THE DEEPEST DAYS

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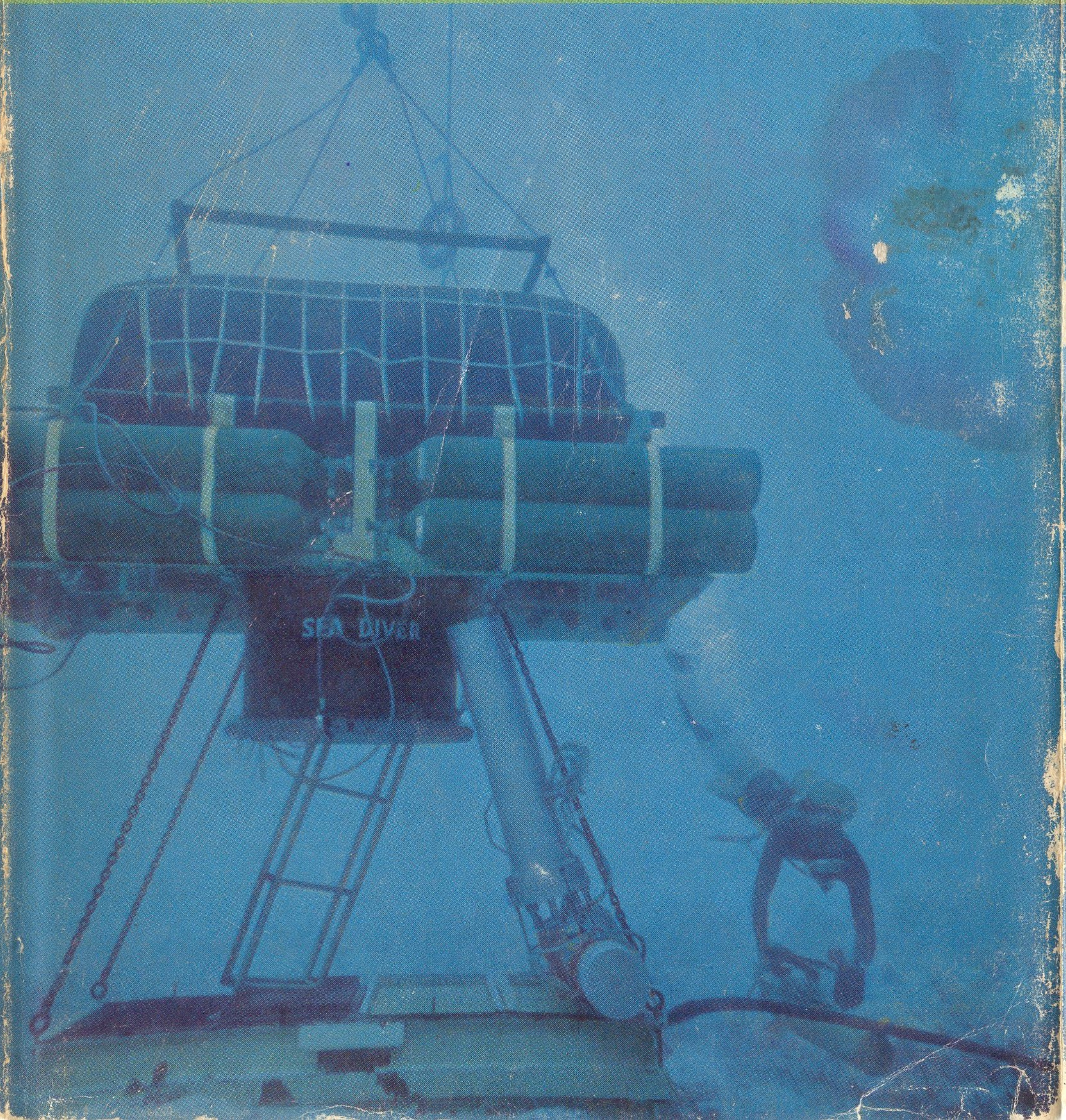
A remarkable odyssey of undersea adventure and of the longest, deepest dive ever made—by the chief diver for MAN-IN-SEA project.



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Robert Sténuit

Illustrated

Salt water covers seven-tenths of the earth's surface. Four hundred feet below the ocean's waves lies the Continental Shelf filled with vital raw materials unexplored and unexploited. Yet, while man is travelling the cosmos and heading for the moon, the science of oceanography remains relatively primitive. In THE DEEPEST DAYS Robert Sténuit, who was chief diver for Edwin A. Link, the father of the Man in Sea project, tells the exciting, adventure-filled story of a spectacular leap in that science—from dangerous and ineffective "hard-hat" deep diving to the beginnings of systematic, productive undersea research. A story that was climaxed by a record-breaking dive in which author Sténuit and Jon Lindbergh lived and worked in an undersea house at 432 feet for 49 hours—a feat that helped pioneer the way for the recent exploits of *Sealab*.

The prime objective of the Man in Sea experiments was to find a way for the diver to live "in his skin" without cumbersome suits and equipment—at depths of 400 feet or more. To accomplish this, Edwin Link (inventor of World War II's famed "Link Trainer") designed a submersible decompression chamber and an undersea tent to be sunk, inflated, and filled with a viable breathing mixture. In the waters near Villefranche, France, Sténuit went down to check out the Link cylinder. Tension surrounded the preparations for this first test—the development of a proper breathing mixture, building the complicated equipment re-

(*Continued on back flap*)

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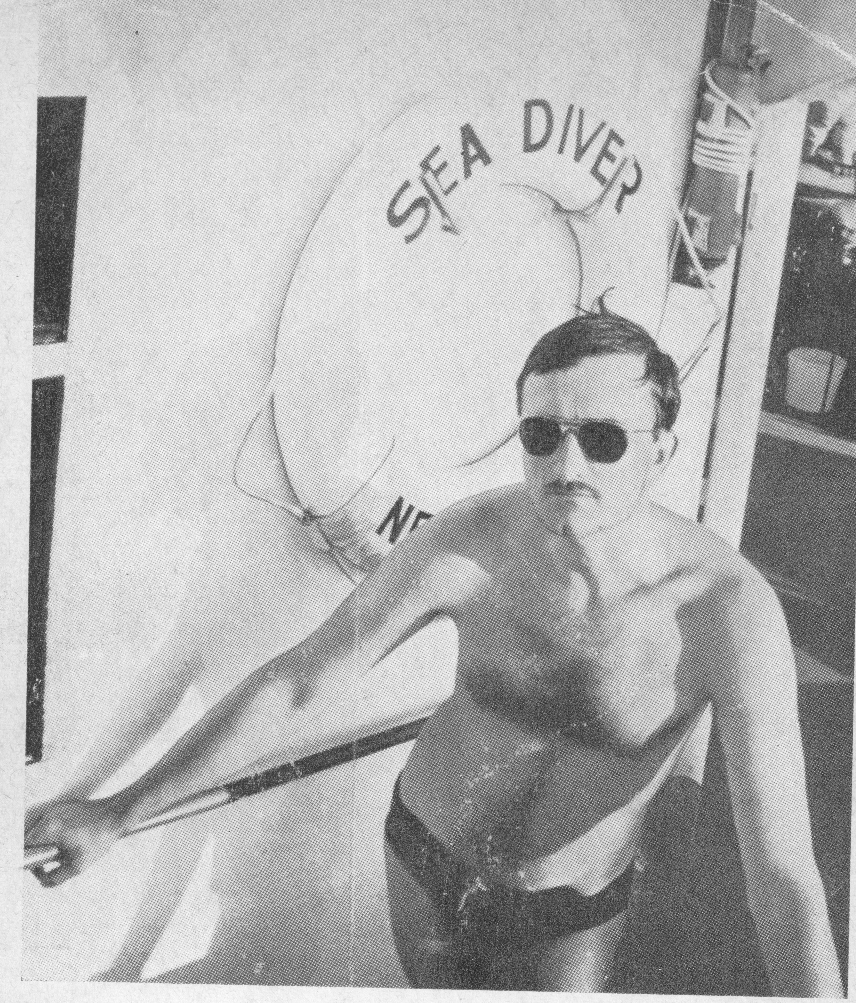
quired to keep Sténuit alive at the bottom, figuring out the required decompression period—as well as the hazardous dive itself, which was complicated by a vicious mistral, the loss of their helium supply, and Sténuit's helium-caused inability to talk through the intercom. But in spite of all the difficulties, Sténuit stayed at 200 feet for a day and a night.

The Villefranche test was a successful preliminary to the longest deep dive which was conducted in the bright waters of the Bahamas, by Sténuit and his companion, Jon Lindbergh. These two young men experienced, as no one had before, the combined effects of the two crucial dimensions of diving: depth and time. Their Submersible, Portable, Inflatable Dwelling, a simple rubber tent, was sunk 432 feet. At 9.30 A.M., they began their descent to the SPID in the Link cylinder. They arrived on the bottom at lunchtime. Sténuit logs their underwater adventures, their difficulties communicating with topside, the failure of their electrical system, the nonfunctioning of their gas filters with its concomitant danger of asphyxiation, as well as the dangerous challenge of the ocean's depths and the thrill of conquest.

The success of Sténuit's dive and of Link's project has paved the way for a new era in oceanography. Now there is a way for men (women, too) to live and work in relative comfort on the bottom of the sea. Sténuit's personal story is an exciting saga of adventure. But more than that, THE DEEPEST DAYS is a storehouse of information on the dangers and problems of undersea exploration, including: "rapture of the depths," the bends, the tragedy of the *Thresher* and other lost submarines, as well as a lively introduction to the sciences of the oceans.



It is safe to say that Robert Sténuit is the world's most experienced aquanaut. Born and educated in Brussels, he has spent most of his working life underwater as a salvage expert or a test diver. He is Chief Diver of the Man in Sea project, and will soon attempt a saturation dive at 650 feet. Mr. Sténuit has written several books about skin diving and underwater archaeology which have been published in France, Belgium and Germany.

The Deepest Days

By ROBERT STÉNUIT

Translated by Morris Kemp

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To my companions of the depths: the American, French, and Russian aquanauts

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INTRODUCTION

The age of science has borne out the time-honored concept of the sea as not only the mother of all life, but also as the treasurer of immeasurable riches. And the mythical proportions of these riches, now supported by hard facts, have always had, as an added characteristic, inaccessibility. In the past few years, pressured by the population explosion coupled with the growing awareness of the limitations of our terrestrial resources, man has begun to challenge this inaccessibility. One of the spearheads of this challenge is the Man in Sea project, about which *The Deepest Days* is written.

The specific aim of the Man in Sea project is to develop a system whereby men can live and work at great depths for a sustained period of time. Already, incredibly deep dives have been made. The "hard hat" Navy divers, linked to their surface craft by lines and air hoses, have occasionally touched 500 feet in depth, and Hannes Keller, the Swiss mathematician, went to 1,000 feet in a pressurized chamber—but these have been "bounce" dives, limited to a few seconds at depth. Nor has the long dive been unattempted. The French commandant, Jacques-Yves Cousteau, has put men down at 36 feet for one month, and at 90 feet for seven days. But none of these dives have *combined* the elements of depth and time, and it is only this combination which will enable man to exploit the riches of the ocean and the ocean floor. The average depth of the continental shelves is 600 feet. Once man has mastered the depth, 10,000,000 square miles of seabed, of mineral, animal and vegetable wealth, will be unlocked.

The extent of this wealth is incalculable. In some cases it would seem to be inexhaustible, for all of the mineral wealth to be found on land exists in even greater magnitude beneath the sea. Since the beginning of time, diamondiferous deposits and other precious stones have been pouring into the sea out of rivers and from underwater volcanoes. The pilot projects which have experimented in exploiting these vast undersea deposits have found that they can produce these stones at rates far in excess of terrestrial mines. Offshore pioneering has also uncovered enormous reserves of coal and oil, copper, cobalt and nickel. Finally, huge areas of the ocean floor have been found to be carpeted with nodules of manganese. It is currently believed that these nodules, constantly in the process of formation, will continue to form at a rate faster than that at which the entire industry of the world could consume them.

More important than the mineral resources perhaps, the ocean also harbors a potential which could feed this overpopulated and hungry world. If the principles of farming are applied to marine life, if fish and shellfish are scientifically bred and the plants of the sea cultivated with plan and purpose, the results would be a plethora such as could provide the entire world with nourishment at maximum efficiency and minimum cost.

For these reasons, the development of our oceans, the last

frontier, and the largest and richest ever faced on this earth, is of immediate and vital importance. A great deal of effort and expense is being invested in conquering this potential. Yet the figures are minuscule when compared to the billions that are being expended on the space program. In view of the facts mentioned above, coupled with the population problem and the diminishment of our terrestrial resources, I would like to suggest that this imbalance is perhaps unwise, and while it is certainly necessary for military reasons that we develop the space project, it is just as imperative to expand our efforts toward exploiting the sea—if we are to forestall a gargantuan famine, a biological world calamity. Already, the food supply is outstripped by the population. In 35 years, the population will double. We cannot overlook the problems which will develop. Yet the solution is all around us. Though only 3½ percent of the earth's surface is arable, in the conventional sense, 75 percent of the earth's surface is covered by that inexhaustible cornucopia, the sea.

Yet, if we are to make use of the sea in the way I have been suggesting, it is essential that man be able to live at great depths, "in his skin," for substantial periods of time—for the work cannot be done by automation but requires eyes, hands and the human brain. Herein the significance, and the daring, of the Man in Sea project. Every kind of pioneering involves risks, and adaptation, but none so drastically as when man moves out of his natural environment. Almost every piece of equipment used for the Man in Sea project had to be especially designed, and tested, and redesigned, and still we could never be sure until it had been proven by human experience. Yet our men, 400 feet down, beyond the reach of surface divers, would depend from minute to minute upon these unproven and intricate devices.

The dangers faced are many. Nitrogen narcosis, the bends, oxygen poisoning—these are only a few of the problems we have had to solve before putting our men down. Their solutions required the efforts of doctors, physicists, engineers, and the final requisite, courage, on the part of the divers and the men who put them down as well—the willingness to take the risk, to challenge that "unknown factor."

When the message "All anchors are set. You'll be making the dive at 430 feet . . ." came over the radio from our U.S. Navy support vessel, *Nahant,* it was with mixed feelings of anticipation and trepidation that I watched Robert Sténuit and his co-diver, Jon Lindbergh, prepare for the longest deep dive in human history. They were well prepared for their adventure. Every inch of equipment had been checked. They had taken several preliminary "dry dives"; every minute of their time on the bottom had been planned and thought out. Yet as I watched these two remarkable young men, I could not help but wonder if we had thought of everything, could not dispel the recurring realization that it is impossible to cope with that unknown factor when moving, as they were, out of the sphere of our knowledge and experience.

I first met Sténuit at Vigo Bay, Spain, where he was one of the treasure divers with John Potter's team. I was very much impressed with his skillful, calm and thoughtful diving. Later, when the Man in Sea project got under way and I needed a chief diver to go to great depths for periods of time never before attempted, I selected Sténuit as one of the very few divers in the world that could qualify for this important task. His companion for "the deepest days," Jon Lindbergh, brought wide underwater experience to the project, together with a quiet courage reminiscent of his famous father.

The dive, described in detail in this book, was carried out successfully, though not without several minor mishaps. On the afternoon of Tuesday, June 30, 1964, Sténuit and Lindbergh signaled their arrival on the bottom. Forty-nine hours later they were back aboard, healthy, triumphant, and with a tale to tell. Our mission was accomplished. We had proved that human beings can adapt to the unnatural environment of the deep sea. We had brought into the realm of the possible the hope that man can someday live there for extended periods. On the agenda for tomorrow: a 600-foot dive, another at 800 feet, and finally we will send our men down to 1,000 feet for a period of several days to a week or more.

There is no one more qualified than Robert Sténuit to write this book, which I'm sure will be stimulating and helpful to all readers interested in the Man in Sea project and its meaning for our future.

EDWIN A. LINK

1.

THE CHALLENGE OF THE DEPTHS

IN October 1962 I was attending the Second World Congress of Underwater Activities in London. The theme of the convention was the "challenge"—the gauntlet flung at landsmen by the sea, and one of the most applauded speakers was Edwin A. Link, because he was determined to meet this challenge, and to meet it with imagination and courage.

It has become a truism to state that our planet should be called the Sea, not the Earth, since salt water covers seven-tenths of its surface. But now, when man is traveling the cosmos and setting his sights on the moon, the ocean in which we wade remains unexplored and unexploited.

We know that a large platform surrounds the continents completely, like an easy first step on the way down—it is the continental shelf which gradually slopes to depths of 700 to 1,000 feet. There, the bottom drops abruptly, almost vertically, toward the deep ocean plains. All signs point to these 30,000,000 square miles of submerged lands (as large as the surface of Asia) which surround our 54,450,000 square miles of emerged lands as a primary objective for colonization.

On October 20, 1962, Edwin Link reported to the divers, the engineers, the naval observers, and the oceanographers from every field of scientific research who were present, how a decisive victory had just been won in man's long struggle against the hostile sea. He described how, for the first time, a man had been able to work, eat, sleep, and live under the sea at a depth of 200 feet for more than 24 hours.

I was the man about whom Mr. Link was speaking and it was there, at the London Congress, that I fully grasped the significance of what was at stake, and the precise impact of what I had done by agreeing to become the first inhabitant of the first house under the sea.

For the leitmotiv recurring in all the scientific papers, presented by speakers from all parts of the world, was the immensity of the resources in food, energy, minerals and vital raw materials waiting on the bottom of the sea for man to exploit them.

The subterranean world was my first love.

At seventeen, I discovered the caves: the dark, the mud, the cold, the silence, the exhausting effort. For a Brussels boy, this was the kind of adventure most readily available, and any young man from the city needs adventure more than he needs bread. On Saturdays, equipped with rotten ropes and improvised head lamps, a team of three or four of us would head toward the caverns of the Namur area. When I recall these descents, I wonder why we were not killed several times over by our rashness and serious mistakes.

Often, the water would stop us. Water is the most common obstacle for a spelunker exploring an unknown cave. A gently sloping gallery, a cone of fallen rocks, a clay embankment, might terminate in a sheet of calm water, so crystal clear that it was invisible in the beam of the head lamp. One couldn't go farther. The explorer might wade or swim in it if he likes the 43° F. temperature, or he might, with a better chance of success, navigate it in an inflatable dinghy, but the moment would come when the rocky ceiling would curve down to merge with the water level, and his exploration would end right there. To get through, one had to dive.

In 1953, I was twenty years old. Skin diving in Belgium was unheard of. Well, then, how about cave diving? Every weekend, two of us would feel our way deep inside some tortuous hole flooded with liquid mud. With a scuba tank on our back, we shivered in borrowed wet suits. Our technical and physiological knowledge was dangerously rudimentary; frequently our dives would terminate in inundated culs-de-sac or inextricable labyrinths.

There, in the silent darkness of the caves, I found my second love: diving. And diving made me discover the sea, and the world under the sea, where man is weightless, where the improbable is normal, where the marvelous is the rule, where I felt I was born again, in a second universe.

For many years I continued to think of the sea as a hunting ground. I was after fish, pictures, sunken treasures, emotions and joy. But one day my thinking changed radically.

I was writing a book on speleology, when a striking parallel came to my mind. For weeks I had been working on a complete synthesis of discoveries in archaeology and human paleontology in the grottoes of Europe, when suddenly the thought flashed through my mind that the condition of Europe at the time the descendants of the Cro-Magnon man established themselves on land was precisely the condition in which the ocean has been left in the middle of the twentieth century. With respect to the ocean, we are today in a Stone Age phase. We fish, we hunt, we set crude traps, we take what we can pilfer, we pick up what is within our so feeble grasp.

That is what the men of prehistory did with their land. But one day, one of them no doubt had a bright idea: "Let's keep this musk-ox, this rabbit, this goose alive, with its legs tied—we shall eat it tomorrow," and then another idea followed: "Let's keep it in a cage, an enclosure, bring its mate, feed them both, and they will give us their young and eggs or milk—our livelihood will be assured day after day, winter and summer." And still another: "Let's plant these seeds in the soil in great quantity, we shall eat the fruits of the harvest in the summer and keep the surplus for the winter."

Now, when these men whom we dare call "primitive" began to cultivate the earth and keep cattle in captivity, they had to settle down to live permanently in a hut which they had made comfortable, and from which they could keep an eye on their farms and possessions, night and day, winter and summer. This settled way of life was the prerequisite for an organized and systematic cultivation of the soil, which became for them and the human race the security of the morrow.

Let us, men of the twentieth century, living in a world where two-thirds of the population is starving, let us in turn understand that if we want to guarantee our future, we will have to find fresh natural resources. The ocean may contain more of them than we shall be able to consume, but in order to exploit the bottom of the seas intelligently, we too will have to settle down, and stay permanently on the bottom, in a comfortable hut from which we shall be able to watch

our farms and our goods, night and day, winter and summer. For the brief sorties of the divers, helmet divers or skin divers, won't do the job. One hour's work at 200 feet requires, before resurfacing, four hours of decompression stages, or else the risk of crippling or death; and the efficiency and productivity of this hour's work that is so dearly bought is sharply reduced by nitrogen narcosis which also endangers the diver's life.

The scientific results of dives in submarines, in diving saucers or bathyscaphes, are invaluable, although very limited; but the practical usefulness of these submersibles from the point of view of productive work is nil.

It must be said, shouted and repeated: We shall never be able to exploit the continental shelf economically by sending divers there. To colonize this world's last virgin continent beyond the last frontier, colonists will have to settle on it, to live there for a long, long time, like the French oil workers in the Sahara, or the scientists in the Antarctic. And perhaps, ultimately, instead of living there like hermits, they will be able to take along their wives and their children.

2.

EDWIN LINK: PILOT, INVENTOR, EXPLORER OF THE DEEP

FROM the first moment I met Edwin Link and dove with him to the depths of the Atlantic around the Carrumeiros reef to show him a newly discovered wreck, I was delighted by his piercing intelligence and no-nonsense approach to difficult problems. Although he has made several fortunes in business, is a crack pilot and diver, the inventor of the famous Link Trainer of World War II fame, and is about to present the world with the key to the continental shelf, he is almost comically diffident about his achievements.

"All my life, all I did was to have fun," he will say, with a little smile, his eyes teasing behind his thick eyeglasses. "To have fun fourteen hours a day, just doing what I found exciting."

