring is being used extensively now in space programs for monitoring decompression and several other sectors.

We continued with Doppler studies both in people and in animals, of particular interest was the effect of exercise on decompression. We used dogs in that study. The conclusion there was that two factors affect the results of exercise during decompression. On the one side the situation is made worse by cavitation effects, mechanical effects initiating bubble formation. On the other side of the coin was an extreme vasodilation and an increased blood flow. One should be eliminating nitrogen faster. As it turned out, at least from this study, the cavitation effect predominated. So it is not recommended to exercise during decompression. It is an area that I think needs a great deal more research.

We also used people in testing the Edge decompression computer with a variety of dive profiles. We monitored them with a Doppler and found no bubbles at all on the profiles produced by the Edge. I find the theory behind the Edge is excellent but nevertheless it is a gadget. I took it out yesterday on a dive, turned it on underwater and it flashed at me that I had forgotten to change the battery and it refused to co-operate. It still comes back to individual responsibility.

HYPERBARIC FACILITY

The chamber obtained in 1974 is large. It was given to us by the Lockheed Corporation because they needed the space for something else. It is not an easy thing to transport around especially across 20 miles of ocean, as it weighs 22 tons. The size is very useful as we have had up to four patients simultaneously in there with a tender each. One cannot manage that in a 54" diameter chamber. The chamber also serves very well for research purposes and for training. We have, in 12 years, made over 2,000 dives in the chamber for training purposes. We can put up 10 people in it at a time. We have done 515 treatments, the last one was the day I left to come to Moorea. It was a woman with a beautiful air embolism who made a good recovery.

UNDERWATER HABITAT PROGRAMME

A very brief history of saturation diving. The concept was developed by Captain George Bond of the US Navy in the 1950s, and we ended up naming our habitat for George Bond. He died about three years ago, a very disappointed man because saturation diving had not developed the way he envisaged it would. The first open water saturation dive, off Southern France, was run by Ed Link in 1962. The diver was Robert Stenuit. Very shortly after that Cousteau put his houses down, several models, and they lived underwater. The interesting thing here is that if one compares Cousteau's Conshelf habitats of 1962 and 1963 with the single habitat still being used there is really very little difference.

This project I started in the early 1970s as far as thinking about it. I actually started in 1980 when we applied to NOAA (The National Oceanic and Atmospheric Administration) a sort of a wet NASA although not nearly as well funded. It was a joint operation between NOAA and the University of Southern California. The purpose was to utilise saturation diving techniques to do marine science in the ocean. This was not anything new. It has been done before by using a number of habitats but generally it has been done in tropical waters not in temperate waters. Our water temperatures, down to 30 metres, varies anywhere from 10° to 20°C. Predominantly it is in the 13° to 15°C range. The exceptions were in the US Navy Sea Lab and the Helgoland, a German habitat. The idea was to place the habitat offshore from the Marine Science Center with the full support of the Marine Science Center. This has been lacking in previous scientific habitats. Our concept involved the full support of a sophisticated station and we felt that would produce much more effective work.

The main advantage of saturation diving for people who need a great deal of bottom time, much more than scuba can afford, is that they only have to decompress once. Another advantage is that if the habitat was at 24 m one has an unlimited excursion time from 24m to 45m. The diver can come back to the habitat with no decompression. If one goes below 45m there is some decompression to pay. This allows much more in-water time. If the habitat is in 24m of water, one can work upwards to about half of that, say to about 12m and downwards to 45m for an unlimited time. In a word the purpose of this project was to enable the marine scientists to do very long bottom times.

There are advantages with a habitat when compared to a surface saturation which is what is used in the commercial diving industry for deep diving operations. They saturate on the surface in a chamber and transport the divers down to the work site in a bell. After the dive they bring them home to the chamber on deck. That kind of diving is generally mixed gas (helium and oxygen) and very deep and it is the only way they can operate. In the scientific arena the habitat is in relatively shallow water and the advantage is that the people inside can enter and leave the habitat at will. They do not have to be transported by a bell, which requires a crew to move it. It is a significant advantage. We have had some scientists enter and leave the habitat up to 12 times a day. If one had six of them out of the bell and two or three of them are on different schedules there is quite a problem if you are saturated on the surface. A habitat does have definite advantages.