Edwin Link's incredible career began with the 1929 depression, which swept through Wall Street like a hurricane, burying forever an industry already half ruined by the success of sound motion pictures: the Link family industry which manufactured player pianos and Marie-Keater organs in Binghamton, New York. In spite of the collapse of his family's business, Edwin Albert, ruined at twenty-five, retained one self-made enthusiasm—airplanes. He had learned piloting, the hard way, and was fascinated; here was fun. Many serious-minded persons, at the time, thought of flying as an amusing curiosity, an acrobatic sport for daredevils. The romantic feats of a few pilots, of a few aces, would never weigh very heavily in the outcome of a war. As for transportation, hadn't the railroads, the motorcars and the steamship been perfected? No, Edwin Link thought, hell no! —but he knew that the timid and the laggards would be right, as long as the pilots had as much trouble learning their profession as he himself had had, and as long as flights were limited to beautiful, sunny days.

He was ahead of his time, so he found himself alone. To make a living he founded a training school for pilots on a grass runway. It was one of the first schools in the country, at a time when candidates for the "flying coffins" were scarce, and these were depression days and the rent was not always paid. As an instructor, he knew there just had to be a cheaper, more reliable, more efficient way to train young pilots. And he developed one: the Link Trainer, consisting of a cockpit, two pedals, a direction stick, and a compass. This instrument was the first flight simulator, and he has not ceased to improve it since. But in 1927 the device was premature. For many more years he eked out a living by giving lessons, barnstorming across the country, and teaching blind flying. With his own hands he constructed new dashboard instruments and he demonstrated them time and again on foggy days, in the dark above the mountains and in the stormy rains of the Great Plains.

At the end of 1929, a young woman reporter went to interview him. These "daredevils of the sky" were wonderful subjects for a lively article. Ed Link was only too glad to show her through the shaky hangars where he patched up his "big cloth birds" and he talked at length about the sky, his plans, and his faith in the future of the flying machines. Marion Clayton, the reporter, was too fascinated to take any notes, so her article was never written, but the "madman of the sky" enrolled her in his class. Starting as a pupil, she soon became the professor's assistant. Every night they collaborated in editing a theoretical course on piloting, the substance of which is still used today. The better Ed Link became acquainted with Marion Clayton, the more charming he found her, so charming in fact that he decided to marry her, so she could follow him to heaven, and generally everywhere. Since that time, Marion Link has followed her husband in the air, in the depth of the forests, on, at, and under the sea.

Everything changed the day when what was then called the Army Air Force adopted the Link Trainer to make pilots out of its mail couriers. At the same time, America was emerging from the depression, and civil aviation getting its real start. Ed had assembled the first Link Trainer with his own hands, using the footstool of a harmonium, the pedals of a player piano, and pipes of an organ as pistons. Very soon he had to shift to mass production, and the mushroomlike growth of his success gave Link a new personality—captain of industry. His diary was replaced with a thicker one, and on his desk the telephones were lined up. His first factory gave rise to a second one, then another. In these early factories were born the panel instruments, the navigation devices and the safety equipment of the modern civil airplanes.

The day after Pearl Harbor, America began to construct flying fortresses and fighter-bombers at the pace at which Chicago meat packers normally turn out sausages. These ten thousands of airplanes needed pilots and navigators. The Link Trainer trained them all on the ground, quickly, thoroughly and securely, not tying down a single plane or burning one gallon of fuel. Canada, Australia, New Zealand, South Africa, England, were asking for more flight simulators and for more instruments. Link was no longer having fun fourteen hours a day—rather sixteen and eighteen hours, Sundays included. Doing so, he made, in Winston Churchill's words, "an extremely important contribution" to the Battle of Britain.

After the war, he found himself heading a huge industry which he led successfully through the postwar upheaval and the vicissitudes of reconversion. Fifteen years after the war he was employing sixteen thousand people, he had interests in an airline, a bank, and half a dozen different industries, such as precision instruments, navigation, photography, and electronics. The jet pilots, civilian as well as military, were learning their profession in sophisticated flight simulators constantly adapted and brought up to date in conformity with the evolution and progress of the latest models. Today, at the new NASA base in Houston, the future astronauts, eyes fixed on a three-dimensional, fully colored lunar landscape which thrusts itself toward them and hands on the controls of a Link Lunar Approach Simulator, solidly attached to the Texas soil, rehearse in every detail man's first landing on the moon.

What drives Link? Why this devouring activity? Why this constant research? Edwin Link, as I have come to know him, is a lover of nature, the woods, the skies and the four oceans. Since there were no means to stroll and loiter at leisure in the sky and under the seas, he invented the vehicles

which could take him there in all kinds of weather, and when arrived, shelter him safely for a long and good time. He made a few million dollars on the way? So much the better, but that is not important.

American beavers and American businessmen, the real ones, seem to have this in common: they work by instinct until their very last breath. Blind or ulcer-corroded, they stubbornly keep building dams or fortunes. But Ed isn't that kind of businessman. Having mastered the problems of postwar reconversion, he shed his borrowed personality and became a shadow president. He bought a 43-foot yawl, the *Blue Heron*, a magnificent yacht which he sailed himself through the Gulf Stream and the Caribbean with his wife, second in command, and his two sons as crew. By this time, the Bahamian fishermen, those of the Florida Keys and those of Cuba were well acquainted with him and so were other yachtsmen, who often followed in his wake during oceanic races. But his managers and vice-presidents in Binghamton, New York and Washington were hard put to get hold of him.

On the dashboard of his planes, Ed Link had adapted the classical navigation instruments used in ships, and he took them back from his planes to install them on his boat. He won the famous St. Petersburg-Havana race over all favorites by applying the methods of aerial navigation, and taking advantage of aeronautical weather bulletins which cover vast areas.

But he soon got tired of racing. Vagabond cruising was more fun.

In the spring of 1951, the Links put into Vaca Key (between Key West and Miami) with William, their thirteen-year-old son, and Clayton, who had just turned nine. Bill

Thompson, the owner of the yacht basins of Marathon, was an old acquaintance. No sooner had they moored than Bill got on board and told the Link family a story which would radically alter the course of their lives.

Bill had located a wreck: "An old carcass of a galleon," he explained, lowering his voice, "no doubt about it." He had seen cannons, brought up cannonballs, pewter plate and tin tankards, a teapot and several elephant tusks. And that wasn't all. Half buried under the sand, he saw and touched dozens of black, oblong, thick bars, so heavy that he could not raise them. Quite obviously, they were silver ingots. Bill was preparing another expedition on the spot with a couple of physicians. Would Ed like to be in on it with the *Blue Heron*?

The next morning, when Marion, who had just finished the housework, looked for her husband, he had disappeared. But a second glance disclosed William and Clayton working hard on a hand pump, from which protruded a rubber hose which disappeared into the water. Over there, far away, big green bubbles made the surface boil. Ed was taking his first underwater steps, his head in a kind of upside-down bucket which served him as a helmet. The bubbles came closer and closer to the shore and the bucket emerged with a smile behind its porthole. "It works, but I sure need more air."

A few years later, Marion wrote: "Right then, I should have realized that one of those crucial times had arrived in Ed's life when it was essential that his perpetual need for enthusiasm should find a new alignment to progress in a new direction. . . . What I realized, though, was that an activity like diving and treasure hunting was going to make a deep change in the way of life we were accustomed to aboard the

Blue Heron."[1] What Marion could not have foreseen, however, was that the graceful *Blue Heron*, inspired by the romantic tradition of the sailing ship, was going to be sold ignominiously and be replaced by a plebeian shrimp trawler, one of those backfiring and vibrating "floating buses" on which Ed heaped choice insults every time he crossed their path. What she couldn't foresee, either, was that she was on the threshold of one of the finest adventures of our times.

The treasure hunters arrived. The expedition got organized Dr. Crile, who was in on the first discovery, led the three boats to Looe Key. From the start, Ed and Marion were in good hands. But the wreck looked like nothing they had seen in Hollywood movies. To begin with, there was no wreck. There was nothing there but debris scattered and crumbled by hurricane waves and twisted masses of coral and ghastly objects, camouflaged and distorted by the teeming inhabitants of the reefs.

The ingots? They were there all right, all over in the sand, but when Ed approached them with a wrist compass, the needle turned crazy. Too bad! They were only pig iron. (They served as ballast for the boat; probably a British man-of-war, for the debris strewn over Looe Key obviously did not come from a galleon of the King of Spain. Later, long investigations in London convinced Mrs. Crile that the wreck once had been a frigate of His Majesty, lost in 1744, while cruising along the Keys. H.M.S. *Looe* had bequeathed its name to the reef, but everybody had since forgotten.)

With the salvage of the ill-fated frigate *Looe*, and the identification problems presented by the remains, another science was born in the United States, underwater archae-

[1] See *Sea Diver* by Marion Clayton Link, University of Miami Press, 1964.

ology, and Mendel Peterson, Curator of the Department of Armed Forces History at the Smithsonian Institution in Washington, who was there on his first expedition, became with Ed Link one of the first American authorities on the history of wrecks from the sixteenth to the nineteenth centuries. Today a special department, the Department of Underwater History (in the Art and Industries building in Washington), houses the remains of the *Looe* and other wrecks which have been salvaged since.

Obviously, nothing is less suitable for salvage work than a sailing yacht. Salvaging is dirty work; engines make the masts vibrate, compressors shake up the ribs, oil and gasoline seep everywhere, cables and slings scrape the paint and scratch the varnish, rust makes indelible brown spots on white roofs under the weight of lead belts, sand and coral bits become encrusted in the deck, slinging cannons and ingots batter the bulwarks, and dripping divers carry salt, talcum powder and dirt all over the spotless white bunks.

Very soon Link found himself at the helm of a second boat, the *Eryholme*, a 72-foot diesel cruiser which could have made an acceptable platform for work if it had been less chrome-plated and more seaworthy. But like all American yachts of this type, she was nothing more than a very comfortable pleasure boat with large pane-glass windows designed for vacationists in blazers and white pants.

As every seaman knows, there is no such thing as the ideal boat. It would have to reconcile too many irreconcilables. But the one Ed decided to buy and convert for diving became, nevertheless, an excellent workboat.

From the outside, the first *Sea Diver* looked just like any other humble shrimper, one of those solid wooden hulls with superstructures far forward which drag their trawls all over the shrimp grounds of the Gulf Stream. Inside, it was a comfortable yacht, with no useless luxury, which testified to the good taste and common sense of its first owner, a yachtsman from Miami.

Marion was seduced at once by the harmonious interior decoration, but to Ed it represented 66 feet of thick, solid deck which could be scratched without remorse. It was an eight-cylinder Diesel Caterpillar, practically new. It was equipped with a hoisting boom capable of raising cannons and above all, it had room, more room than was needed to store the equipment and install the compressors and all the detection devices existing or to be invented. . . .

Ed was now spending more of his days under water than above. He worked with Art McKee in Florida and with Teddy Tucker in Bermuda, two famous treasure hunters of the U.S.A. The carcass of H.M.S. *Winchester* yielded its secrets to him and the wrecks of three or four Spanish galleons yielded a melted gold doubloon (melted, no doubt, in the burning of the ship) and buckets of silver coins, pieces of four and pieces of eight, badly corroded and almost unrecognizable. While Ed was stirring up sand under water, he was having some dust shaken off the records of the libraries of London, Paris, Seville and Simancas. On board his ship, he set up a nearly complete collection of documents pertaining to naval architecture, ancient artillery, firearms, side arms, ancient navigation instruments, cartography, etc. If he found a bronze demiculverin with a strange mark on the breech on a Cuban reef, he had only to climb up the diving ladder to locate the print which would give its date, and the document which would give clues to its nationality.

During the four years he roamed the Caribbean on *Sea Diver I*, Ed never stopped installing new navigation devices, new instruments, new detectors and new gadgets. But diving did not bring him all the satisfaction he would have liked. He was always dreaming of nearly intact and untouched wrecks. Of course, these would have to be very deep. But like everyone, he was stumbling against man's physiological limitations under the sea: nitrogen narcosis and decompression. For diving in 1955 was about as advanced as flying in 1925. Ed had made his own little conquest of the sky and now was determined to conquer the sea. "Nitrogen is narcotic at great depth," he said, "so, let's get rid of nitrogen." Resurfacing brings problems? "Very well, let's not surface, let's live on the bottom in a shelter, a house of some sort from which we shall go out by day to go to work and to which we shall return at night to eat and sleep." At the time, such an idea seemed amusing but utopian.

To serve as base ship for the first underwater house in history, Ed Link began to build his dream ship, *Sea Diver II*.

At the end of 1956, he submitted his own plans and extremely exacting specifications to a Boston naval architect, the firm John Alden & Co. Soon afterward, the keel was welded in place in a Massachusetts shipyard, the Quincy Adams Yacht Yard, and plate by plate the dream of a man became reality. Building the yacht took two years, and Edwin Link made many trips to the yard to make sure that his orders regarding choice of materials and equipment—from the engines to the crow's nest—were carried out to the letter and in all their details. One day the foreman of the shipyard summarized the orders with the comment: "Nothing but the best."

In 1956 also, Link officially presented before a research committee of the Smithsonian Institution, his project for a

"diving cylinder," which could be a livable little house under the sea.

In the meantime, his three-button, Madison Avenue suits and Saks Fifth Avenue hats were slowly fading in the mothproof wardrobe of his deserted apartment in uptown Manhattan. Himself? He was living, living under the sun of the islands like the free man he had succeeded in becoming. Laden with honors and an esteemed member of the committee of experts of the NASA "Man in Space" project, the road he followed was the road of a Schliemann.

For how could one make better use of a fortune, whether earned in the wholesale grocery business or the precision instruments industry, than by unearthing the ruins and the treasures of Troy and the palaces of Mycenae, by looking for and salvaging the museums that sank under the seven seas, by inventing, by constructing the necessary search and salvage equipment that will make it possible to work—sorry, I mean "to have fun"—on ancient wrecks, too deep for today's divers?

It was at the end of 1957 that I met Link for the first time. I was twenty-four and for two full years I had been diving day after day in the chaotic depths of the Spanish Atlantic, at the mouth of the Ría de Vigo.

I had associated myself with the Atlantic Salvage Company, Ltd., for my second expedition in search of the wrecks of the galleons of the 1702 Plate Fleet, and was then a member of a very cosmopolitan and somewhat colorful team of half a dozen frogmen, led by John Potter.

Edwin and Marion Link were on their way to Israel to explore the site of Caesarea, where they planned an archaeological expedition. Between planes, they made a detour via Galicia to greet a team of colleagues, and one fine morning Potter, in the Chris-Craft of a friend, brought us Ed Link. He was suffering, I recall, from a sinus infection, the only one, he said, he ever caught in his life. But it would have taken more than that to keep him on the surface. Johnny Nathan, the tallest and heaviest among us, loaned him his neoprene wet suit, and I took him into a moving forest of giant laminaria to show him the cannons, cannonballs and thousand pieces of wreckage debris which I had just discovered under the sand and in rock crevices all around the Carrumeiros reef.

He needed only a glance to shatter our illusions. "That cannon," he said to us, "is about fifty years older than the date of the battle. What's more, I wouldn't be a bit surprised if it were English." He was right. When the time finally came to bring it up to daylight, when the tired derrick of our old boat, the *Dios Te Guarde*, set it down on the deck, when its thick crust of oxide and concretions burst under our sledgehammer blows, the "broad arrow"—the sign of the British Ordnance—appeared on the breech and the monogram of George II of Hanover on the muzzle, both perfectly clear and indisputable.

Ed remembered this encounter and invited me several times afterward to join his expeditions. I missed Port Royal because I was at that time working in the ports and canals of France, pouring concrete, cutting up sheet pilings or bolting down lock gates, but later on I did sign up for the Sicily expedition.

In 1958, while making a pilgrimage to the Mecca of all treasure hunters, Link took his trawler to one of the most

murderous, the most inaccessible "hot spots" in the world: the Silver Shoals, a perpetual fury of foam and breakers, a reef big as a province, a hundred miles off Haiti, in the middle of the ocean. There, William Phips had raised thirty-two tons of silver, gold, and miscellaneous treasure from the holds of the *Nuestra Señora de la Concepción*, the galleon of the Vice-Admiral of the 1643 Plata Flotilla which was almost entirely lost.

He returned empty-handed, as everybody did since Phips, but Marion considered herself lucky that they returned at all.

He set himself a new goal. This time it would be the oldest wreck of the hemisphere, the carcass of a caravel lost on a reef off Cap Haitien on Christmas Eve of 1492. A very small boat it was, called the *Santa María*, and under the command of a visionary named Christopher Columbus. Extensive research had familiarized the Links with all the autographed documents relating to this shipwreck, beginning with the logbook in Columbus' own handwriting and his reports to the Catholic Kings. They knew that all easily recoverable objects had been removed by Columbus and his companions from the vessel which was split open on a shoal, but the carcass itself, or what was left of it, the anchors, the ballast, some piece of artillery perhaps, and what was in the flooded holds, should still be there, somewhere along the endless coral banks which hug the north coast of the island.

One evening, after many weeks of research along all the shores which might have fitted the descriptions of the time, Marion, swimming on the surface, spotted an anchor. It was covered with coral and solidly welded to the bottom. The experts saw in it a hand-forged anchor, of a type in use at the time of the discovery, and therefore probably lost by the *Santa María*. This historical treasure was presented to the Government of Haiti during an official ceremony.

On his return trip, Ed Link dropped anchor at Port Royal, Jamaica. At the end of the seventeenth century, Port Royal was the most famous city of the West Indies. Founded opposite the Kingston of today, it was the capital of vice, the bastion of gambling and debauchery, the headquarters of Sir Henry Morgan, his associates and competitors, and the place of damnation where all the pirates of the Americas came to spend the fruits of their bloody plunders in orgy and profligacy. It was Sodom and Gomorrah, "the most wicked of all the cities of this world." But for Link it was, above all, a whole city put on reserve, a slice of colonial life of the seventeenth century, preserved intact by the waters, since the divine wrath, in the form of the earthquake and tidal wave of 1692 which swallowed half the city, had put to rights the licentiousness of the lost children of Port Royal.

Sea Diver I did not linger over the ruins of the sunken city. Link located the ruins of the main fort with an echo sounder and the guns of the city, thanks to a metal detector which he had developed. He followed the walls under the mud and salvaged a cannon on the way, but he saw enough to convince himself that he had to set up there a well-organized, long-lasting expedition. That would be the first task of *Sea Diver II*.

3.

SEA DIVER II: ARCHAEOLOGY UNDER THE SEA

MARION threw out the ribboned bottle of champagne. It made a graceful curve and burst like a flower of foam on the white bow of the ship. *Sea Diver* the second slowly glided over its cradle, and the waters opened to welcome another ship, the culmination of one man's dreams and experience.

It was May 1959. Under Ed Link's feet was the boat of his life, and the four oceans were his. Now he could go wherever he wanted to, take any weather, and remain long enough in God's most forgotten corners to carry any project through successfully. To do just that, he had at his disposal the most modern navigation and research instruments and salvage equipment. Most of the ship's devices were the sole, original models.

Sea Diver is 100 feet long, 22½ in beam, and draws 6 feet, fully loaded. The welded steel hull is divided into seven watertight compartments and protected by a double bottom, which constitutes the fuel and drinking water tanks. Their capacities: 72 tons of oil, a cruising range of 7,000 miles (round trip of the Atlantic), and 22 tons of fresh water.

In the trial runs, the ship lived up to its promises. Its twin 180-240 hp GM diesels gave an easy ten knots cruising speed. Very easy to maneuver thanks to its twin screws, it could even turn within its own length, when helped by two high-pressure water jets installed in the bow. Mooring or delicate steering between the teeth of coral banks would now be much safer. The pump of these two water jets is driven by a third 100 hp diesel, which also operates a special generator of 50 kw-220 volts for the hoisting boom, the anchor winches and those of the davits of *Reef Diver* (the small auxiliary vessel), and a high-output industrial compressor for the air lift—a basic tool on all archaeological sites. In addition, the ordinary generator of 30 kw and an emergency generator of 10 kw each has its own diesel. Also, in the engine room, there is a complete workshop with electrical saws for wood and metals, a drill, a milling machine, posts for welding and cutting (oxy-arc or oxyacetylene), a complete set of mechanical and electrical tools, etc.

From bow to stern, from the double keel to the top of the mast—everything on board was conceived and built with one single purpose, underwater research. At the time, *Sea Diver* was the first boat ever built specially for oceanography and diving. Two electrical winches fore and a capstan aft permit a precise anchorage on all parts of an archaelogical site; one needs only slacken or haul the chains and the cables of four anchors cast crosswise.

In the rear of the chain well, a watertight, vertical funnel leads to the observation chamber where two submerged portholes open on the sea bottom below the waterline. The crew's quarters (four bunks, a shower room with hot and cold water), the cabin for the engineers (two bunks and a bathroom), and the scientists' quarters (also two bunks) are

directly fore of the engine room. The owner's cabin, his office, and the guests' quarters (two additional bathrooms) occupy the central part of the boat which, of course, is completely air-conditioned. Aft there is a completely equipped dark room and a spacious laboratory with hot and cold running water, electric outlets with three different voltages, compressed air and gas, etc. The diving compartment occupies the entire stern. On the starboard side are the racks for scuba tanks, the rows of regulators and wet suits and the small gear. The compressors on portside are two high-pressure and two low-pressure, two drums also in which are wound up the 100 feet of reinforced air hose of two Desco masks. And these hoses may be used also for the penumatic tools, the pneumatic hammer to break up the coral, the saw, the riveter, the metallic brushes, drills, dowel or pin drivers, etc.

To give the divers direct access to the sea, the central part of the rear hatch lifts up, and to store away the treasure chests directly in the hold the bridge itself opens up wide into a double loading hatch.

The hoisting boom (with electric winches) can lift and deposit on board five or six tons of treasure in one operation, or even Link's twin-engine Grumman seaplane when he carries it on the rear deck for aerial reconnaissance. Above all, it can lift the Link cylinder, weighing a little less than three tons, for which the ship had, in fact, been built.

Sea Diver was ready, but the cylinder was not. The problems that come with all prototypes were multiplied here by the novelty of the basic concept, and by the difficulties in welding special aluminum alloys.

All through the summer of 1959, *Sea Diver* was the base camp of the Links, Mendel Peterson, and about a dozen divers, who were groping under the mud and dirty water for the remnants of Port Royal. Mrs. Link, the research staff of the National Geographic Society, and the specialists of the Smithsonian Institution had been doing painstaking research for two years in the archives of several countries. Starting with the maps and notices to mariners of the time, they had reconstructed, bit by bit, the layout of the port at the time of the earthquake. Now, the divers were trying to correlate this map with the landmarks which seemed to appear under the sediments. At the time of his first visit to Port Royal, Link had found the walls of old Fort James and fished up an old iron cannon; he had been astonished to see that the usually flat mud bottoms rose up like dunes over the sunken walls. *A fortiori,* he reasoned, the important buildings like the King's warehouses must show like mountains. To draw a three-dimensional underwater map, he first systematically ran a recording echo sounder over its entire probable area. For such a mission, *Reef Diver*, the small auxiliary boat of *Sea Diver*, was the ideal launch: 20 feet long, it has no propellor which could cut slices in the divers as they often do, or get tangles in the towlines; no rudder either, but only a powerful jet of water which propels the boat by reaction. The engine is a 42 hp Perkins diesel, which, in addition to the pump, drives the generator for the electronic instruments (echo sounders, mud pingers, sonars, magnetometers, radio, etc.) and a low-pressure compressor which supplies two divers with air. In these muddy waters, though, the underwater portholes in the bow were useless.

The bottom of the sea soon took shape on the electrolytic paper of the echo sounder. An entire cross section of the city began to appear with clearly defined mounds rising from the average depths of 40 feet up to 10 feet from the surface.

When the divers went down to anchor floats at the four corners of the mounds, a complete map of the sunken city formed by multicolored buoys popped to the surface.

Sea Diver anchored east of the fort's walls. The compressors started at once and the hungry mouth of the air lift began digging into the hard mud which had preserved the city for two and a half centuries. Deeper and deeper the air lift burrowed—four feet, six feet, ten feet of sediment, a large funnel with solid walls, and on the bottom of it the city. On the surface the big ten-inch pipe was spouting its heavy black stream with a turmoil of mud and debris. Clayton and Marion were watching for the relics of the past: clay pipes, rum bottles, intact and sometimes full, bricks, silver spoons, knives, pothooks, bronze mortar, grindstones, etc. Along side of a brick wall, the divers found a complete set of kitchen utensils in tin and copper, pots, stoves and pans, then a whole dinner set, and finally the blackened bricks of an oven.

Among the finds of the following weeks, Mendel Peterson was particularly interested in a fifteenth-century, completely anachronistic iron swivel gun and a pocket watch made of bronze and silver in very good condition. Carefully cleaned, it appeared engraved by a famous Dutch watchmaker who had signed it ten years before the catastrophe. Under X-rays, the trace of the hands, which had been completely corroded by the seawater, appeared very distinctly. The watch had stopped at 11:53 A.M., the exact moment when the city of Port Royal crashed into the sea.

At the end of the summer, Ed Link weighed anchor to head west. He went to help some Mexican divers on the Yucatán coast salvage the cargo of the *Nicolasa*—the Spanish caravel that in 1527 was sailing north, up the still-unknown coasts of Central America, when she burst open on a coral reef off the Isla de las Mujeres. In all likelihood, she was carrying a cargo of Mayan treasures. Here the metal detectors and the pneumatic hammers worked wonders in locating the iron lombards camouflaged under the coral.

Spring of 1960; *Sea Diver* cut a swath eastward. A squadron of sea gulls which had followed in its wake from the port made a wide half circle and the white birds flew away swiftly toward land, toward the skyscrapers of Miami Beach, whose clear silhouettes were fading in the morning fog. Ed Link, lost in thought, watched on the Weems Plath compass the course which the Sperry automatic pilot faithfully maintained. Nobody held the helm, and the steering wheel turned automatically, like that of a phantom ship. At most, one could from time to time see Ed Link turn a little knob. The beams of the two radars silently swept the luminescent screens and traced the distant coastline. Link was now waiting for the north point of Andros to appear, a tiny yellow spot, right in front, on the black screen. He paid little heed to the fog; neither his radars nor his radio goniometer or the loran needed eyes to see. His next port of call would be Puerto Rico, then Gibraltar, eighteen days away. From there he would enter the Mediterranean and moor finally in the port of Haifa. Having arrived, he would be ready to go and anchor nearby in front of a city buried under the sands and over a port swallowed up by the sea. He would be off Caesarea, the city of the Jews, of the Christians, of the Romans, of the Arabs, of the Crusaders, of the Turks, of the dead.

The Caesarea expedition was sponsored by the Israel-America Society, the Theological Seminary of Princeton and *Life* magazine. Under the crystal-clear waters and the marine sediments, the same archaeological "sandwich" was

awaiting the divers as the one from which the classical diggers of the Israeli Government were cutting every day big slices of history.

Caesarea was the city that had risen out of the desert in ten years, under the impetus of Herod the Great, King of the Jews, father of the Biblical Herod. Friendly to Rome at first, it was subjugated, like all of Judea, the year Jesus was six years old. Jesus was nearly thirty when a public servant named Pontius Pilate came to Caesarea to take up his new job. A few years later St. Peter arrived in the city where he was to convert the first Gentile, the centurion Cornelius. St. Paul was imprisoned in the town's main prison. In the year 60 A.D., 2,500 Jews were thrown to the Abyssinian lions in the arena, as were many Christians, after them. The Saracens captured the city in the seventh century, the Crusaders recaptured it in 1101, and the Arabs reconquered it again in the thirteenth century. Then the city died forever.

In its days of grandeur, Caesarea possessed the only sheltered port in all Palestine, and was channeling the whole maritime traffic of this part of the world. Historian Flavius Josephus, who went through Caesarea 1,900 years ago, wrote: ". . . and he [Herod] gave Caesarea a port which was always sheltered from the great waves of the sea, and where the great ships could stay in safety. . . . A semicircular, artificial jetty, 200 feet wide, and skirted by a quay (a pleasant walk for those whose taste inclines toward such an exercise) enclosed it completely, and on both sides of the entrance stood three colossi, three giant statues made of the most polished stone."

The artificial jetty is still there. Edwin Link saw it clearly from a plane—a dark, green streak, straight on the north side, circular on the south side, sharply visible on the clear, sandy bottom and broken off where the entrance to the port used to be. Josephus wrote: ". . . the entrance to this man-made port was through the north, from where blew the weakest of all the winds of this region."

Sea Diver dropped anchor just there. The air lift was in operation all summer and for a long time, in vain. The weather was abominable. Three times Ed had to weigh his three anchors to flee back for shelter in the port of Haifa. Night and day the boat was buffeted by the wind and the swell without a second of calm. The stones of the mole, which loom out of the sand covered with hairlike pine-green algae, are hardly more than the crest of the jetties. Ed had to dig more than 16 feet under the sand to finally reach the Roman stratum. Then the treasures came up. Alas, not the stone colossi. Earthquakes must have smashed them to bits many centuries ago, in spite of the lead pins which fastened the enormous limbs to the colossal bodies, and the abrasive effect of the sand, stirred up by the waves, has probably worn them down beyond recognition, but a thousand small artifacts, more significant perhaps than the statues, came up: Roman and Hebrew amphorae, pottery, a bronze seal bearing the effigy of the god Horus, a unique shell-shaped oil lamp, hair-pins of sculptured ivory, bronze ship nails and many bucket-fuls of coins. The Israeli archaeologists studied in great detail each of these objects before they filled up a museum hall with them.

When winter and the short nasty Mediterranean swells chased *Sea Diver* from an anchorage that was exposed to all the south and west winds, they went to seek refuge once again in Haifa. In the meantime, *Reef Diver* was riding a tank carrier toward the Sea of Galilee. The water level of this interior sea has risen several meters since Jesus used to

perform his miracles there, and one day Link's divers found themselves standing on a sunken road which, no doubt, was perfectly dry the day Peter went over it. Farther away from shore, a complete cargo of Roman pottery, perfectly intact, seemed to await the divers. They turned out to be brand-new kitchen pots, similar to those in which Mary used to boil the family stew.

When spring came, *Sea Diver* resumed operations at Caesarea, but the most important discovery, the most sensational artifact, was discovered on the last day. While Link was getting ready to halt the entire operation, one of his Israeli divers found a medal, no bigger than a nickel. It was a commemorative tessera, which he at first mistook for a coin. It showed the port of Caesarea with its two jetties, its stone giants and two Roman galleys under sail. On this tiny medal is the only known picture of the famous port of Herod, the first port of Palestine, "which was always sheltered from the great waves of the sea."

After Caesarea, the *Sea Diver* moved on to Greece, Salamis, Rhodes, the islands of the Aegean Sea, for a long leisurely cruise. It stopped at Malta and then in Sicily, where I finally came on board, at Syracuse, on May 10, 1962.

4.

SYRACUSE: THE BEGINNING OF THE MAN IN SEA PROJECT

TO be working on *Sea Diver,* to dive all day long in the gin-clear waters of Sicily, to exhume from the sand the wrecks of ancient ships, to sniff the air of these small Sicilian ports, where today's wine tankers pump into their holds through a rubber pipeline resting on the bottom the same tart wine which the Greek and Roman merchant ships used to load here in earthen amphorae—this was nothing new to me, I had dreamed about it so often.

But from dream to reality, the ship had become more perfect still, the colors softer, the water clearer, the archaeological treasures more admirable and the May sun warmer.

Ed Link was collaborating in his undersea "dig" officially with Marquis Piero Nicholas Gargallo, Honorary Superintendent of Antiquities for Southeastern Sicily, Department of Underwater Archaeology. Upon my arrival in Syracuse, I paid a visit to the Marquis's palace in the Old Town. The entrance hall was a museum, a unique collection of anchors, stocks, amphorae, carved marbles. . . . Before I could catch a glimpse of the rest, I was ushered into an immense library, the four walls of which were hidden by several thousand square feet of old gilt-titled, leather-bound books. The whole history of Sicily was there, partly written by the last five or six generations of Gargallos, within hand's reach of the remarkable man who joined me in the library: Piero Gargallo, diver-archaeologist and world traveler, the quintessence of the Latin aristocrat, full of warmth and enthusiasm, and so very deeply in love with "his" old Sicily, or at least with what "they" had left of it. Piero speaks four or five languages fluently, and spends his time in as many countries.

He told me in French about his underwater finds. He showed me through his museum, the marbles, the pottery, the medals, the broken mosaics, the bronze weapons and statuettes, the lead figurines he had found in Greek wrecks all along the southern and eastern coasts, and above all, this unique and exceptional object brought up from the bottom of Syracuse's old harbor, a Greek warrior's bronze helmet coming right out of the pages of the *Iliad.*

We went down together to the yacht basin, where *Sea Diver* was moored, its poop toward the quay, the prow facing the same bay where Roman and Syracusian galleys had rammed and set fire to each other, a little over two thousand years ago.

I found Ed and Marion unchanged. He had the same energetic face, furrowed all over by the sun and the spray, with the same sharp beak and the same glint in the eyes; he had his same big strong body which so gracefully carried his fifty-eight years. Marion smiled the same smile, and showed the same kindness, and offered the same warm hospitality.

As for the big, white dream ship whose photo I had admired in all American magazines, it took me many days to fully realize how elaborately efficient each part of her really was.

On the rear deck I had immediately noticed a brand-new, aluminum cylinder. "Well, well," I said, "what a strange recompression chamber." It was a massive tube, welded lengthwise, closed at one end by a heavy, bolted plate pierced with watertight connections (an electric cable and two reinforced rubber hoses), and at the other end by a double dogged circular hatch that locked like the door of a safe. It was about ten feet long and three feet in diameter, with four portholes and several mysterious appendices. Under Captain Link's amused eye, I inspected the monster several times.

"No, no," he insisted, "it is not a mere recompression chamber; it is much more than that. It is altogether a submersible decompression chamber, an experimental dry chamber for simulated dives, a submarine, an observation turret, and above all, it is the first house under the sea."

Jules Verne's Professor Aronnax was probably not much more startled than I was then when he listened to Captain Nemo's explanation of the workings of *The Nautilus.* It has taken two years and several sometimes well publicized demonstrations to make even the layman familiar with the concept of extended life under pressure in undersea houses. But in May 1962, living on the bottom of the sea seemed as far away as a landing on Mars.

I changed the subject.

For three weeks we worked on several Greek wrecks with Piero Gargallo and a German archaeologist, Gerhardt Kapitän. One of them, in front of the small port of Ognina, yielded us mosaics, vases and glass flasks of incredible delicacy, a seal with inscriptions, dishes and pottery. The metal detector which I systematically ran over the bottom reacted several times. Where the needle vibrated I dug, and, from under two feet of fine white sand, bronze statuettes and the ornaments of a small chest came into view.

But our main effort was concentrated on the scattered remains of a Greek cargo vessel of the sixth century A.D., off the commercial port of Marzamemi, the traditional export center for those ordinary wines of southern Sicily which have been used for blending since Noah's time. The air lift turned over dozens of tons of sand to exhume the cargo. The cargo, lost with the ship, 40 feet down, at the foot of a reef, consisted of the ornamental component parts of a prefabricated, paleo-Christian, Byzantine church. The sand held everything: columns of white marble, composite cornices, foundations, mosaic fragments, a ritual saucer engraved with typical orthodox religious motifs, even the pulpit, carved in green marble, with its steps and artificial small columns, in every way similar to its prototype which can still be seen today in several Turkish churches or in the Cathedral of St. Mark in Venice.

Finally the boom of *Sea Diver* unloaded on the quay of Syracuse, after thirteen centuries of delay, at the feet of the Curator of the Archaeological Museum, some twenty-five tons of wrought marble. From then on, putting aside his interest in undersea archaeology, Ed busied himself with his cylinder which henceforth was going to monopolize all his attention, all his time and energy and a good part of mine.

In the yacht basin, under the museum windows, two hundred people were jammed on the quay one Sunday afternoon to observe the strange behavior of a singular American, all dressed in rubber, who was playing in the water with a colossal tin can. The American dived, disappeared under the

surface, but did not come up again. A little later, the can sank, then shot out of the water like a torpedo, only to plunge again toward the bottom.

I watched the baptism of the Link cylinder from another angle. Ed had explained to me at length what exactly he had in mind, and my first perplexity had given way to enthusiasm. The "Man in Sea" project, the "houses under the sea," this was the most exciting development a diver could dream about. Like everyone concerned with the conquest of space, I would have volunteered immediately for an expedition to the moon, or a survey on Venus, but what were my chances to take a part in the conquest of the cosmos? And besides, when you come to think about it, what would one do on the moon? Get rid of the earthman's ball and chain? Yes, but one would return empty-handed. Now, I saw my chance to play a role in conquering the continental shelf, by working in my own environment, with a man who would make our century remembered as the time of the conquest of the seas, as well as the conquest of the sky and the stars, and my mind was made up when Ed Link, after observing me at work under the sea for a month, asked me if I would like to spend a day or two in his aluminum house about 200 feet deep.

A whole day at 200 feet, what a prospect!

Until then, like all divers, I had never been able to spend more than fifteen or twenty minutes at that depth. What's more, I had to pay for such a stay with a decompression time twice as long, at 30, then 20, and finally 10 feet below the surface. A helmet diver, being supplied with air from the diving boat through its hose, can stay there one hour if he is exceptionally resistant to nitrogen narcosis (an insidious "intoxication of the deep" which clouds the mind, prevents one from working intelligently and sometimes leads one to make a fatal mistake), but he will spend the rest of his normal working day, three to four hours (more if he has worked hard), waiting in mid-water on a platform stage until the nitrogen dissolved in his blood is willing to pass again into his lungs, and is then exhaled.

In other words, deep, prolonged, conventional dives with air are uneconomic because of two basic problems, decompression and nitrogen narcosis. Today, all the actual underwater work is still done by the heavy gear or the scuba divers. The "dry" diving vessels such as bathyscaphes, mesoscaphes, diving saucers, or these innumerable small scientific submarines whose blueprints are swarming the United States are, at present, by nature, incapable of any real work. Their only use is scientific observation and reconnaissance photography, or perhaps the collection of a few samples of debris if they are equipped with an articulated external "arm" (which is often paralyzed by a strange form of arthritis). As for the open "wet" machines (i.e. where the rider is *in* the water), such as the underwater scooter and other capsules, they are merely vehicles for seated or towed scuba divers, who can no more escape the effects of the surrounding pressure than a motorcyclist can escape a sudden shower.

Comic strips, adventure stories or certain television series that show the feats of a diver without fear or reproach and are on the same level of technical accuracy and scientific probity as the *Son of Zorro* series or Doctor So and So and other Robin Hoods, tend to plant a great many false ideas in the minds of the layman.

Let us explain, therefore, what problems divers really encounter. What is decompression sickness? What is the "rapture of the depths"?

Our ancestors, the helmet divers, used to call collectively

all decompression accidents the "bends." For the laborers who were working eight and ten hours a day in diving bells or in pressurized caissons to lay the foundations of quays, of bridge pilings, etc., in the late eighteen hundreds, it was the well-known "caisson disease."

Since the studies of Paul Bert (1833–1886) and Haldane, we know that these accidents are connected with the prolonged respiration of compressed air. The air we breathe contains approximately 79 percent nitrogen and 21 percent oxygen. When the diver goes down and stays on the bottom and inhales compressed air, it dissolves in his blood every time the blood circulates in his lungs. The oxygen which is carried to the muscles is consumed there to produce energy (muscular combustion) and thus disappears, but the nitrogen remains in the body in liquid form. The amount of dissolved nitrogen is proportionate to the pressure (i.e., the depth attained) as well as to the duration of the sojourn under water. The amount does reach a limit value when the blood and the whole body become saturated at the pressure involved. This limit is almost never attained by divers, because it would require a bottom time of over eight hours under water, but it was frequently approached by caisson workers. The dissolved nitrogen is circulated by the blood which, at every heartbeat, loads with it the tissues it irrigates. The nitrogen in solution will also diffuse from one tissue into another, thus after a length of time will spread over the entirety of the fatty, nerve and bone tissues.

No harm done, up to that point. But on the way up, as the pressure in the lungs begins to decrease, the nitrogen which dissolved in the blood under the pressure of the greatest depth reached will return to the pulmonary air, through the capillary-irrigated walls of the lungs' alveoli, in proportion to the pressure decrease following the reverse cycle. Simultaneously, the nitrogen dissolved in the tissue will be "taken back" into circulation by the blood and restored in gaseous form to the air breathed, at the time it is flowing in the pulmonary capillaries.

If the ascent is slow enough, the return to the gaseous state will take place normally, and the nitrogen will be eliminated with each breath. If the ascent is too rapid, or, in other words, if there is too great a difference between the pressure of the dissolved nitrogen and the hydrostatic pressure (the water pressure, which is also the pressure under which the air is piped to the diver by his regulator), the gas will not be able to "pass through" fast enough, and will come out of solution in tiny bubbles in the blood and tissues. That is about what happens in a bottle of soda water or champagne which is suddenly uncorked, whereas the same bottle opened very gradually, or poorly corked originally, will be "flat" and nongaseous, because the gases dissolved in the liquid under the pressure of bottling will have been regasified during the slow return to the atmospheric pressure, and will have escaped. Therefore, the diver should surface slowly enough so that his blood will always remain "flat." To accomplish that, he need only follow the indications of the well-publicized and very safe U.S. Navy Decompression Tables.

What becomes of these bubbles if the ascent is too rapid? The bubbles forming in the blood will slow down or interrupt the circulation in the small blood vessels where they get stuck, with often serious consequences for the tissues which are not irrigated any more, specially for the brain cells. If a large quantity of bubbles reaches the heart, the embolism is fatal, as the heart cannot keep pumping.

The bubbles which lodge in the adipose deposits or in muscles are gradually reabsorbed, leaving limited damage. The bubbles which form in the bone and marrow tissues, where they remain imprisoned much longer, cause excruciating pain and dangerous arterial trouble. They compress the blood vessels around them, thus preventing for quite a long time the normal irrigation of the bone. A few months after the accident, osteoarthritis and decalcification of the bone may set in. Stiffening of the joints and an irreversible deformation, comparable to that of rheumatoid arthritis, may take place. Minor, but repeated accidents, usually lead to the same result as one severe accident.

The bubbles appearing in the nervous tissues, in the spinal cord or in the brain may cause deep, burning pain or paralysis. These are the real "bends" which constrict the limbs or one entire side of the body (hemiplegia), and actually bend a man in two. In the worst cases they may bring about an immediate paralysis which will sometimes affect progressively the entire body. At the outset, the feet do not react, then the legs are immobilized, the urinary and intestinal channels are blocked, and finally, if the paralysis continues to spread, respiration itself ceases.

In benign cases, certain local paralyses are temporary; in other cases, hemiplegia turns the diver into one of those incurable invalids who can be seen warming their painful joints in the sun in many small Greek ports which specialize in sponge diving.

The only treatment for all these accidents is recompression (preferably in a recompression chamber; if necessary, in the water) which redissolves the bubbles again, followed by slow decompression to allow the nitrogen to be slowly regasified and eliminated, which should have been done in the first place.

And the "rapture of the depths"?

Yesterday, this strange kind of dizziness, this temporary mental impairment, was called nitrogen narcosis. Most divers feel it at 150 or 200 feet; others don't until much deeper. Some Italian coral divers, for instance, currently dive and work breathing air to depths of 330 feet; and the writer has never experienced it, not even at 285 feet. A diver, at the same depth, may be affected today and not tomorrow, inexplicably. The affected diver will feel euphoric, in top shape, as in early alcoholic intoxication, or sometimes oppressed, or will panic with no reason. Later he will have a certain difficulty in coordinating movements, reflexes will get slower, his brain may become totally impaired. He will often forget what brought him to the bottom, he will work clumsily, slowly, and, in extreme cases, he will make a foolish, fatal mistake. But all the symptoms will disappear in ascending, and he will not remember them. Classic examples are the scuba diver who takes off his mouthpiece to offer it to a fish which, poor thing, lacks one, or the heavy gear divers who, in ascending, pretend in good faith that they have completed their job when they have done nothing or done the job all wrong. I have seen a diving companion, at 180 feet, completely forget the search plan he was to follow with me, and blissfully fall asleep in the sand on his back, with his legs crossed and his hands under his neck. (I grabbed him by the strap of his tanks to bring him up immediately.)

With practice, the onset of narcosis can be retarded during a deep dive. One must make an effort to be lucid, concentrate on what he has come to do, compare his plan of action, item by item, with what he is actually engaged in doing, and frequently check the manner in which the job has been accomplished. If he begins to feel giddy, hilarious or awkward, he can try to go up a few feet until he has recovered his senses. If there is no improvement the second time, it is best not to insist.

Until recently, the reason for this narcosis was traditionally attributed to breathing nitrogen (or other heavy inert gases) under pressure. American investigators had discovered that the heavy gases, which have a high solubility coefficient in the fatty tissue, are the same gases which are intoxicating when inhaled under pressure in an oxygenated mixture, and this narcosis was attributed to a still unexplained biochemical action of the gas dissolved in the fatty tissues which make up the gray matter.

Several years ago, the Swiss mathematician-diver Hannes Keller and his associate, Dr. Bühlman, reverted to a different theory (which they have amended somewhat since), according to which the agent responsible for narcosis is carbon dioxide (another heavy gas), which is poorly evacuated at depth as a result of poor oxydation of the hemoglobin of the blood when the air has become too dense under pressure, too viscous, and can no longer properly ventilate all the recesses of the pulmonary alveoli.