One example of what we wanted to study was an algae which only grows below 24 to 30m and it has been totally unstudied because with scuba you simply cannot get enough work time at those depths to accomplish anything worthwhile. The plants may grow 15m or more long with blades sometimes two metres wide. The algae settles along the bottom with the current. Underneath the fronds is the offshore fish nursery where all the little baby fish grow up. Studying this would have a tremendous impact on fisheries research, yet it was totally inaccessible to scuba divers. Our concept was to put the habitat within a very short distance off-shore and run an umbilical to it for support. It would open up tremendous areas for study.

In 1980 we contracted for a conceptual design. Then for detailed engineering and then another contract for its construction which was done in Texas over the past year. It was completed about May 1986. The habitat is 12m long, 2.7m in diameter. It has three compartments, a wet porch, a work area and a main living area (Figure 4). It is not much different from Sea Lab or many of the other habitats. As a physiologist it was quite fascinating getting involved in the engineering of this. There are so many implications on the physiology and the medical aspect going through the engineering. The concept involved making it

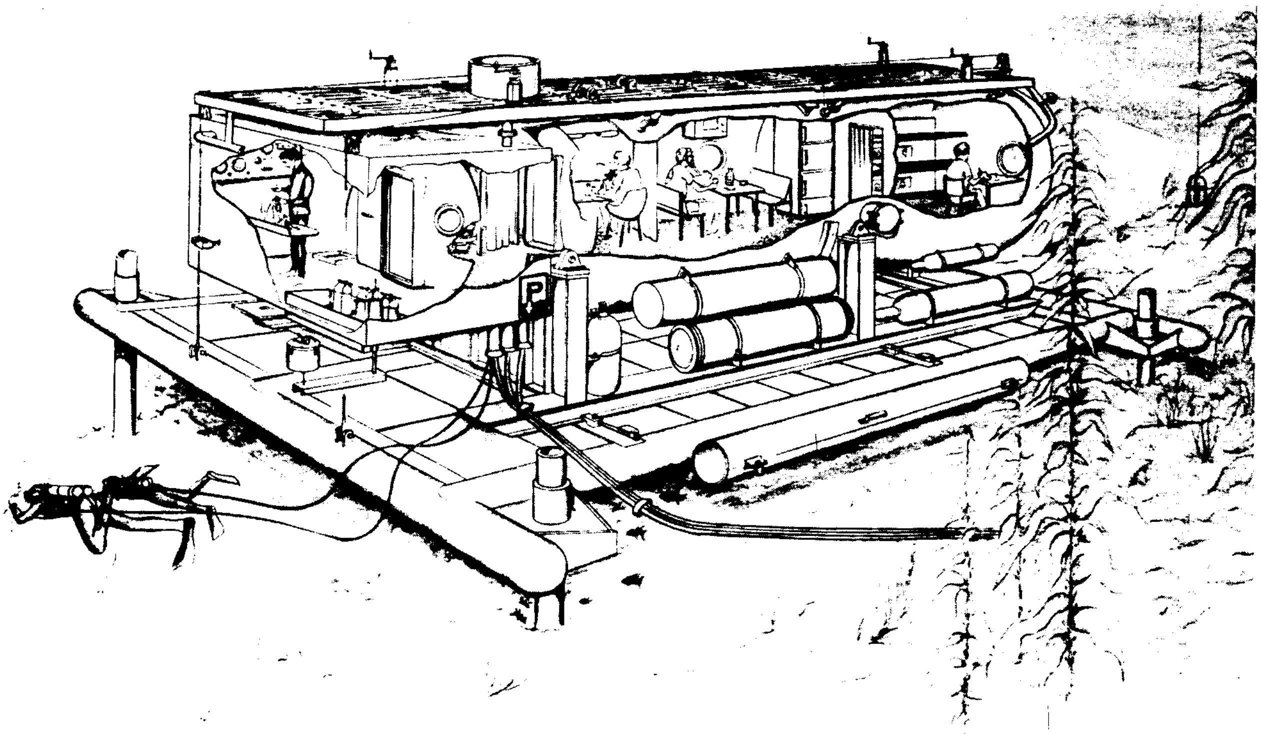


Figure 4. A cutaway view of the George Bond Habitat. From the left it shows the wet porch, the ablutions area, work space for scientists, living and sleeping areas.

positively buoyant with a heavy base plate and raising and lowering it through a launching system so it can be moved, floated to another site or just at the surface for restocking and what have you.