At any rate, it seems today that one should revert to the classical theory of solubility in fatty tissues of the brain, keeping in mind though that carbon dioxide certainly aggravates (when present in abnormal quantity) narcotic effects and decompression accidents (as well as oxygen toxicity).

Recently, Dr. H. R. Schreiner and Dr. G. F. Doebbler have obtained experimental evidence (research work of the Linde Laboratories in Tonawanda, New York) for the new hypothesis that chemically inert gases exert their effects in biological systems by displacing oxygen from critical sites within the cells.

Be that as it may, those are the two main obstacles which had blocked the progress of man's penetration under the sea until 1962.

Confronted with these two problems, which prevented him from going and looking where he would have wished, Link immediately hit upon two solutions, characterized by the simplicity of genius.

So resurfacing presents problems? Well, let's not resurface. Is nitrogen narcotic in depth? Well, let's suppress nitrogen.

As a matter of fact, the two ideas were not new. What was really new was that someone, instead of writing: "It would seem therefore . . . that it may suffice to . . ." in some very documented scientific paper, was going to roll up his sleeves this time, loosen his purse strings, build the necessary hardware, and operate it efficiently under water in a practical demonstration. It was this impetus from an individual, from an amateur, which was to revolutionize diving.

In drawing up the plans for his cylinder, Link was not exactly inventing the "houses under the sea." Without knowing it at the time, he was reinventing them.

For of all modern techniques which emerged from the Industrial Revolution, that of underwater diving has been marking time the longest. The diving helmet had become the norm, without any magnificent improvement, for a century and a half after its introduction in England in 1819. And the diving helmet was nothing more after all than a small portable diving bell with a window, carried on the head and attached to a tight-fitting suit.

And the diving bell itself is as old as the sea.

In the fourth century B.C., Alexander descended in a bell under the waters of the Bosphorus "to see what was there and to defy the whale." Legend assures us that "he saw there a fish so big that it passed in front of him for three days, although it moved about with lightning speed."

In ancient times, in fact well before Alexander's time, bells were routinely used in the Mediterranean, as they were throughout all of Europe during the Middle Ages. But it was Edmund Halley, inventor, astronomer, and secretary of the Royal Society, who in 1716 built the first *modern*, safe and efficient apparatus and demonstrated it himself in the Thames River. (He had built his first bell in 1690.) It was a wooden, lead-sheeted bell in which the air was renewed, by means of ballasted barrels which carried down 160 quarts of fresh air each, that made it possible, for divers wearing wooden helmets, to work not only under the bell but also all around, as far as their greased leather hoses could follow them, and where the first rivernauts could return from time to time to rest on a bench, warm up a little or nibble on a sausage. The modern caissons and the heavy diving gear (Augustus Siebe, 1819) have evolved from that early diving chamber and from the more modern inventions of the compressor and synthetic rubber.

The self-contained diving apparatus, or scuba, or aqualung, invented and demonstrated by Commandant Le Prieur between the two wars, improved by Commeinhes during the Second World War and perfected by Cousteau and Gagnan, broke the umbilical cord which held man to his native habitat, but it did not free him from his eternal physiological restraints: narcosis and decompression.

To obviate the daily loss of time involved in decompression, Sir Robert Davis (the author of the most monumental treatise on diving ever written: *Deep Diving and Submarine Operations*) invented around 1930 a hemispherical "chamber for prolonged immersion": which was similar in principle to all the present models (except that it was supposed to remain at atmospheric pressure), but never went further than the drawing board. He also invented and built a Submerged Decompression Chamber or SDC, which is still in use today, and this was the first real important step toward a partial solution of decompression problems.

To overcome narcosis, the nitrogen of the air had to be replaced with another non-narcotic, inert gas. The U.S. Navy's Experimental Diving Unit, which had been working with helium since 1925, had succeeded in eliminating all narcosis, but only for the short deep dives of the Navy heavy-gear deep-sea divers.

"Let's not go up," Link had been saying since 1956, "let's live under the sea. Let the inert gas, the solvent of the vital oxygen, saturate us slowly to the marrows. At the end of our expedition, we will be decompressed once and for all."

What would divers gain thereby? One simple example will make it clear. An ordinary diver who works for one hour in the open sea, 200 feet down, half knocked out by narcosis, must spend four hours more waiting at different decompression stages, before getting back to the surface. One hour of productive labor, therefore, will cost the company employing him a full day's work, while the diver, crew, boat, compressors, and special equipment are immobilized.

For example, if the job requires 40 hours of effective work at the bottom, it will cost the company 40 full days of work, or two whole months (not counting storms, engine trouble,

fog, etc.). If the diver is replaced by a worker living on the bottom around the clock, in some kind of dwelling like a Link cylinder or a submerged house, our man will then work his eight hours, five days at a stretch. He will go home, in his comfortable and well-heated shelter, for lunch, for a drink and to relax and sleep at night. When the job is done, he will lock himself in his cylinder, and be brought back on board for safe deck decompression in fine comfort, and under medical supervision. His decompression will take 48 hours, but won't immobilize the whole crew of the ship.

To get the same job completed, done better by a clear-headed diver, who will have taken fewer risks to his life and health, the company will have devoted 5 instead of 60 days, a saving of 12 to 1.

Besides this particular case, which is typical of any ordinary underwater job such as salvaging wrecks, sewer laying or underwater construction, most of tomorrow's lobster raising, fish farming, mineral extraction, scientific work, etc., will probably require permanent surveillance of the bottom by oceanauts, and here again the ability to live under pressure for weeks and months will be a sine qua non condition. Like the oil workers in the Sahara, like the scientists hibernating at the Pole, or the colonists "settling" in the jungle, the colonists of the bottom of the sea will have to "settle down" and, when civilization has won the continental shelf piece by piece, they will be able to live there in comfort with their wives and children.

"Let us suppress nitrogen," Link would also say, "and we will have suppressed narcosis."

Nitrogen is a chemically inert gas, useless in the respiratory cycle, except for diluting and carrying the fuel of the body—

the 21 percent oxygen in the air—into the lungs. Of this 21 percent, the blood hemoglobin, when in contact through the capillaries of the pulmonary alveoli, will take about 5 percent to oxidize itself in exchange for the carbon dioxide which it returns from the muscles. It is only the oxygen, therefore, which ensures the purification of the venous blood, and it seems logical that nitrogen, this apparently useless, inert gas, which is responsible for narcosis as well as bends, be suppressed purely and simply. "Why not breathe pure, undiluted oxygen?" the Frenchman Sandala was already wondering in 1842, and 36 years later, an Englishman, H. A. Fleuss, constructed the first breathing apparatus for diving, using closed-circuit oxygen, and it did not kill him. Davis perfected it, and put it on the market.

This type of device operates perfectly in shallow depths. Military divers, British diving spelunkers, and many Italian sportsmen use it today, in a hardly modified form. Unfortunately, pure undiluted oxygen becomes deadly at depths below 27 feet. Below 27 feet (sometimes a little lower, O_2 partial pressure about 2 atmospheres), an attack of hyperoxemia (the "unexplained oxygen poisoning") will soon bend the diver brutally in a series of epileptic-like convulsions, sometimes blinding him or leaving him in a coma, and often resulting in drowning.

Therefore the diver's breathing mixture requires a solvent which keeps the oxygen partial pressure low, but since nitrogen, a natural solvent, has no useful action per se, one can replace it with another inert gas.

But which one? There are heavy ones and light ones, common and rare ones. Those which have been tried in the past are mainly certain rare gases in the air, such as argon, xenon, neon and helium, that the American and British navies are

using at the present time, and hydrogen, unsuccessfully pioneered by the Swedish Navy.

Hydrogen is light, tasteless, colorless, and odorless, but unfortunately it is not an inert gas. Although it is perfectly utilizable at present depths, it might, one day, under greater pressure, have biochemical effects on the fatty tissues which would transform a man into something which would no longer be a man. Besides, it is extremely explosive when combined with oxygen in a proportion (over 4 percent oxygen) to form water (H_2O). This is the reason why the Swedish Navy has discontinued its experiments, and why the Americans never use it.

Argon and xenon are heavy gases; one can breathe them on the surface in an oxygenated mixture, but in depth their narcotic action is extreme. Xenon, five times heavier than air, is narcotic even at atmospheric pressure; it has sometimes been used as an anesthetic. Worse still, in diving, the viscosity of argon and xenon would prevent adequate ventilation of the lungs, and would bring about a rapid shortness of breath and an accumulation of CO_2, followed by fainting.

So, in practice, helium is the only usable gas left. Colorless, odorless, tasteless and seven times lighter than nitrogen (its molecular weight is 4 instead of 28), it is chemically inert, at least to pressures and temperatures which man would endure on the continental shelf.

Today every schoolboy knows that helium is one of the rare gases of the air (about one part to 200,000), but our grandparents ignored it. Ramsay, who discovered it on earth, had extracted it from a mineral, the cleavite. Before him, it was only known to exist on the sun where Jansen and Lockyer had identified it through their spectroscope. (Hence its name "helium," for *helios.*) When the American petrochemical industry began to separate it from certain deposits of natural gas, in Texas and Arizona, its lightness and incombustibility first suggested it should be used in inflating dirigibles and balloons.

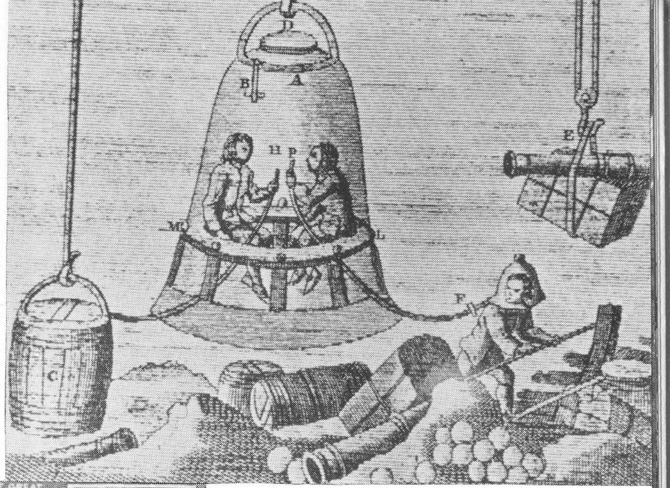
In 1921, Sayers, Hildebrant and Yant recommended its use in deep diving, and two years later, one Charles Cooke officially registered a patent (No. 147337) for the use of an oxyhelium mixture in diving. The patent was based "on the fact that the solubility of helium is half less than that of nitrogen and its diffusion speed double," which is not entirely accurate.

For forty years the Experimental Diving Unit of the American Navy has been making almost uninterrupted experiments which constitute the history of deep diving. They soon verified that helium provided the right solutions to most of the physiological problems of deep diving.

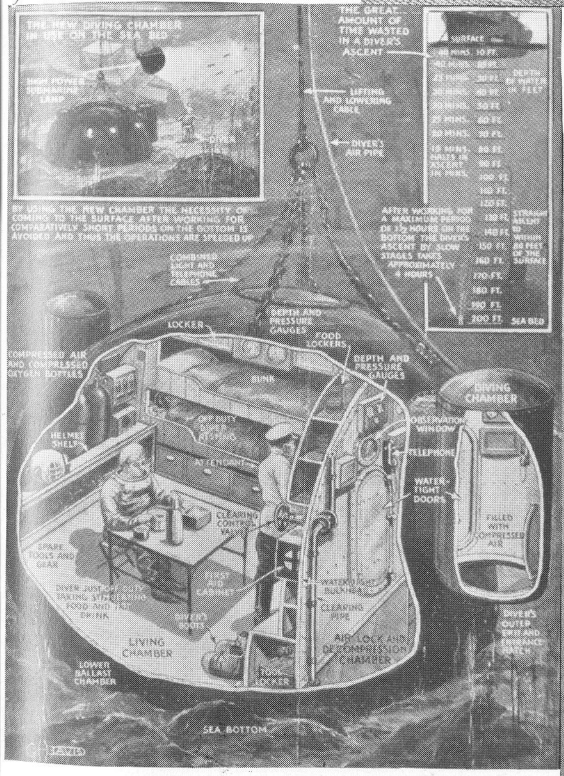
Thanks to its fluidity, it insures, even under high pressure, a good ventilation of the smallest recesses of the pulmonary alveoli (and their 900 square feet of lining), just as a fluid light oil effectively lubricates a hot gear, whereas air, comparable to a viscous and cold oil, does not reach the distant recesses. This is essential, since good ventilation allows good hemoglobin oxidation and good elimination of carbon dioxide, thus slow breathing rate and respiratory comfort. Besides, if the Keller-Bühlman theory is correct, good ventilation would also suffice to suppress or attenuate the "rapture of the depths."

And the most remarkable point is that even if Bühlman's theory of CO_2 accumulation is fallacious, helium still is the correct answer, since it happens to be not only lighter but also less soluble in the fatty tissues than nitrogen.

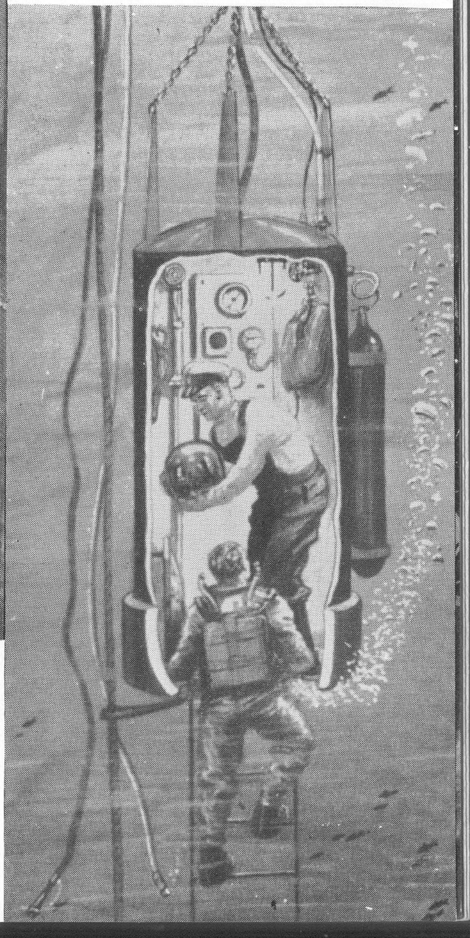
From the standpoint of decompression, helium diving re-



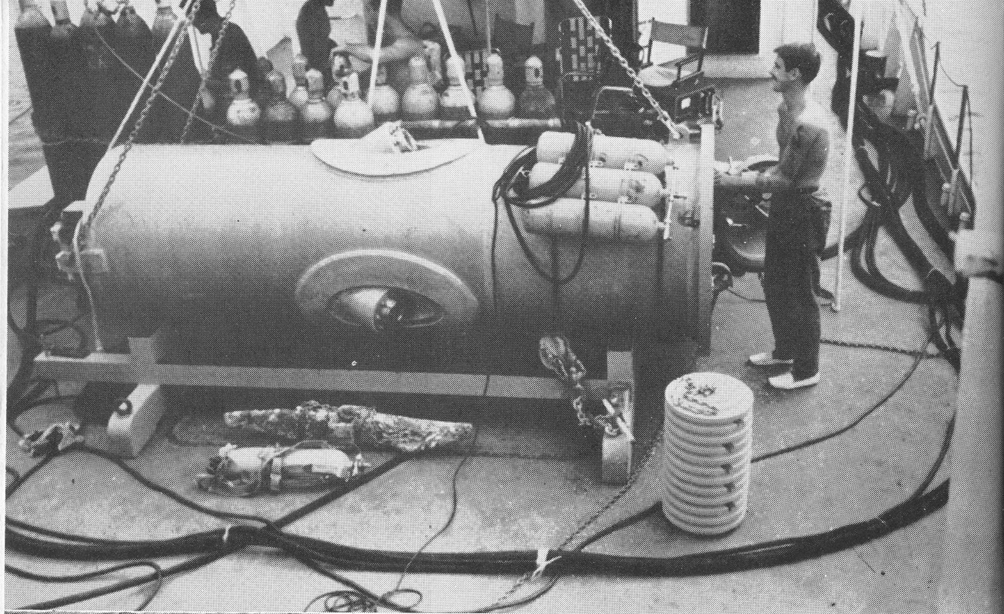
A "house under the sea," model 1716. It is the diving bell of Halley and the first really *modern* version of a vessel known since the ancient times. It is modern because air can be renewed, work can be done all around the bell, not only under it, and the interior is made comfortable so divers can come and rest between two jobs.



The 1936 model, designed by Sir Robert Davis, never left the drawing board.

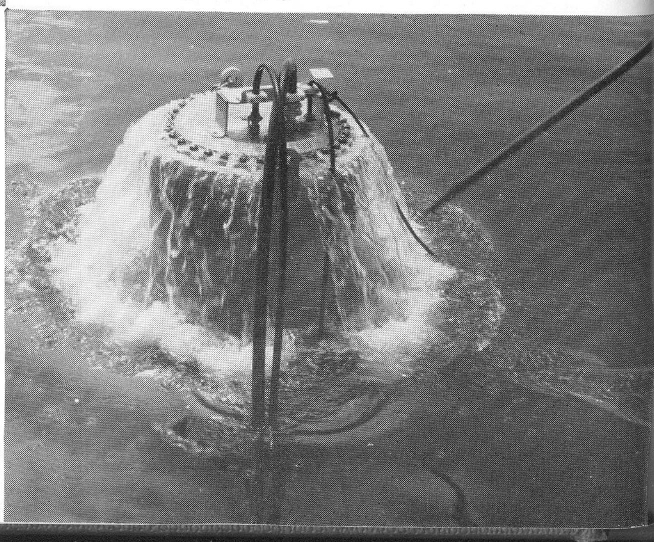


The Submersible Decompression Chamber or SDC built by Davis and widely used by most navies was the ancestor of the Link cylinder. It allows divers to decompress in a warm, safe, comfortable environment under medical supervision.



In 1956, Edwin A. Link invents and starts building his famous Link Cylinder. With it, he will overcome the two basic problems of deep diving: decompression and nitrogen narcosis.

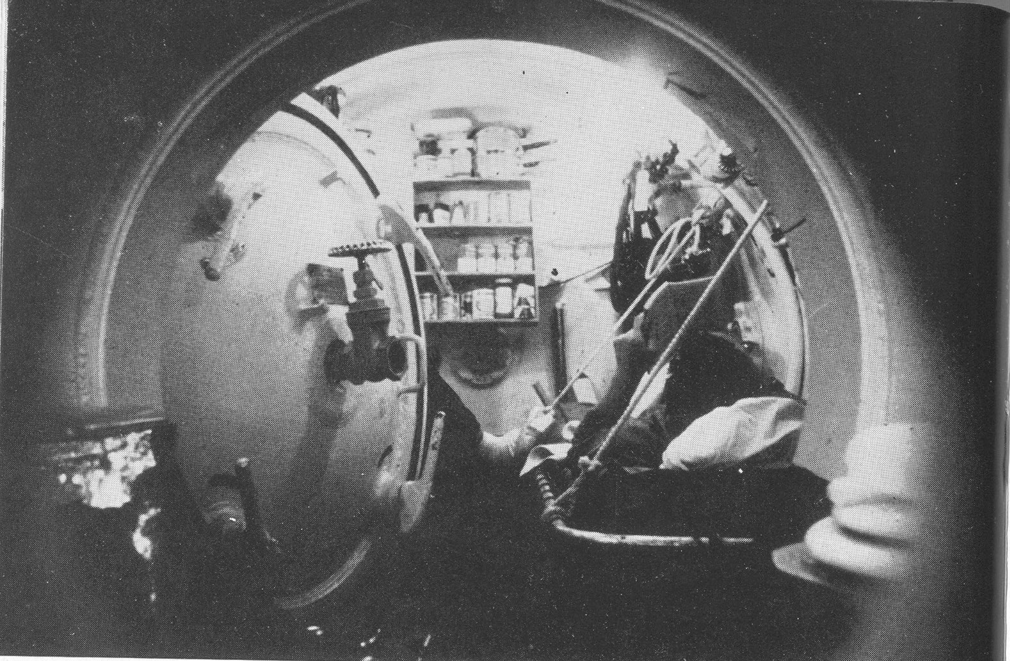
In Villefranche-sur-Mer, France, Link works in and out of it for 8 hours, a normal day's worktime, breathing oxyhelium at a depth of 60 feet. Inventor and builder, he also is the first guinea pig.



In September, I live in the cylinder and work on the bottom all around it for more than 24 hours at a depth of 200 feet. It is the first time that a man is able to spend a whole day in an underwater dwelling.

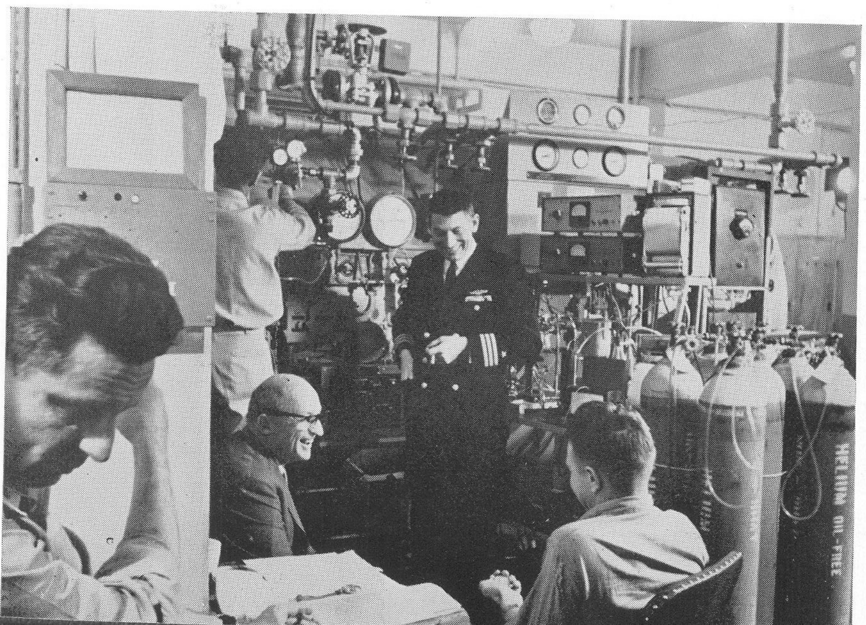
A sudden squall of mistral overturns our launch *Reef Diver*; our valuable supplies of helium are lost.

The experiment, nevertheless, is a total success. Back on ship but still under pressure I am decompressed in the cylinder, now lying on deck.



Washington 1963–64. Volunteer deep-sea divers from the Experimental Diving Unit are decompressed uneventfully after saturation exposures in the "dry chambers". They have remained for 24 hours at pressures equal to that found at 300 and at 400 feet.