There were a number of medical problems we encountered in the development phase. Excursion tables from saturation were not in existence. There were a set of excursion tables in the NOAA manual but not for the depths and the gases we wanted to use. Repetitive excursion tables were simply non-existent. If scientists were to go out repeatedly during the day, go down and then back to the habitat, they needed repetitive dive tables. This was contracted to Dr Bill Hamilton in New York. He has developed a set of repetitive excursion tables for saturation diving and he is still working on that problem. That was the first and immediate problem we had because you could not do the excursion diving we were planning without such tables. We decided to use air for excursion diving and normotoxic nitrox for the habitat environment. The nitrox composition varies with depth as far as exact percentages go. Below 15m one cannot use air for saturation because of oxygen toxicity to the lungs. Reducing the oxygen percentage creates additional problems from the higher proportion of nitrogen. One has to be very careful over decompression and narcosis.

The tables are now in existence although they have not been tested. NOAA is trying to decide how to deal with that problem. As with all new tables how do you determine that they are valid? The last I heard they were proposing to test them on people. That is a very difficult proposition and I do not know whether that will happen or not.

Of equal concern was chronic thermal stress. With the water temperatures we have in temperate areas that is a serious problem. The saturation times we were expecting were 7-10 days per mission. We were looking at anywhere from 4 to 8 hours in the water per day. The acute thermal stress is something that most people immediately think of but that was less concern than what we call chronic thermal stress, the progressive loss of heat over a long period of time. This leads to a loss of performance, which was the primary concern. UMS held a workshop in June 1985 on the subject. The workshop did not solve any problems, it merely emphasized that the problem existed. Our proposal to solve this was to use hot water to heat the divers. That meant they had to be tethered divers. A wet suit or a dry suit, passive insulation, might be suitable for very short duration dives. But the purpose of the habitat was to do long duration dives. The only feasible method of diver heating that we could find was the hot water approach. Commercial diving uses hot water systems extremely effectively. So we planned to install full hot water capability to all the divers. We also designed in a hot tub as full body immersion is the most effective rewarming method there is. We had to rename it diver rewarming something or other because you simply cannot talk to bureaucrats about hot tubs in habitats and have them take you seriously, even though it is an effective means of accomplishing rewarming.

The third aspect was nitrogen narcosis. A normoxic nitrox at 36m is the equivalent of air at a depth of 47m. 36m was our deepest expected depth for the habitat, therefore we would be at a saturation or storage depth where the nitrogen partial pressure was the equivalent of air at 47m with excursions deeper than that. That brings a significant performance detriment from narcosis. There was another UMS workshop on narcosis and saturation diving. It is a very difficult problem. The workshop did not solve the problem. There were many suggestions, but the fact remains that the diver is breathing that partial pressure of nitrogen and there is no easy way around it. Since then some people have suggested that one can train oneself to increase ones performance under the same narcotic conditions. They are still trying to prove that point. I do not know that they will. This factor is probably of most concern because the whole purpose of the habitat was to put people on the bottom to work efficiently and effectively as Marine Scientists. If they have the narcosis level you would anticipate 47m, how valuable is the data that they are gathering? After they send their papers in to a journal will the editor send it back asking what effect does the level of narcosis have on the accuracy of your data. That is a very serious question for people who might use the system.

The other medical aspect is treatment procedures. How would you treat during saturation or on the surface. We have gone through a variety of scenarios and came up with a long list of answers. For example, if one is saturated at 36m and a diver on an excursion surfaces with an air embolism, should he be taken back down to the habitat or to the shore chamber? Does another diver come up to get him? That would mean that there were two individuals with a guaranteed problem. We have been over a whole series of possibilities. We decided that there would always be someone in a boat available on the surface and if someone did surface they would pick them up and take them to the chamber on the barge, rather than take him back down. Under no circumstances was anyone allowed to surface to help that individual.

Medical standards for divers in saturation are supposed to be somewhat higher than surface diving standards, but the scientists are the same so we went through item by item and decided whether the differences were necessary. We tried to eliminate the usual nuisance of ear and skin problems associated with saturation diving by installing a combined heating and dehumidifying system which permitted a shirt sleeve environment. Humidity and temperature can be controlled very well nowadays. It was not possible 20 years ago in the older habitats but now it is quite possible and not that expensive.

We also needed a PTC, a personnel transfer capsule, because the depth was going to be significantly greater than 15m. If one operates in less than 15m they say the diver has about 20 minutes, if he accidentally surfaces, to get into a chamber and be recompressed. I do not know how true that is, they have done it two or three times at Hydrolab but with any great depth you have zero time. So any transfer to the surface has to be in a pressurized vessel. But there were not enough funds to purchase a new PTC so I got the diving company Oceaneering International to donate a PTC, usually referred to as a bell, which we refurbished totally last year. Also, we were given a deck decompression chamber that the PTC mates to which was going to be placed on the support barge, and we refurbished that. Oceaneering also donated a control van to run both chamber and PTC. NOAA paid for all the refurbishing.

The George Bond is currently in St Croix, Virgin Islands. Why is it there as it was built for Catalina? The reason is very simple. The Hydrolab habitat had failed its hydro test. The Hydrolab habitat is probably the most famous scientific habitat of the early 1970s. A lot of productive work was done from it in the Virgin Islands. Hydrolab was originally in Freeport, Bahamas and then it was transferred to St Croix, Virgin Islands. NOAA operated it almost continuously from about 1972 until 1985. Well over 1,000 scientists have saturated in Hydrolab, a great deal of good work was done from it. It is operated with air, saturated at less than 15m. It is very spartan, and very inexpensive to operate. Last year it could not pass its hydro test so it has been sent to the Smithsonian Museum where it is currently on exhibit.

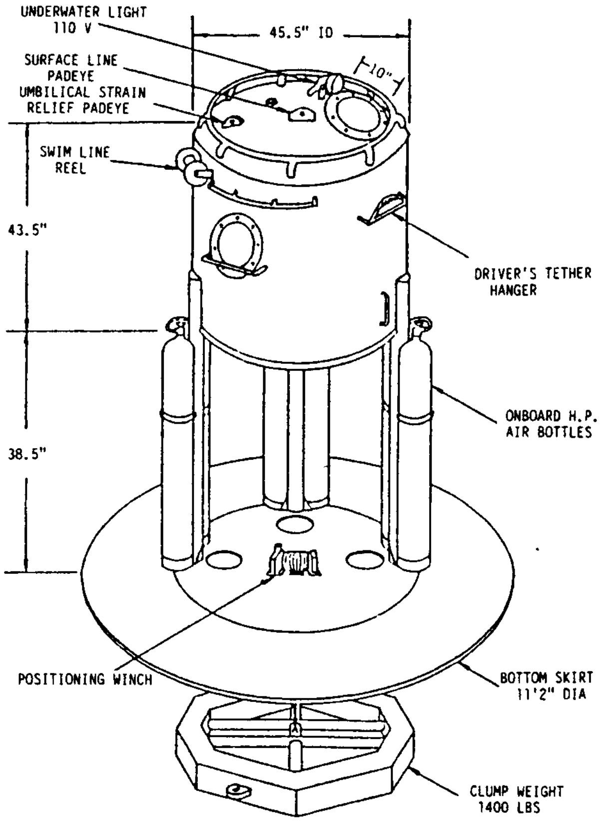
NOAA obtained the eight year old habitat from Hawaii, the only other habitat in the US, to send to St Croix about 6 months ago. It was going to replace the Hydrolab habitat. Then it failed its hydro test and they had to scrap it. NOAA only had one left, the one we were building. Politically NOAA requires a habitat in St Croix, therefore they sent the Catalina habitat to St Croix at the very last minute. So unfortunately our project is no longer in existence. There have been 65 habitats built in the last 20 years and there is only one left. All the other habitats have either gone to the scrap pile or some other means of disposal. The George Bond is the only habitat that is currently in existence that is operable. Well it is not really operable yet, but very close to it. They currently do not know how they are going to operate it in St Croix and at best it will probably be two years before it goes in the water, if ever.

WAYSTATION PROJECT

However something much more productive for the marine science community came out of this project. We developed what we call a waystation (Figure 2). This is again an old concept, the open bell, which has been used for many years for decompression in commercial diving. However we modified it somewhat so that it is positively buoyant attached to the bottom, rather than negatively buoyant attached to the ship. Its prime purpose is to provide a dry area for decompression, but more than that it is a refuge, it is a work station. It can be raised from any depth without surface effect and is essentially self contained in many ways.

We built the waystation or bell or refuge and operated it for two years while the habitat was being constructed. We operated it quite successfully and to me it is a very useful technique for not only scientific work but perhaps some other kind of work, excavation of sites and that sort of thing, where one needs very long bottom times. The combination of the waystation and tethered diving is a program that we ran for a few years. The first thing we had to do was train the marine scientists in tethered diving because in the whole United States there were only two who had had any training in tethered diving. Everybody else uses scuba exclusively. So we set up a training program. We built the waystation on a shoe string budget. NOAA was very happy to provide the money for building a habitat but they absolutely refused to fund something as low tech as the waystation. Although this proved in the end, at least Catalina Island, to be a much more practical, cost effective tool. A habitat is very very worthwhile if you have firstly a lot of money to operate it and secondly a large contingent of scientists who have to work very long bottom times at that particular site.