Cdr. Charles Hedgepeth, U.S. Navy, Officer in Charge (standing up), discusses the dive with Ed Link.

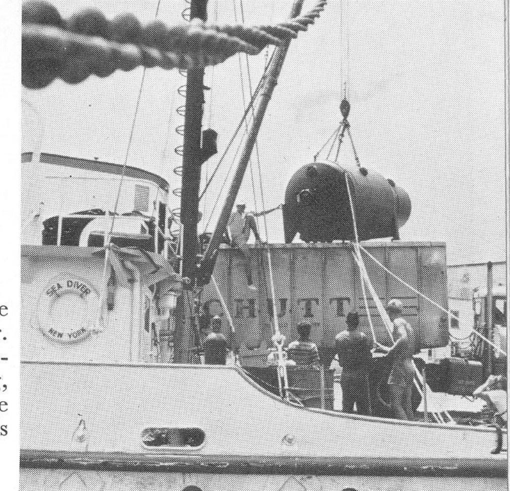


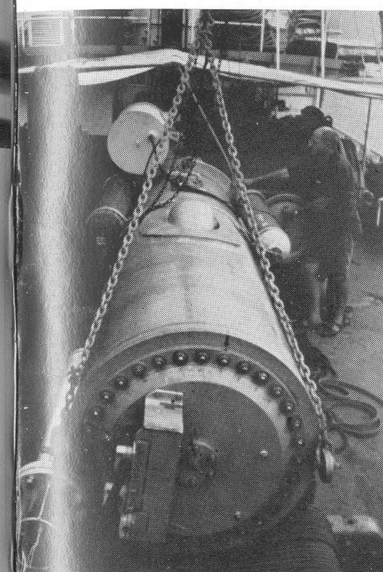
Key West, the spring of 1964. We experiment with a revolutionary inflatable flexible rubber diving bell; it will be the "dry workshop under the sea". We call it the "igloo".

Helium, the inert gas which replaces nitrogen in our breathing mixtures, is very expensive. To save it, we have designed this new "recirculating hookah". The green hose brings the gas to the diver from its "house" or from the cylinder and it is then reaspired through the red hose to be purified, analyzed and reused again and again.

Because helium conducts heat away six times faster than air, I shall have to use this new type of diving suit which I demonstrate to Ed. When flattened by the pressure, it can be reinflated with compressed air, back to its original thickness and insulating qualities.

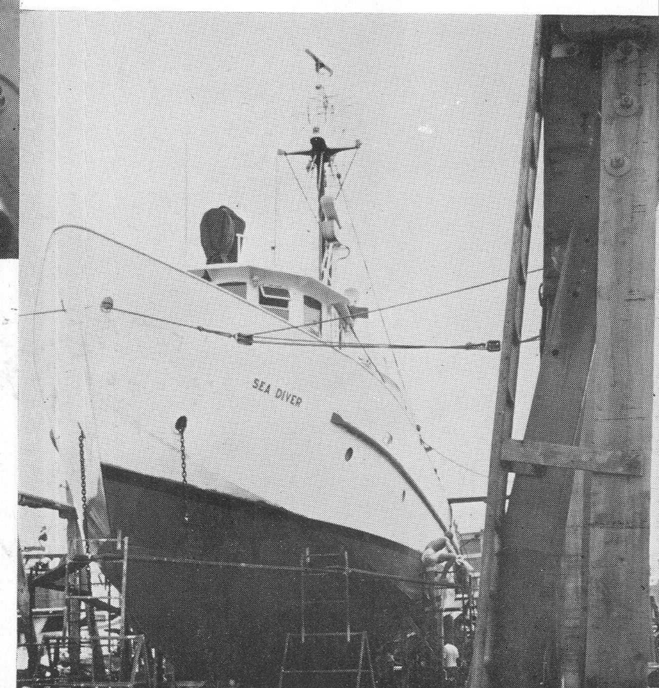
For the second experiment, the cylinder will serve only as an elevator. We will be living in a Spid or Submersible Portable Inflatable Dwelling, made out of a big rubber bag, and we will be decompressed on deck in this comfortable pressure chamber.

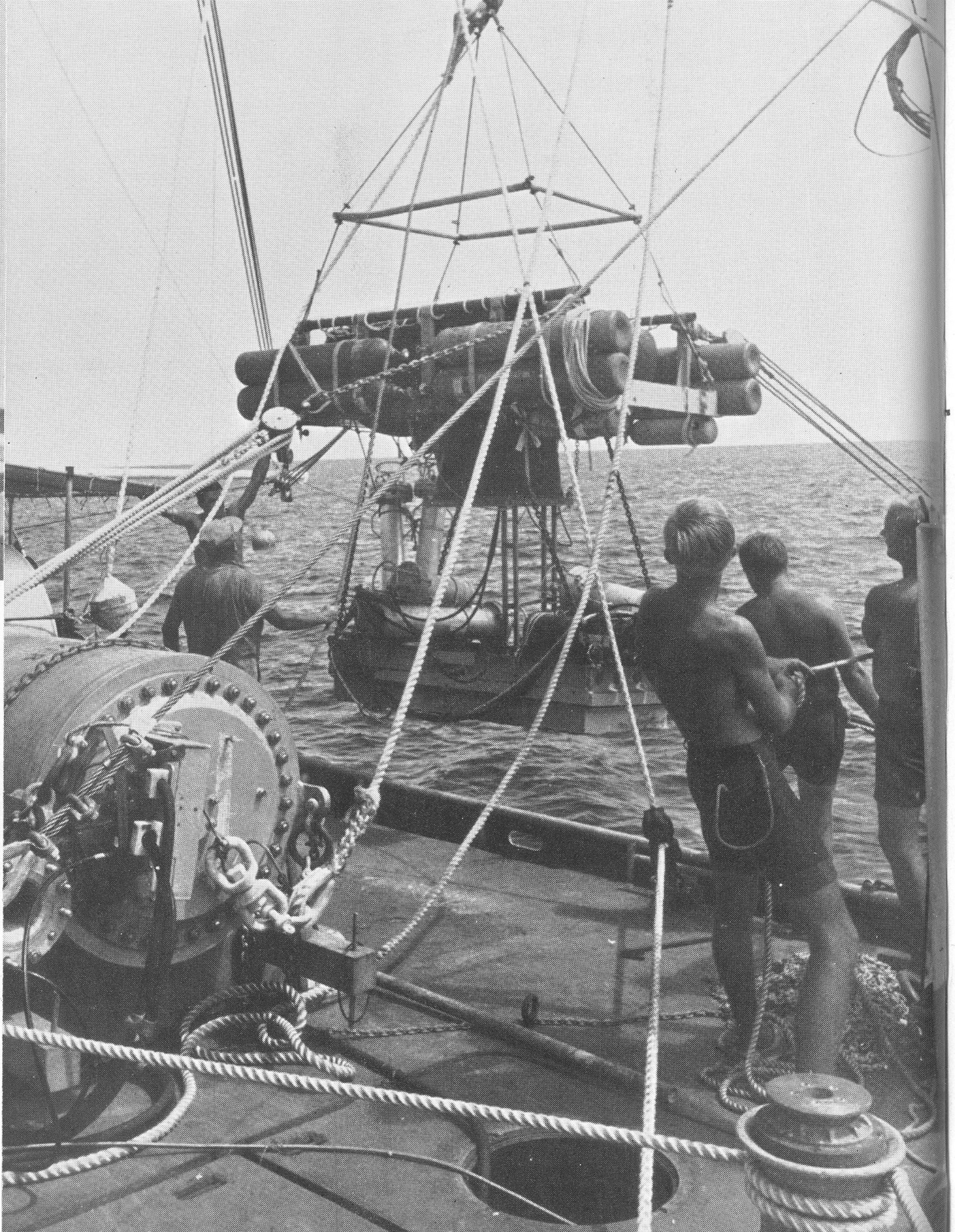




Our elevator will bring us up and we shall switch, still under full pressure.

Before heading for the Bahamas, *Sea Diver* enters dry dock in Miami.





In Bahamian waters, Spid goes over the side.

quires the use of special tables, for, if it diffuses more rapidly from one part of the body to another (transported by the blood where it dissolves more rapidly than nitrogen), it will not dissolve as quickly or in such large quantity in the fatty tissues, the marrow and the brain.

Ed Link was hoping to obtain massive supplies of helium from the U.S. Navy, which had expressed a keen interest in his projects. For, although it is very common in the U.S.A., in 1962 this gas was not available in Europe, because the American Government discouraged its export. Until 1961, the separation of helium from natural gas could only take place under governmental control. Today private industry is permitted to do so, but export remains subject to license.

The theoretical answers to the problems of decompression and narcosis having been roughly outlined, much work remained to be done before Link's theories could be tested at sea.

After my Syracuse vacation, which the hospitality of Ed Link and Piero Gargallo had made unforgettable, I had returned to Brussels and was now following Ed's progress through Marion's letters.

From now on, *Sea Diver* would be based in Monaco because Ed had planned from the beginning to conduct his experiment with the collaboration of Commandant Cousteau's team.

Commandant Jacques-Yves Cousteau had been enthusiastic from the first moment Link had presented his ideas to him. They decided on a joint attempt. Ed would supply the submerged decompression chamber (the Link cylinder), and Cousteau would have the house built. But the house suffered repeated delays in construction, and it gradually turned out that the objectives of the two men were divergent.

Ed Link believed that a demonstration made sense only if made at a depth where the great physiological problems of living under pressure, narcosis and decompression, were frankly faced. Otherwise, one would merely reproduce a situation in which the obscure caisson workers of our ports and rivers had found themselves a thousand times. A few days after our first "big dive," Commandant Cousteau eventually was to anchor in 33 feet of water, off Marseille, a cylindrical "House under the Sea" which he named "Diogenes." To live in it for a week, he chose two of the world's best divers, the excellent Bebert Falco and Claude Wesley.

Later on, during the summer of 1963, in order to shoot some parts of his marvelous film, *World Without Sun,* Commandant Cousteau was to establish a new and spectacular "Village under the Sea" in the clear and limpid waters of the Red Sea: a luxurious house with garage at 36 feet, another one, smaller, at 80 feet. At such a shallow depth, no acute problems of narcosis or desaturation, the problems Ed Link was determined to overcome, were to be expected. It is the extent of the sojourn (6 men lived for one month at 36 feet and 2 men for 7 days at 80 feet) which made this remarkable operation truly significant. And so, Commandant Cousteau and Ed Link each pursued the preparation of his own experiment independently.

"We have been in France since July," Marion wrote me in August. "Edwin is very busy with the systematic tests of the cylinder, and has just completed the series on compressed air with several descents at 200 feet, under all possible conditions. Today he began the simulated dives with helium and he is greatly encouraged with the results. Dan has con-

structed a special tank for the mixture, the control and desiccation of the gases. We have made most of our dives in the bay of Villefranche-sur-Mer which offers a complete choice of all depths in sheltered waters. Ed is of the opinion that the best time for the 'big dive' would be the first week in September. . . . Could you come for at least a week? You would spend the first days in getting familiar with the equipment."

At the end of the month, Ed wrote me: "This week I began the trial dives with helium, and shall continue them until your arrival, to iron out all remaining problems. Bob Bornmann, the U.S. Navy doctor, will be with us for the entire experiment and the Navy has allocated to us 100 tanks of helium."

In Brussels, I was counting the days!

5.

VILLEFRANCHE-SUR-MER: THE FIRST BIG DIVE

A HAIRPIN bend in the road, a gap in an old wall wreathed with wisteria—and there lay the bay, far below us. It was immense and blue, and reflected in its calm waters the rocks of Cap Ferrat, down toward Italy, then the white villas and the long, pebbly beaches, swarming with tourists, and the tall, green, yellow or blue houses of the old town, all faded by the sun, and a Vauban fortress bathing its high walls in the old yacht harbor.

Behind me, a horn blasted angrily. All right, all right; I steered my car to the right. The Middle Corniche, suspended between the rock and the abyss, had remained the same old winding highway through which the stagecoach used to link Nice and Monaco.

Standing on my seat, I looked for the familiar silhouette of a white boat with a long, black, oblique boom. It was in the late afternoon, the sun was low already. Several warships were anchored in the road; wasn't it Colbert who converted the bay of Villefranche into an anchorage and harbor for the Levant squadron?

"Let's see, that one is too small. That's a pleasure yacht.

That one—no—that isn't it. Over there? Yes, that's it, there is *Sea Diver*." For a long time I kept looking at the tiny white shape in the middle of the road, and I noticed I was smiling, for one does not live or work on a boat without giving it a kind of affection and patriotic attachment.

From the corniche I rapidly descended toward town, zigzagging among charming little Provençal houses and their trellised gardens. At the harbor, the weekend festival was going on. With the pompons of a summer Sunday, the overflowing parking lots, the overcrowded terraces, and one and a half bathers per square yard of pebbles, *Sea Diver*, far away there in the middle of the water, had to be an oasis of peace and silence. But how to reach it? *Reef Diver* was snugly hanging on its davits; there wasn't a boat or fisherman for hire in sight. How about renting a pedal boat? Of course, a whole flotilla of these red, ridiculous machines were pushing along the beaches, but even a diver has his dignity, especially when he has prepared his soul for great things. . . .

I put on my bathing suit and took off, swimming the breast stroke in the best style.

My! The water was good. How fresh and delightful, after these long days on the hot, dusty road. I had really found my element again. *Sea Diver* had a new coat of paint. Oh, there is quite a crew on board, forty people at least. A party no doubt. Two rows of large bottles of gas, helium and oxygen, were lined up on the deck between the cylinder and the tent. I climbed up the diving ladder on the port side.

It certainly was a party. The gentlemen, dressed in dark suits, wearing respectable shirts and ties, the ladies in high heels and cocktail dresses, their hats alive with ribbons, feathers or spangles, and there I was in a bathing suit, dripping from head to foot. It took Ed a few instants to recognize me: "Robert, did you swim all the way from Brussels? Nice to see you, Robert. Well, well, that is quite a fitting entrée for a diver. Allow me to introduce our guests to you."

"Admiral, my test diver has just emerged. Full Admiral so and so . . ."

"Glad to meet you, sir," I said, extending a wet hand.

"Admiral so and so . . ."

"Nice to know you, sir."

"And Lady . . ."

"How do you do?" and I bowed over the Lady Admiral's couch, which my dripping hair sprayed with salt water.

"Vice-Admiral so and so . . . and Rear Admiral so and so, and Admiral Z and Commander X and Madam X, and Captain Y and Rear Admiral and Madam W, and Lieutenant Commander so and so . . . and oh, yes, Flight Captain so and so . . ."

I kept bowing from one group to another, leaving a long zigzagging puddle of water behind me on the deck.

"As a matter of fact," Ed Link said to me, "no doubt you know that Villefranche is the home port of our Sixth Mediterranean Fleet. Headquarters is cooperating with us in every respect. I am glad they met you. Have a canape."

"Yes, the U.S. Navy takes an official interest in our project," Ed said to me later. We were dining ashore under the arbor of a small restaurant clinging to the hillside, and I was washing down my *loup grillé au fenouil* with a local rosé. "They help us a great deal. We received a hundred bottles of helium last month, and they are lending us Dr. Bornmann, who is a specialist in diving physiology. He will stay on board throughout the entire experiment. Normally, he is attached to the Experimental Diving Unit in Washington and, by the way, he has just been made Lieutenant Commander. I will introduce him to you tomorrow. I believe we will have the *Sun Bird* with us as standby."

"What is the *Sun Bird*?"

"The *Sun Bird* is a Submarine Rescue Vessel; it's a big ship with two diving bells on board, and several recompression chambers. It has frogmen and heavy-gear divers, who dive with helium, of course, and can descend 385 feet, not to mention the search devices and the rescuing and hoisting equipment. It should be here in three days. After you have met the Commander, I think you will be acquainted with everybody in the Sixth Fleet."

"And your first tests? You haven't told me about them."

"Oh yes, with all this partying on board, I haven't told you that I have just completed an eight-hour dive at 60 feet, on oxyhelium."

Eight hours at 60 feet! Had any diver before Edwin Link ever remained at 60 feet for eight consecutive hours?

Link, himself, inventor of the device, had wanted to make the first trial tests, and play the role of the first guinea pig. He was true to type. The first instruments for blind flying he had invented, 35 years ago, had not been entrusted to any other aviator for testing at night, in the fog or in the rain, at a time when radio, radar and control towers were entirely unknown. He had tested them himself. Now he had taken the cylinder to the bottom himself and succeeded in its first prolonged underwater test. And I thought of Halley, the astronomer-inventor who, at the age of sixty-five, had spent four hours 66 feet below the Thames to demonstrate an improved model of a bell which he had first invented in 1690.

Ed told me about his feat. On August 28, at 9 A.M., he skin

dove and climbed in his cylinder. Half an hour later, he touched bottom, and emerged for work. At first, he used a Desco hookah (a facial mask at the end of a long rubber hose which supplies the gas); later, an oxyhelium-filled scuba (8 percent oxygen and 92 percent helium, corresponding at 60 feet to the normal partial pressure of oxygen in atmospheric air). At noon, his son Clayton brought down his lunch and a few letters in a sealed container. The menu was the same as on top: macaroni with cheese, salad and fruit. He read his mail, then dictated the most urgent replies by telephone. After half an hour's siesta, he emerged again for a long series of tests with the Mud Pinger. The Mud Pinger is an ultrasonic echo sounder, invented by Professor Edgerton, to detect objects buried under sand or mud: dock aprons, oyster banks, or wrecks. We had used it at Syracuse to search for sunken Roman wrecks and the columns of our Byzantine church buried under the sand off Marzamemi. At this point, Professor Edgerton, who was carrying out systematic experiments, was on the surface in a boat, in front of the recorder, and Ed, following his directions, moved the sounder over the bottom, now over the prepared obstacles and then over the soft mud.

In addition to the practical value of the experiment, this was a good endurance test, since the transmitting element is quite heavy to carry around skin diving. After that, Ed swam around on the bottom as fast as he could in order to get out of breath. He then returned to the cylinder, and found that he rapidly recovered his normal breathing rhythm.

After his eight-hour stay at 60 feet—the length of a normal working day—Ed could have secured the hatches to have himself decompressed for seven hours on deck, nice and dry. But he was having too good a time. He preferred to continue his sorties while the cylinder was being raised progressively to various decompression levels: 30 feet, 20 feet, and 10 feet.

Late in the evening he was finally taken on board again, and finished his decompression while asleep in the horizontal cylinder.

At half past eleven, Dr. Bornmann had to wake him up to tell him that he could leave, for Ed is a sound sleeper. When the deck of *Sea Diver* was under his feet again, he was, as Marion told me later, "happy as a kid who had just tried out his new electric train."

"How have you felt since?"

"In perfect shape. No aftereffects whatsoever."

At any rate, his appetite was good. I could testify to that, since French cooking had discovered that night an enthusiastic addict in Edwin Link.

This first experiment represented a full normal working day at the maximum depth where caisson workers or professional divers would ever be called to perform the classical operations of pouring concrete, cutting, demolition, restoration, or construction of bridges, quays, dock aprons, etc. The results were tremendously important, since they proved:

1) That the prolonged respiration of oxyhelium at close to three atmospheres does not lead to any impairment of the mental or physical faculties, nor to any immediate or future illness, and that oxyhelium therefore made it possible to work for a full eight hours in good conditions of comfort and security.

2) That decompression under these conditions did not require more than seven hours, which could be devoted to rest or sleep, in comfort and safety.

3) That there were no grounds for avoiding strenuous physical exercise, which is forbidden to ordinary divers, since it was possible to resume normal breathing rhythm after serious shortness of breath.

4) That the cylinder was ready for deeper and longer dives.

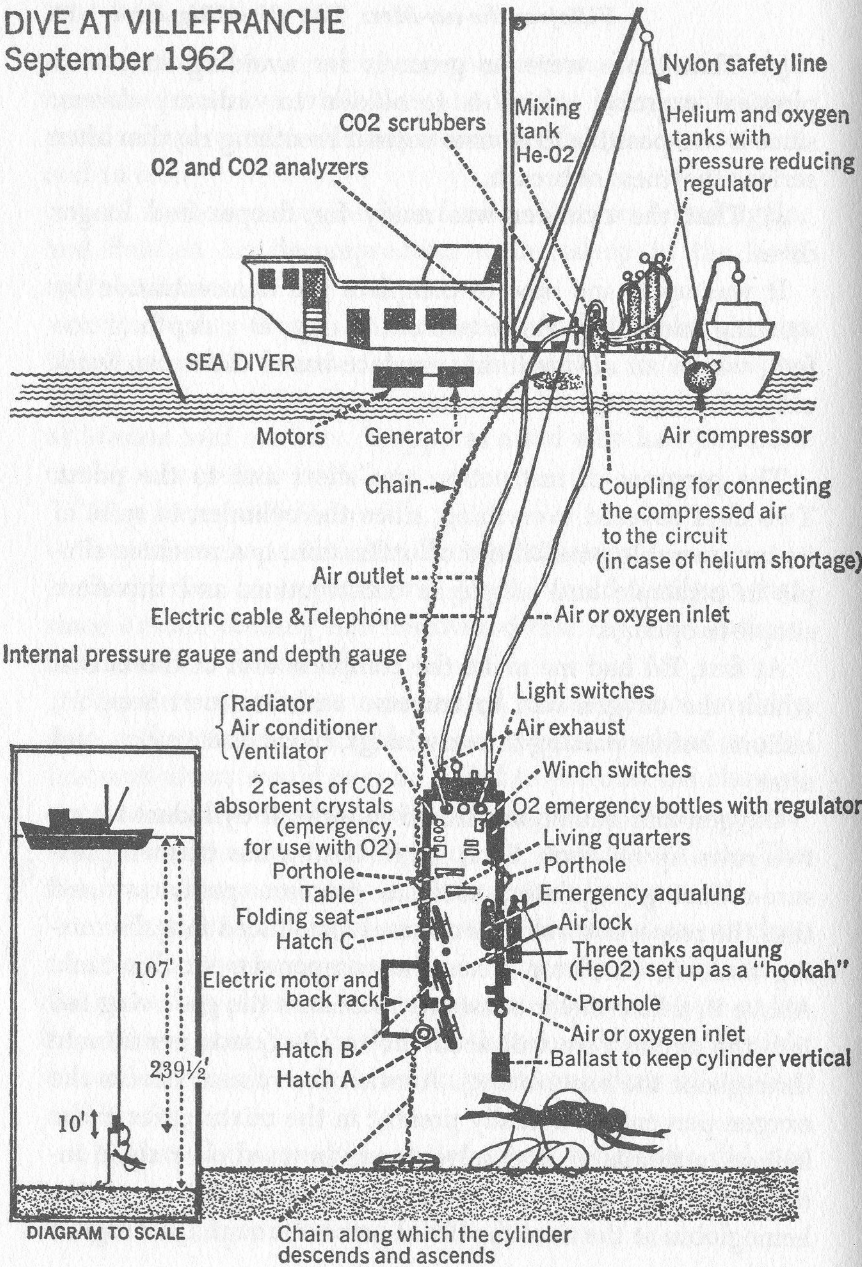
It was up to me now to complete the demonstration by working and living one or two entire days at a depth of 200 feet, where an air-breathing, surface-based diver can work only a few minutes.