We quickly learned that the transition from scuba to surface air required a little finesse, a standard commercial oronasal mask simply did not fit well on a 95 lb young lady going to sit on the bottom and count fish. We found it much more appealing to use simpler systems. We bought a cheap mask and installed the communications and a regulator into it. It made the transition from scuba very easy and it worked well. The communications worked well. I think each mask



NUR/USC WAYSTATION

DIVING CAPABILITIES AND EQUIPMENT

TETHERED OR SCUBA DIVING
EXTENDED BOTTOM TIMES WITH O_2 DECOMPRESSION
DRY ATMOSPHERE FOR DECOMPRESSION
LIMITED HOT WATER CAPABILITIES FOR WARMING DIVER'S WET SUIT
LOW PRESSURE AIR FOR TETHERED DIVING
HIGH PRESSURE AIR FOR FILLING SCUBA BOTTLES WITHIN THE WAYSTATION
PNEUMOFATHOMETER FOR ACCURATE DEPTH READINGS
HIGH INTENSITY U/W LIGHTING FOR NIGHT RESEARCH
FULLCOMMUNCIATIONS: DIVER TO DIVER, DIVERS TO SURFACE, WAYSTATION TO SURFACE
THE ABILITY TO SEND VERBAL DATA TO SURFACE FOR TAPE RECORDING

Figure 5. Diagram of the National Undersea Research (NUR) Program and USC waystation.

cost us $40.00. We bought 50 of them in a box and at a very low price, probably $20 apiece. When the mask perished we simply threw it away and put the regulator and communication into another one. Compared to a Kirby Morgan type mask, which runs around $1200 each, this was a very inexpensive way to operate. It may seem hard to believe that communication in this mask was as good as in other types of full head gear, but they were very close. Once the individual learnt how to enunciate and speak properly they worked quite well and they fit just about everybody.

We have communication, hot water, low pressure, high pressure air, oxygen BIBS (built in breathing system) for decompression in the waystation. There are two seats the divers can climb on inside and be completely out of the water. They can write up their notes while they decompress, they can talk to each other and to the surface. They are held down by a clump weight on the bottom. They are suspended from the bottom up, that is they are floating. The divers can crank the waystation down or up. We would set it down the bottom and then when the divers were ready for decompression they would raise it to their first decompression stop and go on oxygen.

There are a couple of comments I would like to make in closing on this waystation and tethered diving approach, I think it is something that might be applicable in a number of situations. The productivity that came out of it was incredible. The main advantages were unlimited air and hot water. We ended up diving the scientists five to six hours a day at depths that ranged anywhere from 15m to 36m. For all of that 5 or 6 hours they were highly productive. The tether supplied them with air, communications and hot water and the hot water was the thing that made the difference. When they got back to shore they were not fatigued at all. They went right to their labs and worked for another six hours. That was the number one observation that came out of this. That they continued to be productive after a six hour dive. I do not know how many in this room have ever done a six hour dive in 15° water. It is very taxing on the system. Yet by using hot water we essentially eliminated the stress.

The bell can be launched when we want to use it. It floats until the air is pumped out of it. We tow it with a small boat to the site then dive down and attached it to the clump weight and then winch it down to a stable position at whatever depth we are working. There are two tethers on the waystation, so two divers can work independently 60m away from the waystation (Figure 5).

We have a Navy surplus boat that we converted to a dive boat. We put a compressor and the diving manifold and the communication system on it. The standby diver sits on it. As we could not fit the hot water system into the boat we built a little raft for it. The heating system has a diesel boiler and pumps hot salt water down the hoses to the diver. One can regulate the temperature of course depending on the length of the hose. We can move the whole system to a new site in about two hours and do another dive. I feel that this bell and tether technique was the most productive thing that came out of the six year project for building an underwater habitat.

Somebody asked whether there is a future for saturation diving. I am having a hard time deciding whether it is a dinosaur or 20 years ahead of its time. I think in the commercial diving field saturation diving is on the way out. However in some of the other fields it might be 10-20 years away, or maybe it is a dinosaur. As I said earlier, in 20 years of development nothing much has changed. The techniques were there 20 years ago, and yet after 65 habitats there is only one operational one, so that should tell us something I suppose.

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