The program of instruction was short and to the point. Two days covered everything, since the cylinder, in spite of its innumerable possibilities of utilization, is a machine simple in principle and simple in construction, and therefore simple to operate.

At first, Ed had me make the complete tour of the circuit which the oxygen had to traverse with its inert support, helium, before passing into my lungs, blood and tissues, and after.

Oxygen and helium are stored in large K cylinders set on two rows up on deck. Each set of bottles has its own pressure-reducing regulator, used to measure pressures, and thus the respective volumes of gases introduced into the mixing tank. A ventilator mixes the components in this tank. Above it, a flow meter constantly monitors the gas being fed into the circuit (we will need 120 to 160 quarts per minute throughout the experiment). Another instrument checks the oxygen percentage actually present in the mixture, for if the helium, a simple neutral solvent, can be used over again indefinitely, the oxygen consumed by the oxidation of the hemoglobin at the time the blood passes through the lungs of

DIVE AT VILLEFRANCHE
September 1962



the diver (±5 percent of the 21 percent oxygen contained in the air) has to be replaced. The content of carbon dioxide is verified regularly by another analyzer.

From the mixing tank, the gas is pumped to the cylinder through the supply hose. Normally, it enters the cylinder at the bottom, to rise while ventilating the interior, toward the exhaust valve on top, and to the return hose. Then the gas, fouled by the carbon dioxide produced by the diver's respiration, goes back up to the purifying filters on deck, where it is forced through one of the two scrubbers of granulated lithium hydroxide. The scrubbers are agitated regularly to reactivate the crystals; the absorbent of course may be replaced in one filter without interrupting the operation of the other one.

Once purified, the gas goes through the mixing tank again, its composition is adjusted, if necessary, and a new circuit begins. Once this operation was quite clear to me, Ed did me the honors of my future little house.

The cylinder weighs a little less than three tons. It is 11 feet long, with an interior diameter of 37 inches. It is divided into two distinct compartments: the main chamber, i.e. the living quarters, at the bottom (therefore, on top when the cylinder is in operation, in a vertical position), which is 6½ feet long, and an air lock, 4 feet long. Seen from the outside, the cylinder resembles a stovepipe, and I did feel at first glance that I'd have to be a dachshund to ever feel at ease in it. I was very much surprised, when I entered it behind Link, to find it spacious and almost comfortable. In fact, two men can fit into it, and even live in it quite tolerably.

The three watertight and airtight hatches are called A, B and C, from bottom to top. A and B are at the base of the cylinder. A is designed to resist outside pressure. It keeps the water out, while B, designed to withstand the interior pressure of the gas, keeps the gas from escaping. C is only used on deck for the air-locking operations which make it possible to send hot food, reading matter or a doctor, if necessary, to the diver, during his decompression. C, therefore, never has to resist any but the internal pressure which is maintained in the capsule. The hatches are dogged with a double lever; they are perforated by two small conduits, closed by valves, which permit the precise equalization of the internal and external pressures, prior to the exiting and air-locking maneuvers.

Three oblique portholes give the cylinder inhabitant a good panoramic view of everything going on around and on the bottom; during decompression they enable the physicians to watch the occupant. A fourth porthole opens on the air lock.

The control dials and all operating levers are centralized at the bottom of the main chamber (therefore on top), within hand's reach. On the ceiling are the depth gauge, the internal pressure gauge, the inlet and outlet valves for the mixture (labeled IN and OUT). On my left, the heater switch (two positions: low, high) which can also operate the air conditioning during the decompression on deck (this is summertime), the fan button and the light switch (there is a big, white bulb over my head). Next: the two UP and DOWN buttons which operate the winch motor. The motor itself hangs outside in its own container; it activates a rack which permits the diver to have himself hauled up a vertical chain which runs from its moorings on the bottom up to the deck of *Sea Diver.*

In its version "house under the sea," the cylinder is therefore autonomous. It floats on its chain like a child's balloon

on a string because its ballast is so calculated that it retains a constant positive buoyancy, and the occupant makes it work its way up or down at will.

"You see," Ed concluded, "it is all very simple. You know as much about it now as I do. Oh yes, there is the intercom mike here, on its five feet of wire. You can take it to the lock when you get ready to leave. And then the little table and the folding seat, you attach them here, in this screw thread. If you sleep well on a train and in an airplane, you will sleep well in the cylinder. You have got a pneumatic cushion and a backrest. Normally, they are stored behind these pipes—you need only inflate them before lying down, pardon me, I mean before sitting down. . . ."

"Let us go," I said. "It is beginning to get a little warm."

"There are a few points," Link continued when we were outside, "on which I want to insist. Keep this in mind. First of all, before opening the hatches, always shut the OUT valve, the air outlet. Then make very sure that you are in perfect equal pressure. If you open when you still have a high internal overpressure, the gas will escape with terrific force. You may blow the gasket, and perhaps be ejected yourself. The cylinder would then jet up toward the surface, and when it came down again, you'd be flooded. That can be serious, because when the water starts to rise in the cylinder, it becomes correspondingly heavier, and so it'll sink. The farther down it shoots, the more water pressure increases. The higher the water level rises inside, the heavier it'll become. Finally, you'll find yourself encrusted in the bottom like a suction cup with mud up to your ankles, and water up to your shoulders. That is exactly what happened to me the first time I tried the ballasts. Even in shallow depth, it is a surprising sensation, and I don't recommend that you repeat the test in 200 feet."

"Is it for the same reason, I suppose, that one must shut the OUT valve before opening the hatch?"

"Precisely. Better keep a little too much air; the excess will escape through the vent. That is also why you must never touch the winch, neither for ascending nor for descending, when your cylinder is open. The slightest motion is self-accelerating, and you risk taking off like a rocket before you know what is happening. But don't be alarmed. In practice, you will only have to open the X valve—this one, at the entrance. It is the only part of the water ballast system which you'll use. As long as air whistles and escapes, you're in overpressure; when water spouts in you're in underpressure. You shut X and you open B vent; when you've got perfect equal pressure, you can open B. Then you open A vent and as soon as nothing flows in or out, you may unlock the last hatch. There you are. . . ."

For the afternoon, Link had promised me some practical exercises. But beforehand, I had some questions which kept running through my head, now that D day was approaching.

"The circulation of the mixture depends on an electric motor," I said to him. "What happens if the motor breaks down?"

Daniel Eden, the project engineer, replied for Ed: "If the pump motor jams, I warn you, you shut the OUT and IN valves and you wait quietly for about twenty minutes. That's the time I will need to replace it with the other motor right here." And he exhibited the twin brother of the first one, carefully stored in its case, 20 inches from the tank.

—All right. With the volume of air or gas in the cylinder, I can hold out for two hours without any trouble.

"Now," I said, "what happens if the mixing system fails, or the CO_2 analyzer or the oxygen flow meter, or if—"

Ed interrupted me. "The mixing system is too simple to break down, or then it would be repaired as quickly as it breaks. As for the analyzers, I have spares on board. But at any rate, if worse comes to worst, we can always feed you compressed air in the circuit—merely turn this valve."

"I see. It's this black hose, no doubt, that comes from the air compressor. But what if the air compressor breaks down?"

"The volume tank is there just for that. It gives us ample time to connect the hose to the second compressor."

"Which gives you time," I said, "to repair the first one. But what if the hose is cut?"

"Again, you close OUT and IN and we repair. A diver connects the two ends on a small bronze tube which—which, to be sure, is not ready, but which can be made in ten minutes," and Dan sent his second engineer to cut three small bronze pipes, an inch and a half thick.

"Such a repair job," Ed went on, "can't take more than two hours, but if it ever did, I am sure you'll understand the purpose of the emergency scuba which is inside at all times next to the folding seat. Of course, it is filled with oxy-helium. Oh, I am sure you'll never have to use it, but who knows? Some day, it may help you leaving the cylinder to swim to the diving bell of the *Sun Bird,* or perhaps you will take it under your arm to be out for a stroll when you'll have emptied the hookah tanks."

"Oh no. I certainly shan't go away from the cylinder without an Ariadne's clue, be it a line or a hose. If I lose my mask or get carried away by the current, I may never find my way back."

"You are entirely right. Good thinking! Now then, you'll have at your disposal inside a bottle of oxygen with a regulator and two boxes of granulated lithium hydroxide. See them behind the radiator? They were made to slide like a drawer in this groove in front of the ventilator. It is an extra precaution. In case of accident, you can gradually admit supplementary oxygen into the closed cylinder, and eliminate the CO^2 by having it absorbed by the crystals every time the air is driven through the box by the ventilator. Any more questions?"

I had found one on the spur of the moment: "What if the ventilator stops?" But I also had found the answer: I merely needed to blow through the box when exhaling. I queried: "Suppose the power cable is cut. How do I see?"

"I have provided a watertight flashlight in easy reach, with spare batteries and bulbs. Of course, you have a spare main bulb also."

"Good, but apart from the light, the telephone also may be cut, and the heating system."

"Right, and at that point you'll decide yourself if you wish to continue or come up to your first decompression stage. At any rate, I'll send you a diver. He will knock three times, let us suppose. If all is well, you will reply with three taps, and if you want to explain something to him, you merely need to show him a note at the porthole."

"I come up, you say, but I have no power for the winch motor."

"That can be taken care of, Robert. The nylon safety cord is there to hoist the cylinder with its moorings and chain, or

even a sperm whale or a sea serpent, if one swallows the cylinder."

"I see. So all is well on the bottom. On the surface, I can keep my internal pressure no matter what happens, and you can always bring me back on board, come what may. Fine, fine. But I have been wondering, during the decompression what would happen if I should get the bends and lose consciousness?"

"That makes no difference. You aren't the one who controls the pressure changes on the surface, and what's more, you are being watched, and don't forget that all valves and all locks can be operated from the outside as well as the inside. That isn't all. Tomorrow I'll have two more connections drilled in the cylinder, in the frame of hatch A and in the top plate. Normally the valves will be shut. If everything ever breaks down at the same time, I can install in three minutes an independent circuit of gas or air for you. Next question?"

Only one was left, which had been waiting for some time, and I knew Ed would not have a ready answer to that one:

"Suppose we are in the open sea. The experiment is at its height. I am on the bottom in my cylinder, completely saturated in dissolved gas. At this point, through a porthole, I see *Sea Diver* descending, having just sprung a big leak. What should I do?"

During my first dive with Ed, only air was circulating in the cylinder. "During my life," he told me, "I have taught thousands of people to pilot planes, but as far as the cylinder is concerned, you are my very first pupil."

Three seconds after departing from God's fresh air and I was already breathing the air of the machines. What is this odor like? The subway . . . no, it is more like the smell of an elevator. Vertical, the cylinder is another animal; from down below with its 11 feet in height, it looks like a tall dungeon to the diver who pushes his head into it. I had to choose my holds for the climb.

Methodically, Ed Link made me execute the basic maneuvers: closing hatches, descent, ascent, equalizing pressure, opening, leaving. It was absolutely thrilling. I could see now how this marvelous metal toy revived the enthusiasm which impelled him in his youth toward the first flying machines: each machine adds a new dimension to man, each opens up new worlds to him—the world of birds and the world of fishes.

The second exercise was to give me confidence in case of an incident. We shut down the air circulation so as to breathe only chamber content. Together we had over one hour of leeway. Alone, I would have had two hours.

All through the forenoon of next day, Ed worked on the interior of the cylinder while Dan Eden and Bob Bornmann checked the entire gas circuit again, step by step. I was glad to know that when I'd be on the bottom, Daniel Eden would be watchman on top, at the other end of the safety line. Dan, an Englishman from Oxford in his early forties, had seen combat with the Royal Air Force from North Africa to the Far East. A diesel and aeronautical engineer, he had been the ship's Chief Engineer since Caesarea, and the mainspring of project Man in Sea. Any time something went wrong on board one would say: "Say, Dan, you have a minute?" With these three men topside, I knew I was in good hands.

In the afternoon, I made my first solo dive. At 60 feet I opened hatches, swam away with a scuba, went back in, closed again, reopened, swam out again. At the end, I was hoisted on board with the chain and moorings, as if the winch and its gear rack had just broken down, and I left the cylinder dry, on deck, as I would normally leave after my decompression.

The first mistral of the year rose the next morning, September 5, the same time we did. *Sea Diver* left its mooring caisson, and turned into the wind to reach Cap Ferrat where the "big dive" was to take place. At the foot of Cap Ferrat, rocky cliffs drop off abruptly, in some places vertically, down to the flat mud bottom. When the echo sounder registered a smooth bottom of 240 feet, near enough to the shore so we could tie a mooring line there, Ed cast the first anchor. The morning passed before the two other anchors fell into place, but at noon we were moored steadily on three anchors and a cable. Whatever wind or current might do now, we would hardly budge ten feet.

That afternoon I went on shore with Bob Bornmann. He took me to the American Hospital of Villefranche-sur-Mer for a complete physical examination: two hours and a half of auscultations, tests, analyses, measurements and X-rays, which culminated in the expected verdict: "You are in perfect health."

I met Ken MacLeish on the quay as I was waiting for the mistral to subside. I had met Ken at Vigo in 1957, when he came and spent a month with us to prepare an article on our treasure hunt. He was still working for *Life* magazine then, and had come this time to follow the Man in Sea experiment. We also had on board two photographers from the *National Geographic:* Thomas Abercrombie and Bates Littlehales. The reporters and photographers of these great American magazines are a bunch of husky fellows who have always filled me with admiration. First of all, they are probably the best photographers in the world, but they also are at the same time writers, divers, alpinists, explorers, parachutists, horsemen and what have you. They are everywhere, they see everything, they live everything. They sleep with one eye closed only; the other is behind the viewfinder, wide open.

Lord Kilbracken, an Irish writer-reporter and gentleman farmer, who was working for the English press and a big news service, was also waiting in port for the wind to subside.

When at last we were able to get back to the ship, Link was at work in the cylinder. He was installing a second heating element for the electric radiator. He worked until 4 A.M. The next morning, as usual, he was up at seven o'clock.

I am shivering; it is cooler suddenly. Big drops of condensation water form on the aluminum walls. The depth gauge needle stops at 200. Two hundred feet, sixty meters under the surface. The internal pressure gauge indicated 103 PSI.

I have been confined in my box since morning. I take a blue notebook out of a plastic bag. It's time to begin my diving log.

Let's see. . . . At dawn, Ed created a vacuum in the cylinder, then filled it with the breathing mixture (at the beginning, it was 80 percent helium and 20 percent oxygen; the oxygen content would be lowered to 6 percent according to the depth). The cylinder went overboard where it floated vertically alongside *Sea Diver*, four-fifths submerged like an iceberg. About nine o'clock, I think, Jay, the first mate, dove to open the hatches for me; now when I enter the cylinder

through the bottom, I shall find inside a gas mixture almost wholly devoid of nitrogen.

9:55 Getting dressed. The sun is already warm; it is dead calm. Many people on board. Final instructions from Ed, then I reach for the diving ladder. With flippers on my feet, wet suit on my back, mask on my face, I skin dive to the lower hatch. I empty all the air from my lungs and I enter my home. First, I store my lead belt, my mask and my flippers. Good. I lock hatches A and B, and climb up to the living room.

10:00 As a routine check, I push the button of the electric rack winch, and have myself hauled off along the anchoring chain down to 200 feet. Inside, I am still at sea-level pressure. Fine. Everything in order.

11:00 Returned to the top. Pressurizing begins. The compressed gas feels slightly warmer while I equalize the pressure on the internal side of my eardrums by blowing hard and holding my nose.

11:30 Internal pressure 103 pounds: theoretically, I am at 200 feet, the experiment has started.

11:35 My voice is unrecognizable; it sounds like Donald Duck's. In helium, sound travels very fast and the vocal cords vibrate differently; strangely, the effect gets worse as pressure is increased. Impossible to make myself understood on the telephone. All I produce are ridiculous quacks. To tell Ed that all is well, and I have just turned on the heat, I must write a message on a piece of paper which I show to a diver at the porthole. It's so bad that through the whole dive, I'll have to say O.K. or No to answer questions; topside can no longer distinguish Yes from No, because they are two monosyllables.

11:50 The descent begins in earnest. The gear rack of the winch pulls me to the bottom at a speed of 23 feet per minute along a big chain which goes from the deck to a mooring weight set on the bottom. I now communicate in Morse code, and lacking a manipulator or whistle, I clear my throat to emit short grunts and long rumblings.

12:00 200 feet.

12:30 Getting settled. Up there silence reigns, everybody is eating lunch. I have taken off my diving suit to put on dry clothes and I fastened down the table and the folding seat. Condensation makes the ice-cold walls drip with water. I wrap myself in a bath towel, and slide another behind my back to insulate myself from the metal. Both radiators and the fan are on. I have got a burning head and two frozen feet.

15:00 I write: "Appointment with *Life* and *National Geographic*," then I close my notebook, and get ready to leave. My wet suit is a zippered model, with separate hood, quite easy to put on and take off alone, but the expanded neoprene which contains billions of tiny gas bubbles is crushed flat by the pressure.

I make sure that the internal gas pressure is exactly equal to that of the water, I open hatch B, which I pull toward me and fasten solidly in an open position, then I unlock A which

opens up wide. There is the Mediterranean, a blue, clear, fresh circle which gently laps at my feet. A deep breath and I slide out to sea. I unhook the mouthpiece of the hookah rig attached outside (tanks filled with HeO^2). I open the valve, drain the hose, inhale, and take off, free as a fish.

This is the crucial moment of the whole experiment; I am leaving my house to go to work.

The water is very clear, but in the subdued light everything seems unreal. I am moving in a dream, in an atmosphere from some other world. At first, I swim to the bottom, 43 feet under me. It is a flat, dismal surface of brownish mud, spotted with long white, indistinct streaks. Not a single fish, not an alga, not the tiniest living thing.

Well, here I am, ready for action, wide awake, in perfect safety, ready to work my eight hours. The characteristic hissing noise of a regulator makes me turn my head. Two divers from above shoot out of the blue with big flipper strokes. They stretch their hands out and while the photographer of *Life* ceremoniously shakes my hand in front of the cylinder, the one from the *National Geographic* immortalizes the meeting, after which they change roles, and the shooting resumes.

Now I have to simulate several simple operations.

Through a porthole, I peep into the cylinder. The electric light is pink, as always under the sea. My little home looks hospitable, intimate and warm, and an image comes to my mind of those English Christmas cards showing through a misty window an open fire in a cottage half buried under the snow. I inspect my house, carefully, from top to bottom—the owner's tour of inspection. Everything is in good order. With a wave, I signal good-bye to the photographers, who are on their way up in a double trail of silver bubbles. Because they are breathing air, their bottom time is sharply limited at this depth, and a long decompression awaits them. (One of them, most concerned about his pictures, will complain when surfacing of having experienced a severe narcosis.)

I return home to warm up. Barely returned, I shout toward the microphone: "Back home, Ed." He won't understand a thing, but all he wants is to hear my voice. With all doors closed, I rub myself and munch a few biscuits.

16:15 Topside informs me that they are going to cut off the helium circulation temporarily, so I close valves IN and OUT. Every five hours, the lithium hydroxide crystals which absorb the CO_2 produced by my respiration have to be replaced. The regular hissing of the gas stops. The silence now is broken only by the rainlike noise of the condensation drops but this silence is no cause for worry.

17:00 I reread Céline: "D'un château l'autre."

17:45 Jannis, our Greek cook, is on the phone, and I order my evening meal in Morse code.

18:00 I have been here six hours. Now, my body is almost completely saturated with dissolved helium, saturated to the bone marrow. This is the first time it has ever happened to a man. I feel perfectly fit. Certainly no trace of narcosis. I compare my handwriting with what it was at noon: not the slightest change.

19:00 First call for dinner. It is time to go shopping, and I get dressed to go out. Anticipating that I shall return shivering, I spread out my sweaters in front of the radiators.

It is so cold at the bottom of the cylinder that I do not feel any difference in temperature when I slide into the water to put on the external hookah. A container awaits me on top of the cylinder. The cook has let it descend along the nylon safety line. I come in with the container. A vent valve allows me to equalize the pressure before opening the cover; without it it would remain as hermetically sealed as the two Magdeburg hemispheres. After taking out the food, the newspapers and, contrary to plans, half a cubic foot of seawater, I stuff my refuse in it, with a plastic bag containing my mail. I swim up again and shackle it to the nylon line so that topside can recover it. While closing my box again, a queer thought crosses my mind: I have been playing frogman for ten years, but this is truly my first day as a sardine man!

Dinner is delicious, but cold: seawater soup, roast beef with sea salt—a strange unrecognizable mixture (apparently Greek) of nondescript vegetables, Camembert paste on soaked French bread, muscatel from Provence well iodized, salted cake and, at last, sweet hot coffee, in a thermos bottle, filled to the brim.

20:00 Night has fallen and made black holes out of my windows. I run through the newspapers. It's getting colder and colder. To insulate myself somewhat I have placed an inflated pneumatic mattress back of me. When on a level with my head the thermometer shows 60° Fahrenheit, but when I bring it down toward my feet I can see the quick drop of the needle. I am having so much trouble by now recovering my lost body calories that I am reluctant to descend down below to check the exact temperature; in the lock it must be as cold as the water. The thermal conductivity of helium is 7 times greater than that of air, which explains the drop of my body temperature.

20:30 I put on more long underwear, then still more. With my argyle socks, my three layers of sweaters, short sleeves over long sleeves, and my Lapp bonnet which winds twice around my neck, I feel irresistibly ridiculous.

21:00 To bed. I wait for sleep sitting up, with my arms on the table and my head on my arms.

September 7

0:20 I have slept a few hours, I think, but the cold which deep-freezes my feet just woke me up. I gobble six pieces of sugar and suck a tube of condensed milk.

Oh, oh! I just noticed some water at the bottom of the cylinder. A good 3 inches of water. How the devil did it get in? I am sure I have locked the hatches tight and shut the vent valves. Could it be condensation water? No, not this much. I take a reference mark to verify whether the level is rising.

2:00 I must have fallen asleep again. A glance at the ground level: my reference mark is invisible. It must be under water. There is over a foot of it. Suddenly, I am wide awake. I call the surface. Dan is on duty. I tell him in Morse code what is happening.

"That is most surprising. Did you close the hatches tight? Check whether the gaskets were clean? Close the outside and inside drains of B and A?"

"O.K. Of course, I did all that."

"Well, it's most surprising indeed."

"O.K."

"All right. I am going to turn on the pressure to flush it out."

Obviously, that is all we can do, but that means I have to undress to go and open the vent valve of hatch B, which is presently sunk under a good foot of ice water. The prospect gives me the creeps. I take off my socks, underwear, pullover, and gloves—a doubtful precaution anyway because the humidity has already soaked them completely; then I close the out valve at the top of the cylinder. With extreme reluctance, I come down from my roost. At the bottom, the difference in temperature hit me with a slam on the shoulders. I jump. The water comes just below my knees. I plunge my arm into it to open the vent valve, and I watch the pressure go up: 215, 220, 222. . . . Very slowly, through the very tiny hole, with a very slight suction, water escapes.

I have been shivering for ten minutes. The level goes down slowly. My feet are two blocks of ice.

Good, it is almost empty. I notify Dan and hurry to climb back to my paradise of warmth.

3:00 I am reinstalled, bundled up but not yet warmed up again. To reduce the volume to be heated, I spread a towel under me which blocks the orifice of hatch C.

4:30 I glance at the bottom. Wouldn't you know it would happen? Water is rising again. Well, it's just too bad but I am too cold and I prefer to go to sleep again.

8:00 The telephone wakes me up. It's Ed.

"Did you sleep well?"

"O.K."

"Do you want to come up now?"

"No."

"Do you want to come up tonight?"

"No."

"Do you want to stay there on the bottom forty-eight hours?"

"O.K."

9:00 The water continues to rise. So much the worse—I shall have to empty it in any case when I go out to get my lunch. For breakfast, my own supplies will do. But what is going on?

For half an hour, all kinds of discordant noises have been disturbing my tranquillity. The chain is lashing the cylinder; I am rolling and pitching. Through the portholes I see my hoses go up and down, rhythmically.

11:00 More and more shaken up. The weather must be getting stormy up there. In theory, the cylinder is independent from the surface since it floats like a balloon at the end of a ballasted chain, but the air hoses, flexible as they are, transmit every jump of *Sea Diver*.

12:00 Topside calls: "Uh . . . er . . . Robert, we want to tell you . . . the mistral came up this morning, heavy seas are rising. Don't worry if you are a little shaken up. . . ."

How nice to let me know!

12:30 Dr. Bornmann, very calmly, orders me:

"Winch up to 100 feet."

"What? Repeat."

"Go up to 100 feet."

"But why?"

"Well, I will tell you why. First of all, we seem to be using a little more helium than anticipated. There have been a few leaks up here, and with this wind which gets worse all the time, we'll have to wait for the evening lull to take you back on board. There isn't enough helium to wait until tomorrow night, so we must do it tonight. And that isn't all, Robert. *Sun Bird* has received new orders and she is leaving. We do not want to take any unnecessary risk."

I feel fine. The more the cold and the sea want to oppose it, the more determined I am to hold out here forty-eight hours.

Disappointed, and furious, I obey.

13:00 One hundred feet on the depth gauge, I let go the winch button. The needle of the internal manometer creeps up. My decompression has begun. Well, whatever may happen now, the first step down has been taken. A man has lived and worked for more than 24 hours, 200 feet below the waves.

13:30 Still 100 feet down. 59 P.S.I. inside. It is much less cold. I think of what Bob Bornmann told me: Leaks topside? Why couldn't they stop them? Something else must be wrong. Strange gurgles reverberate in the air hoses. Is that where the leak is? I let Ed listen to them on the microphone. "Don't let that bother you. It is only the water condensation which gurgles in the conduits. We had the same noise at 60 feet."

So what?

14:00 Things don't seem to improve topside. The cylinder tugs at its chain with brutal smashing jolts. I am tossed from one wall to another. The water rises steadily, about one foot again.

15:00 No hot meal; the sea is too rough. I can no longer postpone another flushing. I turn the valves, open the vent—now, it is empty. To save helium, I have had the cylinder go up this time instead of increasing pressure. Nobody can explain this continual flow of water. Trying to clear the matter up, Ed sends Jay down to check whether the exterior vent valve of A is tightly closed. Of course it is.

15:45 A diver disentangles my hoses which have fouled the chain and the nylon line in their erratic jerks, while Ken MacLeish, the reporter, swims around the cylinder like a moth around a candle. Before going back up, he comes and presses his nose against the porthole and says hello.

17:00 Since the hoses have been cleared I dance on a slower tempo. I read the very exciting book of Commander Tailliez: *Aquarius.*

18:00 Through the portholes which again are getting dark, I can see big grayish particles of plankton go by. A strong current pulls from south to north.

After these lines, there is a gap in my diving log: two blank pages. Things got so hectic after 8 o'clock that I had no time to devote to literature but according to my notes written the next day, here is what happened:

First, I notice that the cylinder has risen twenty feet on its own, then as I watch the needle of the depth gauge, without understanding what's happening, I see it drop again a quick ten feet. I start the winch, *up:* nothing happens; *down:* nothing happens. Another try: still nothing. The next second I hear a long, long scraping. All the slack of the chain is freely sliding through the spinning rack—and then what?

The cylinder slowly goes up and there isn't a thing I can do about it. The surface calls me. It is Skip, our electronics man. In a calm voice, too calm to be sincere, he explains: "Robert, you are losing your neutral buoyancy. We are sending you a diver to tie more ballast to the cylinder."

"Well, well, so I am losing my neutral buoyancy! Isn't that the cutest euphemism?" I notify Ed:

"Cylinder rising again."

"Yes, you are ascending."

"I didn't do anything to come up."

"I know."

Actually, both of us understand what has happened. The axis pin of the rack has given way under the jolts of the short nasty mistral surge, and I am floating freely, in mid-water. Since the cylinder is lighter than the water, it rises slowly. The higher the needle of the bathymeter goes, the more I dance. I can see Sullivan, one of our divers, through a porthole struggling with the chain. He tries to tie a line on it, to get hold of the cylinder, I guess. But no sooner has he caught it than it slips through his fingers like an hysterical snake. He will never make it. Now, in despair, he comes and looks at me through a porthole. I give him the O.K. signal to cheer him up, but he shows me his cable, gestures, and makes me clearly understand that things are not really entirely O.K. He surfaces with me, clinging to the cylinder.

It is not the decompression that worries me. As long as my internal pressure is maintained, it matters little where the cylinder may be wandering, but what could be serious is a head-on crash of the cylinder on the hull of *Sea Diver.* That would give my hoses quite an awful beating.

But not at all; the cylinder breaks through the surface far from the yacht. It is night. The sea seems frightfully rough. The evening lull has not come. I am tossed around in my cylinder like dice in a dice box. Through the portholes I see the black sky, then the white ship, then the blue water—all dancing a mad ballet. Chains are lashing everywhere. My books and food drop in disorder at the bottom of the cylinder, in a well of foaming water.

Bornmann on the phone: "The sea won't calm down tonight, Robert. We are going to take you back on board now. Be prepared."

Well now, if Ed has decided to hoist back on board a swinging mass of several tons in a sea like this one, at the risk of smashing his ship or knocking down half of his crew, he must have pretty good reasons. They must be hiding something from me. Well, at any rate, I can't do a thing about it, so I don't ask any questions. I have full confidence in Ed and his judgment. Otherwise, I wouldn't be here to begin with.

I am concerned for the diver who has now to shackle the second chain to the cylinder, the chain that makes it possible to haul me, horizontally, on board. A backlash of it could tear out one of his arms, and I prefer not to imagine him caught between the cylinder and the hull.

Sea Diver had just enjoyed two months of dead calm, and

the first bad mistral of the year would come down on us on D day!

A quarter of an hour has passed, half an hour; I am still bouncing on the surface in the oblique, jolting cylinder. Full of solicitude, Dan asks, "Need any Dramamine?" You can't hide anything from him. My stomach mistreats me shamefully. At least the cylinder is lying flat.

"There you are, you are going up now." My back to the wall and pushing out with feet and arms, I try hard to hold fast in my cocktail shaker. The water which fills the bottom of the lock splashes everywhere and I am drenched. Bang! A heavy blow on *Sea Diver.* I hope it is merely the winch box. I can hear Ed shouting orders. Lights are flashing; Bates must be having a field day. *Zzing.* Another hammering ram smashes the awning. I fervently hope that the crazy cylinder won't knock down the helium and oxygen tanks like in a gigantic bowling game, or shatter the delicate mixing apparatus. My thoughts go to the cluster of sailors hanging on the check lines. After all, I am safer in here than on deck. More overpowering blows. I can't do anything but hang on teeth and nails, and wait. A final jolt, and the relieved voice of Bob: "You have arrived. The cylinder lies in its cradle. All is well."

So we had won the first battle. Now for the decompression.

My diving log resumes on September 8:

4:00 Horizontal, the cylinder has become a decompression chamber. I recline on a pneumatic mattress, busily cleaning house and putting things in order. Last night, I bailed out as much water as I could and it passed into the lock. But every lurch sends ten quarts back to me over the dam formed by the sill of hatch C. All night long my mattress has floated at the mercy of the waves, and every time *Sea Diver* shook itself, the undertow would overflow the mattress to freshen up my rest for a while.

4:10 Second decompression stop. Dr. Bornmann brings pressure down from 100 feet to 75 feet. My voice sounds as comical as ever, but I begin to make myself understood. The mattress inflates like a balloon, and I quickly remove the plugs to avoid an explosion. Throughout my decompression, the hardening of the mattress would be the barometer of my return to open air.

4:55 As Bob brings me up from 75 feet to the next stop, a sharp pain awakes in my right wrist. Oh? A bend? I notify him.

"Are you sure?"

"Not entirely sure; go on, I'll stop you, if necessary."

The needle keeps dropping, 60 feet, 59, 58, 57. No doubt now—my wrist and the whole forearm are aching. It is an articular, deep, disturbing pain which gets worse with the pressure decrease.

"Bob, I am 100 percent sure now."

"O.K. Bringing you back to 75 feet."

The needle creeps up again.

"How now?"

"Gone. No more pain."

"Good. It's just too bad you'll have to stay there for twelve hours more now."

8:00 The sun is getting hot. Danny rigs up a tent to shade the cylinder. *Sea Diver* is getting ready to return to her anchorage in the roadstead.

9:00 My grotesque voice delights radio reporters. They make me talk. They don't understand a word but they are overjoyed. At least they have got it, their "story with an angle."

10:00 I plug in the air conditioning. Now for a change my head is cold and my feet are too warm.

We are back in Villefranche bay sheltered from the wicked swell of the mistral. Now, I may bail the water out again; a good part of it stays in the lock.

Everybody on board takes turns at the intercom, to make conversation.

14:00 Lunch is ready. It is to be passed on to me through the airlock, with the newspapers. To get room to swivel and shut hatch C, I have to deflate my mattress, roll it up, put it away, move tons of boxes, utensils, books, packages of clothes, and a scuba tank, then find sufficient space to store all that again elsewhere in a 6-foot-long, 3-foot-wide tube, the largest portion of which is already taken up by the instruments and my curled-up body. Good. Door C is closed. Ed empties the air lock, opens A, then B. He bails out the seawater, arranges my lunch tray and the daily papers, locks everything again, then makes a vacuum while I am waiting, crouching, and finally refills the air lock with gas. Now I can reopen C to take my first hot meal.

15:30 It is not until after lunch that I open the *Daily Mail.* On the front page, pictures and a big headline catch my eye:

Villefranche-sur-Mer, September 7
from our special correspondent
Lord Kilbracken

BATTLE TO SAVE POPEYE DIVER

Diver Robert Sténuit, baptized "Popeye Diver" because of his voice distorted by helium, has had to be brought up tonight on the deck of *Sea Diver*. The news that the ship's launch, *Reef Diver*, sank this afternoon in a particularly violent blow of mistral, with fifteen precious bottles of helium on board, was kept from him. The three crewmen had to swim for their life. Tonight, helium supplies are rapidly coming to an end. Now, Sténuit should be supplied with an oxygen-helium mixture at least until four in the morning, before compressed air may be substituted to terminate decompression. Otherwise, he will not escape the terrible bends. The U.S. ship *Sun Bird* is desperately trying to have a new stock brought from land. Helium tanks may be brought by helicopter from Marseilles. While Sténuit is quietly sleeping in his cylinder, the long watch in front of the needle of the manometers has begun. . . .

By Jove, the papers are full of exciting news these days and this is a true masterpiece of modern journalism. It has everything: humor, drama, suspense, human touch, educational bit, everything really. . . . I interview Bob:

"What am I breathing right now? Helium or compressed air?"

"How does your voice sound, Robert?"

Of course, I am still parodying Popeye; this was a silly question.

16 o'clock Very gradually, I "rise" to 58 feet. Sullivan watches me through the porthole. The same pain reappears, milder, but I say nothing this time, and it soon fades away.

18 o'clock Several times today I seemed to notice new symptoms but it is difficult for me, stiff as I am because of inaction and humidity, to determine whether a transient pain is a mere cramp or an alarming symptom of decompression trouble. I try to watch closely my left wrist, then my right foot, then my ears; now, if I concentrate hard enough, it does not take me long to discover, in each of these extremities, the most disturbing manifestations. So, was the first alarm serious or not? Yes, I guess, since the symptoms yielded immediately to recompression. Nevertheless, I can no longer be 100 percent certain. It is a little like reading a medical dictionary. . . .

21 o'clock At 40 feet.

September 9

2:20 30 feet.

8 o'clock 20 feet. A few "twinges" still in the right wrist, but I cure myself with autosuggestion.

11 o'clock Jay, the mate, tells me about his shipwreck. He left Villefranche harbor in a dead calm. Hardly outside the roadstead, *Reef Diver* was hit by a blow of sudden mistral which rapidly got worse and worse. The small overloaded boat began to take water with every wave. When arriving near the yacht, he was unable to transship the gas tanks. He wanted to make fast some of them under the ship to lighten the load of *Reef Diver,* but water poured in too fast. *Reef Diver* sank in minutes, vertically, stern first. Finally, an auxiliary boat of the U.S. navy brought a fresh supply of tanks in the middle of the night.

Afternoon Reading and meditation.

18 o'clock I "rise" to 10 feet. (This is the end of my diving log.)

On September 10th, I woke up at five o'clock after an excellent night. I had begun to indulge in the habit of talking to myself and readily commented on my own actions and thoughts. At the first word I addressed to myself that morning, I noticed something new: my voice was normal, I was no longer Donald Duck. So, I had to be breathing air! I twisted my neck toward the pressure gauge over my head. The needle was on zero. The sun was rising when I returned to the world.

Whether it lasted twenty-four or forty-eight hours, the experiment of Villefranche was a complete success. At 200 feet, it did not take much more than eight hours for my whole body to become saturated in dissolved helium, up to the marrow of my bones; from that moment, it mattered little whether I remained another day or a week at bottom. The decompression time stayed the same; the immunity to nar-

cosis was proved; all objectives of the experiment were attained.

The reporters who crowded on board, the day after the "big dive," proclaimed everywhere that a world's record had just been smashed. I don't like the word "record."

What does matter is to work quickly, efficiently and for a long time, while taking the least possible risks with one's life. Well, I lived under the sea and was able to emerge for quick efficient and prolonged effort, and would come home afterward to have dinner and sleep like any other pen pusher. . . .

The Villefranche experiment demonstrated for the first time that a man can really live and work at a depth where old-fashioned divers and frogmen can only make brief and dangerous forays.

The Link cylinder really worked. I emerged from it full of confidence, in spite of the cold, the leaks and the small surprises. For its imperfections were common to all prototypes, and easy to remedy. (The influx of water which disturbed my sleep stemmed from a loose sleeve in the faucet system of the X valve. If I had known that, I would have repaired it with one turn of a wrench.)

But primitive as it was, the cylinder turned out to be more than a prototype, two days later, when it enabled Edwin Link to salvage *Reef Diver* from 240 feet (the depth of the *Andrea Doria*). . . . First he found the wreck which had drifted far away with the current, by having himself dragged on the bottom in the cylinder, as in an observation turret. Thereupon, using the cylinder as an elevator and submerged decompression chamber, he went down again with Sullivan, whom he sent (breathing from an oxyhelium scuba) to attach a line on the bow's cleat of the launch. To hoist *Reef Diver,* pump out the water and suspend it from its davits was then only a routine job.

I was not there to help in this brilliant practical demonstration. I was driving northward already on National 7 Highway. I was heading for Brussels and my professional obligations, but Link had set a new undersea rendezvous for me next year, deeper, longer, safer.

6.

PLANNING FOR THE DEEPEST DAYS

To ensure optimum safety conditions for this new deep dive, Ed Link and Skip Marquet conducted important experiments with animals aboard the *Sea Diver.* After I returned to Brussels, they had white mice and an eight-month-old goat "dive" dry on deck in the cylinder. Just as animals were the first to be launched into space, so they have also played an important role in the history of experimental diving.

As early as 1923, the Americans Meyer and Hopff, who were studying nitrogen narcosis, had thought of using animals for this type of experiment. At first, they had chosen frogs and salamanders as subjects. Frogs and salamanders! I had to reread the title of their publication twice to satisfy myself that I had not picked up the wrong journal. But it was true. These investigators did really intend to measure changes in the mental faculties of batrachians under narcosis, and compare the effects of different gas mixtures inhaled under pressure. Now, I asked myself, by what objective and scientific criteria can one measure the intellectual acuity of a salamander, and what inferences for man can be drawn from them? In fact, the two scientists resorted to comparing electroencephalograms taken on a frog inhaling compressed air first (narcosis at 1,750 feet) and then an oxy-argon mix (narcosis at 1,200 feet).

In continuing their studies, the first systematic work ever undertaken on nitrogen narcosis, they used mice inhaling air at first (narcosis between 330 and 530 feet) and then oxy-helium (narcosis at 1,750 feet, they claimed, which contradicts the experiments of Dr. Behnke and the more recent ones of the University of Pennsylvania). Without proposing any positive or coherent answer (no better result has been achieved since), they were, nevertheless, first to underline the parallel between the narcotic properties of the inert gases and their degree of solubility in the fatty tissue.

For experiments in deep diving, it would seem logical to use the animal closest to us, the monkey. Unfortunately, all monkeys have extremely delicate bronchials and lungs. Far from their native tropics, they live perpetually on the brink of penumonia, which negates at the outset an important part of the experimental results. Besides, they have a bad reputation: uncooperative, undisciplined, always ready for the most mischievous tricks.

Consequently, mice, rats and guinea pigs which are easy to keep and reproduce quickly are most often used. Pigs and goats, whose muscular mass, blood volume, and respiratory capacity are comparable to those of man, are also used. Extensive scientific documentation is available about goats which further facilitates evaluation of the results.

From 1930 to 1950, Captain Behnke was the real pioneer in these investigations. More recently, a systematic experimentation program on animals was carried on under the direction of Dr. George Bond, head of the U.S. Naval Medical Research Laboratory, in the hyperbaric chamber of the submarine base in New London, Connecticut (Project Genesis). Regular publications make available to all other scientists the results obtained by Bond with the collaboration of Drs. Workman and Mazzone.

Captain Bond is famous for an incredible feat—one that his superiors had thought impossible. In 1958, he had himself "locked" outside a submarine (the *Archerfish*) at 320 feet and then made a 54-second free ascent by means of an ordinary life jacket without any breathing apparatus. The previous record for free ascent was 120 feet. The importance of the difference is obviously enormous; for if a crippled submarine sinks and settles tomorrow on a 320-foot bottom, every single man on board will know that they can surface safely, their confidence will help save their lives, and they will owe that confidence to Bond.

Dr. Bond christened the first part of his work on "dry" caisson dives Project Genesis because it is said in Genesis (1:26) that to man is given the dominion of the ocean. To attain this dominion, Bond proposed, following Ed Link's example, to install men on the bottom in "submarine laboratories," and that is why he calls the second part of his program, the "wet" part, Sealab.

The Naval Medical Research Laboratory in Groton, Connecticut, houses a recompression chamber tested to a simulated depth of 250 feet of seawater. That is where Bond had rats, guinea pigs and goats dive under scrupulous scientific and medical supervision.

First, to prove the innocuousness, at atmospheric pressure, of a gas mixture where helium simply replaced nitrogen at the same percentage, he incarcerated various mammals in his caisson for several weeks. They came out in perfect health.

Then he subjected 24 rats to a pressure of seven atmospheres (200 feet) in compressed air. After 15 hours, nitrogen narcosis had thrown them all into complete apathy; the first rat died at the 28th hour; in the following 7 hours, hyperoxemia killed them all, one after another (pneumonia, edema, interstitial hemorrhage of the myocardium, of the kidneys, etc.).

Finally, he replaced compressed air with a 3 percent oxygen mixture (no more hyperoxemia) and 97 percent helium (no more nitrogen narcosis) and started the same experiment over again at the same depth with rats, monkeys and then goats, which this time survived without any damage, after a long saturation.

Having thus proved the immunity of the animals to a complete saturation in HeO_2, and the possibility of safely decompressing them, Bond passed on to the second phase: the saturation and decompression of human volunteers, in a dry chamber under pressures increasing up to seven atmospheres.

We had already gone beyond this second phase, but because we were now aiming for a 400-foot dive, we resumed animal experimentation on board *Sea Diver.*

Link placed three white mice in a small cage, in full view, in the center part of the cylinder and slowly increased the pressure. Like all divers, mice must equilibrate their middle ear to equalize the pressure on the internal and external sides of the eardrum. When the membrane is distended by the outside overpressure, and bothers them, they become excited and scratch their ear vigorously. That was the signal for Skip Marquet to stop compression momentarily.

In three and three-quarter hours, the three mice had attained 13 atmospheres (400 feet of seawater) and they remained there 12 hours, nibbling, digesting and trotting about in the most normal fashion, their bodies entirely saturated in dissolved gas (He 80 percent, N_2 15 percent, O_2 5 percent).

Their 24-hour-long decompression had been calculated step-by-step according to the basic data of the Experimental Diving Unit of the U.S. Navy, and it was carried on without the slightest hitch. But decompression schedule of 24 hours for so small an animal as a mouse seemed to be much too long; so, Link decompressed on an eight-hour schedule three other mice which had been subjected to the same conditions and they did not show the slightest sign of discomfort.

I heard of this remarkable saving in decompression time from Ed, but I knew it would not work out exactly that way for us. The blood volume of a little rodent is infinitesimal compared to that of a man, and mice are well known for the rapidity with which they can be saturated and desaturated. That luck wasn't for me.

A friend of the Links committed to their care an eight-month-old female goat. She was a very soft, well-brought-up and well-bred pet. Ed, after saturating her at 400 feet in a simulated dive of 13 hours (oxygen 3 percent, nitrogen 6 percent, helium 91 percent) tried to decompress her according to the same eight-hour table. On the ninth minute of her decompression, at minus 190 feet, the animal, which until then had remained perfectly calm and relaxed, began to tap her hind hooves. She lay down, got up again nervously, then repeated the same behavior ten times, always keeping a left rear limb flexed that was obviously quite painful.

No doubt it was a bubble; it was the bends.

Immediately decompressed at 400 feet, the goat regained her composure. After a new sojourn of one hour, she was re-decompressed in 24 hours and returned to the open air in fine shape.[1] It was obvious that for me, decompression would be at least as long.

Ed told me about these experiments when I saw him in London, at the end of October, in the corridors of the Second World Congress of Underwater Activities. The goat, he told me, had been placed under constant medical supervision for three days after its dive, and all tests had confirmed its perfect condition. It was a complete success and Ed Link, after having fired the enthusiasm of the world's specialists assembled at the Congress with the report of our Villefranche "big dive," astonished them even more by announcing his next objective: he was planning now to send his chief diver to spend two days at 400 feet.

Four hundred feet! All eyes were on me.

Four hundred feet—120 meters—under the waves, and I was the one involved! When I thought of it, something started contracting, or crawling maybe, in my stomach. This was for real, now.

Did I really want to go and have a look down at 400 feet, and shiver there miserably, night and day, soaked like a rat, and after that return to a drenched bunk for endless days of decompression, and perhaps supply with big morning headlines the papers which specialize in catastrophes?

Of course, I was itching to go; I knew it all the time. I itched because it was difficult and because I had always found the greatest joy in danger knowingly accepted and prudently overcome. And when a reporter of the British Television asked me, I heard myself replying: "Of course, yes. You need only get used, gradually, to the idea of being very cold and very uncomfortable and a little uneasy for a few days and nights; once you are accustomed to the idea, you go in the water as if you were leaving for the office and then everything follows in a most routine way, like a quiet morning at the office," and I added, in trying out the nonchalance of the natives: "Besides, if a goat can do it, there is really no reason why I can't do it almost as well."

[1] She is still in good spirits and top physical shape today, and so is her offspring (1964).

At Villefranche, the cylinder had been in turn an elevator, an "underwater sentry box," a submerged decompression chamber, and a deck decompression chamber. For the second experiment, we were going to bring into play more elaborate equipment, as originally planned in The Man in Sea project. It was on board *Sea Diver*, on our way back from the Corsican expedition (a trial cruise of two weeks to test the prototype of a new submarine magnetometer, and try to locate along the way the famous so-called "Rommel treasure" which is actually one of Himmler's war booties, that our plan of action materialized.

The next experiment would take place on the other side of the Atlantic, in early autumn, with the always more active collaboration of the U.S. Navy. I would descend in the cylinder, a pneumatic rubber tent would be waiting for me on the bottom completely inflated, which would be my home for the coming days. I would go out to work in the vicinity with a new kind of mixed gas breathing apparatus, and perhaps also I would work dry under an "igloo," a revolutionary underwater workshop, to be made of rubber also and placed on the bottom, near the tent over the spot I was to work on.

To resurface at the end of the job, I would climb again in the pressurized Link cylinder (this time it would be baptized "elevator"); the sealed elevator would be brought back on deck and fitted, horizontally, to the hatch of a large roomy decompression chamber into which I would slip to be decompressed in princely comfort.

7.

A TENT ON THE BOTTOM OF THE SEA

IN June, I received a letter from Ed, whose envelope, stamped in the left corner with a small blue *Sea Diver*, bore the postmark of Bermuda: "How fast our plans change. . . . I'll be still busier this year, because in addition to our diving experiments, I have agreed to direct a section of the Deep Submergence Systems Review Group, which the Navy has just set up and entrusted to Rear Admiral E. C. Stephan, Chief of the Oceanographic Bureau of the Navy."

I remembered that Admiral Stephan had called Ed on the telephone right after his return from Corsica, to ask him to take charge of a group of civilian and industrial specialists within this new committee, the DSSRG, which brought together all topnotch American experts in underwater research. The DSSRG arose out of a catastrophe which stunned the American nation on April 10, 1963. On that day, U.S.S. *Thresher*, the first of a class designed to find and destroy other submarines, the most advanced, the most invincible of the American nuclear submarines, disappeared in a dive with 129 men on board. Her last message was: "Experiencing minor difficulties— Have positive up-angle— Am attempting to blow— Will keep you informed"; then, four minutes later, a few garbled words and maybe "test depth." It is believed that the hull of the *Thresher* was crushed like a nut by pressure as the ship, paralyzed, was heading toward the bottom, after having exceeded its trial depth. All crew members died instantaneously, probably unaware of what was happening to them. But the catastrophe suggested another horrifying possibility: if the sea bottom had stopped the sinking of the crippled submarine before crushing depth (at 700 or 1,000 feet for instance, instead of 8,400), the 129 men on board could have survived inside for many months in complete safety and air-conditioned comfort, eating like gourmets with a different technicolor movie to watch every night—only to die like rats in the end, since there was no way, either in the United States or in any part of the world, to recover a submarine or evacuate the crew from that depth. . . .

This possibility was keeping many an admiral awake at night, and it had impelled the Secretary of the Navy to have an inventory of all past, present and future techniques of submarine research and operations made by a group of top experts, in order that they might present to the Navy a list of recommendations for development of new methods of intervention and research in deep water. A gap which had quickly become wider and wider had sprung up between the operational capabilities of nuclear submarines and the capabilities of the other branches of underwater science and technology. The width of this gap had just been dramatically revealed to the general public.

"That means," continued Ed in his letter, "that I will have to review all the various diving techniques in use or in the

planning stage in the world, as well as all equipment for wreck location and salvage. Since it happens that that is precisely what interests me most and that these investigations, vital as they are for the Navy itself in submarine rescue and salvage operations, may be of accessory benefit to the Man in Sea and our future studies, I could not refuse such a challenge."

By all means! As for me, with my old dreams of treasure hunting not yet completely smothered under a fragile veneer of economic realism, the very thought of the thousand gold-laden deep wrecks which are inaccessible today made my blood boil.

Ed's letter continued:

> Obviously, this brings its advantages and its drawbacks. I am working in an office in the Navy Yard in Washington, D.C., which will delay the progress of our own plans considerably. To compensate for that, the Navy has placed at my disposal the installations of the Navy Yard, which will make it easier for us to accomplish what the Navy itself is essentially interested in, a successful dive. In short, we are temporarily restrained, but with more assistance, we shall be able to go much farther, much faster.
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> *Sea Diver* is now in Bermuda, and in a few weeks I shall bring it to Washington, to the Yard where I work. Then I'll be able to closely supervise the installation of new equipment, and we will need only to go down the Chesapeake Bay to conduct shallow-water tests. We won't be ready to go to Florida or the Bahamas before late September, but as soon as you arrive, we will try out our inflatable tent which is almost finished, and seems all right. . . . Besides, the yacht will be moored virtually under the windows of the Experimental Diving Unit, the diving chambers of which will be available. See you again in September. . . .

And in September I left Brussels and took the S.S. *Burckell*, a Belgian freighter, for the United States. The voyage was delightful—exciting gastronomically, and thought-provoking as well.

The captain surprised me very much when he asked if I didn't, while living at the bottom of the sea, fear the octopi, the sharks and the giant sperm whales. The purely physiological dangers of life under pressure had preoccupied me so much that I had not given a thought to the deep-sea man-eaters.

Octopi would never disturb me. All divers are well acquainted with these graceful animals, so timid and sympathetic; we all have played with them on the bottom—one running behind the other like two old buddies—before we would take them up to the frying pan and the olive oil. However, come to think of it, I remembered a certain plaster cast of a California Octopus which I had seen long ago in the Oceanographic Museum of Monaco, whose tentacles, when spread out, had a span of about 26 feet. . . .

I did not fear the octopi of the deep as much as the giant squid,[1] the "kraken" whose monstrous bodies are sometimes cast off by the sea on the shores of Norway. That one, we know, does dwell in the Atlantic. Its dead body has been measured (80 feet overall) and Prince Albert of Monaco has caught and brought back a few. It is also known to attack young whales on the hide of which squid's sucker discs sometimes imprint marks bigger than dinner plates. And as a matter of fact, a whale and a pneumatic rubber tent are both nothing but a big black, shiny sack; a myopic kraken could easily make a mistake.

[1]Architeuthias princeps.

Let us not mention barracudas or tropical moray eels—they attack divers only on television.

But what about sharks? Divers do not really fear them. Innumerable dives in all seas of the world have proved that, as a general rule, a shark or even a pack of sharks do not attack the heavy-gear or scuba diver. A man when wholly seen under water is about as large as a medium-size shark, therefore he is a priori an equally well armed beast, and a shark would rather attack someone smaller than itself, preferably an invalid. This entirely natural behavior is seen also in the pike, the lion or the birds of prey, to mention only animals. . . .

Numerous species of sharks are absolutely harmless, others are known to have attacked bathers, or surface swimmers (they don't see the shark coming, because they don't wear masks), or even kayaks. But in that case what they attacked was not an unknown animal as big as they; it was a white arm suddenly plunged into the water, a foot visible only from below, or the silvery form of a seal, asleep on the surface.

A few notable exceptions are known to this rule. The Italian photographer Maurizio Sarra was mortally wounded by a shark, while diving about 100 feet in the Italian Mediterranean. Also, when sharks are overcome by a "feeding frenzy," their behavior defies all logic and they immediately become formidable blind machines of destruction. But, again, how do the sharks of the great depths behave? Nobody really knows. Did not a 25-foot shark ram the diving saucer of Commander Cousteau, 1,000 feet under the Red Sea? The voices, the lights, the whirring of the motors, all the sounds and vibrations we were going to make around us on the bottom, could not fail to attract fish wholesale, and where a table is set, sharks never arrive last.

The often fatal bite of a shark is a risk accepted by all divers, which does not concern them much more than the airplane crash concerns modern travelers. Nevertheless, that night, I jotted in my notebook with a big, red pencil: *Provision for anti-shark cage?*

The worm had gotten into the apple. I began to think of all the jaws, all the beaks, all the cavernous mouths, which might be waiting for me on the threshold of a deep submarine house. I took inventory.

The sawfish? It spends its life raking the sand, with its belly stuck to the bottom, in order to extract the thousand little creatures on which it feeds. No, nothing to fear on this score.

The narwhal? It mainly inhabits the cold seas, and despite its formidable weapon, it is described by Paul Budker, the eminent French cetologist, as a "peaceful, very timid animal."

Dolphins, porpoises? I have played ball quite a long time with these charming companions, in the great reservoir of the Miami Seaquarium. They are man's best friends under the sea; they are kind, funny, sparkling with intelligence, and many Floridians keep a pair in their swimming pool, instead of a poodle in the living room. Since they keep the sharks away by just being there, I had even thought of taking a couple of them with me to keep me company on the bottom.

And the killer whale? Here all reputed authors shudder in unison. Orcinus orca is described as the most bloodthirsty brute of all the oceans; it is enormous, 15 to 30 feet, insatiable (up to thirteen porpoises and fourteen seals have

been found in the stomach of an adult killer whale) and dangerously intelligent. In the Arctic ice pack, a photographer has seen a killer overturn a cake of floating ice by leaping on one edge to dislodge a sleeping seal. The same beast then tried to repeat the maneuver in order to bring the photographer-observer within the reach of its enormous teeth. They scour the polar, tropical and equatorial oceans in organized packs of three to forty and, as Owen Meredith Lee has so aptly remarked in his treatise on diving: "There is no known remedy against the attack of a killer whale, except reincarnation."

And the marlins, the swordfish, all the saber rattlers who throw themselves at you like a torpedo? Well, I came across some interesting quotations. Paul Budker, for example, wrote:[1]

> It is well known that swordfish, moved by a still unexplained fury, sometimes dash at ships with all their strength. It is usually to their detriment. If the hull is made of wood, the rostrum or, more colloquially, "the sword" of the big fish breaks and remains wedged in the planking. There are specific proofs of this behavior—eyewitness accounts of sailors, and also fragments of the hulls of ships pierced by a rostrum which was left in it. . . . A beautiful specimen appears in the collections of the Natural History Museum in Le Havre. There are a few also in the British Museum in London.

Now, it was getting even more disturbing:

> The swordfish is also said to attack whales. That is gratuitous maliciousness, a kind of reflex aggressiveness comparable to that of the barking pug behind a cyclist. . . . The

[1] *Baleines et Baleiniers*, Paris, 1958.

swordfish has a choice between two solutions: either his bill breaks as in a wooden hull, or else it doesn't break and this big silly irascible fish will remain impaled in the body of its enemy in a very uncomfortable position. Even if it succeeded in penetrating a vital organ of the cetacean, what benefit could it derive therefrom? Let us consequently admit that, as in the case of sharks, the swordfish is sometimes subject to fits of furious frenzy which impel it to hurl itself blindly against all large obstacles within reach—rocks, ships or cetaceans, regardless of the possible consequences of this frenzy.

Mentally, I could not help adding the submersible inflatable tents to this list of "big obstacles within its reach."

> One must not let this opportunity go by [adds Professor Budker] to mention an actual case from which another significant lesson can be derived. On February 12, 1951, on board the factory ship *Thorshovdi,* operating south of the Orkney Islands, a piece of the bill of a swordfish was found in a 73-foot blue whale in the course of cutting it up. Thirteen inches long, weighing 16 ounces, this piece of rostrum had deeply penetrated the dorsal muscle, near the spinal column, slightly back of the pectoral flipper. Recovered by Inspector H. Koldenspund, the stump of the sword was sent to Professor J. T. Ruud who identified it. . . .

To complete the inventory, I turned my attention to the big ones: whales and sperm whales. No reason to fear the baleen whales, for they live and feed near the surface, in the cold seas where they find the krill—the thick soup of shrimp and plankton which, filtered by the baleen, is their only food. When they migrate to the warm seas, they are thinking only of love.

But their cousin, the sperm whale (60 feet, 50 tons), has different tastes, different habits and different jaws. It frequents all sorts of depths. A cable ship found one dead, entangled in a telegraphic cable lying on the bottom at 3,600 feet. It feeds on seals, giant squids, etc. . . . Dr. R. Clarke of the National Institute of Oceanography found in the stomach of a 46-foot sperm whale, during an autopsy, a 35-foot squid weighing 405 pounds (1955). To chew these monsters, the sperm whale makes use of two rows of enormous teeth, 12 inches long, 5 of which are outside (2 pounds of ivory per tooth), arranged on both sides of a lower jaw or mandible which opens under its massive head. The teeth are set in a corresponding number of alveoli in the stationary upper jaw.

In my place, a good reporter would probably have dreamed of some remake of Jonah's adventure. He would have imagined himself taking a holiday in the stomach of a whale, to be spit out again, unharmed, after a sensational weekend. Alas, a reporter diver, sucked up by a maelstrom under a steam hammer, has little chance of ever finding his way back to the press agencies.

The American authority on whales, Robert Cushman Murphy (cited by Budker), asserts:

> A man might well be engulfed by a sperm whale. Sperm whales are known to swallow seals. It is quite likely therefore that they have engulfed sailors during some of the fracases between the whales and the whaleboats. Many men have disappeared after the wrecking of their frail craft, and one can assume that they didn't all merely "sink."

And Dr. Egerton Y. Davis, Jr., of Boston gave this very clinical description of the fate of a modern Jonah in *Natural History* (1947):

> In February or March 1893 or 1894, I embarked as a young surgeon in the sealing fleet going out of St. Johns, Newfoundland. . . . I was on board the schooner *Toulinquet* . . . one sailor had the misfortune . . . to fall into the water in the proximity of a huge sperm whale. The whale was, no doubt, lost in these Arctic waters, and the sudden appearance of ships and men around it must have angered it. Be that as it may, the poor sailor was swallowed by the sperm whale, which then made straight for one of the small schooners. A lucky shot from the stern cannon mortally wounded the huge beast, and made it change his course. . . . The next day, the sperm whale was found floating belly-up in the air. Since it was impossible to bring it in, the men by a valiant effort and many hours of hard labor, succeeded in opening the animal and reaching its stomach, which apparently contained their comrade. With great difficulty the stomach was isolated, severed at the cardia and at the duodenum, and the sailors brought it to me for inspection, with the hope that the body of their comrade could be returned to his native country, Newfoundland, for burial.
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> With the sharpest galley knives, I succeeded in opening the stomach which gave off an overpowering stench. Then a fearsome sight met our eyes. The chest of the young man had been crushed and this wound by itself was probably serious enough to kill him outright. However, the most striking findings were external. The whale's gastric mucosa had encased his body (especially the parts not protected by clothes), like the foot of a huge snail. His face, hands, and one of the legs, where a trouser leg had been torn, were badly macerated, and partially digested. In my opinion, the sailor did not know what happened to him. The appearance and odor were so bad that all the men present, save I, were forced to turn away. We had to consign him to the deep.

Still, the more divers learn about marine animals in their own realm, the less reason they find to fear them, and the colonists who will be living on the continental shelf ten years or so from now will laugh at my worries when they read these lines. They will have the same amused indulgence for me, I guess, as I feel for Victor Hugo and his man-eater octopus from *The Workers of the Sea*.

September was coming to an end. In Washington, the gray squirrels toddle along for food, so softly that they seem to fly, hedgehopping over the lawn of the Navy Yard. A lone bird sings from its nest in the muzzle of a bronze cannon, burned green by the centuries. The Naval Base of Washington quietly sleeps under its maple trees on the shore of the Anacostia River, a tributary of the Potomac. There is where I step once more across the gangway of *Sea Diver*.

The boat is moored in the river, at Pier No. 5. The Washington Navy Yard, established in 1799, was for a long time the largest naval yard of the U.S. wooden navy. When the era of the great iron ships arrived, which the Yard could no longer construct, let alone launch in its river, the Navy put its main gun factory there. Now that cannons are as obsolete as sailing ships, the Navy Yard does not manufacture anything anymore, and its converted buildings house some of the headquarters of U.S. Oceanography.

But all along the lawns, a collection of guns which have come out of its workshops during a century and a half seem aimed at *Sea Diver*. And another collection testifies to the glories of the Navy: cannons captured from the enemy, trophies of the War of Liberation, the War of 1812 against England, the Spanish-American War, the operations against Japan, the Mexican War and the Civil War.

On the well-mown lawn, among anchors and screws, the souvenirs of two World Wars occupy the place of honor: Austrian and German howitzers, kamikaze planes and torpedoes, German pocket submarines, light tanks marked with a red sun, pierced armor plates, and machine-gun turrets.

Sea Diver had a new coat of paint, all white, spic and span on the chocolate-like waves of the dirtiest river in the world.

On deck, Ed removed for me a tarpaulin which hid a kind of black sack made of many pieces of rubber glued together, apparently the wreck of a fire balloon. The bag was attached on each side to a metal zinc chromated frame. He looked at me, waiting for a comment.

There were no comments, because I never could have guessed what it was. "But," he said, "that is your future home." And he added that his tent was 7½ feet long and 4 feet in diameter when inflated, that he would name it a Spid, short for Submersible, Portable, Inflatable Dwelling, that it would be anchored on the bottom by means of a basket filled with lead, that it promised to be perfectly comfortable, easy to store, very safe, etc., etc.

Two weeks later, when I saw Spid again, on the bottom, 20 feet under the Chesapeake Bay, it was another animal entirely. The diodon had inflated itself, and, as usual, I admitted that Ed Link was right.

We had anchored the ship in an isolated cove of almost clear water, one day's navigation downstream from Washington, a kind of a big pool surrounded with reeds and birch trees reminding me of a typical *Field and Stream* cover. A nasty 40-knot wind had been blowing through our teeth all the day before and again during the forenoon while we were breaking our backs loading 6 tons of lead, in ingots of 65 pounds, into the ballast basket of the tent. The bottles of helium and oxygen were bolted down on the chassis, but only for ballasting, since today we would only inflate with air.

When the entire weight of the lead basket hanging under the boom went over the side, *Sea Diver* listed so heavily that it showed the green fleece of its hull on starboard. Noises of broken dishes came from the kitchen, mixed with a confused flood of Greek oaths.

The air hose was ready inside, the compressors started, the thing palpitated, took on shape, filled out, and *Sea Diver*, 5 tons lighter thanks to this mushrooming buoy, righted itself gracefully. Then Dan Eden released the brake of the winch, and the big black balloon slowly disappeared.

Ed and I soon followed it below the choppy surface. As visitors on top leave their umbrellas in the cloakroom, we got rid of our scuba tank before climbing into the tent. The light was surprisingly bright inside, thanks to the white walls, and accommodations much more spacious than I had thought. What a strange sensation to breathe and live in a cozy dry cocoon at the bottom of the sea! The light is diffused, the sounds are dampened immediately. Seated face to face, our feet hanging in the central access well, we were right in the middle of a Jules Verne story.

We unrolled a tape measure to take inside measurements; here would come the bunks, there the heater, and the air conditioner underneath with the CO_2 canister, and so forth.

One detail, however, kept bothering me. The concept of an inflatable rubber tent is per se a brilliant one: lightness, no storage problem, shock resistance, no corrosion, no painting or maintenance problem. But the thin rubber of which this particular tent was made seemed very, very fragile to me. I hardly dared pull my diving knife from its sheath, and all those stories of maddened swordfish, piercing with their bill the blubber of whales or the flank of wooden sailboats, kept running through my head.

While checking it carefully from the outside, I discovered 22 pinholes from which microscopic air bubbles were escaping like long flexible shining collars. This was too small a leak to disturb us but still, it was not supposed to leak at all and when the tent would contain helium, the molecules of which are much smaller, these holes would become a real problem. The next day I repaired them all from the inside, but then I noticed that certain glued parts were about to come apart, and that the sides of the bag were chafing against the chassis. The wear and tear, there, would be awfully rapid.

The fragility of the tent was not our sole problem. Helium simplified our life by eliminating nitrogen narcosis and by assuring me of good pulmonary ventilation, but, on the other hand, it brought new complications. Since it is highly conductive, helium rapidly dissipates the diver's body calories; being very fluid, it changes the resonance of his vocal cords in the larynx; and because of its high cost, it calls for continuous reuse after purification.

This raised again three important problems of which I had had a bitter foretaste at Villefranche: the isothermic suit, our diver-to-surface communications, and the recirculating breathing apparatus.

In 1962, I had used a wet suit made of expanded neoprene, the regular suit of most amateur divers and spear fishermen. Unfortunately it had proved to be totally inadequate, as the 102 pounds of pressure which was exerted on each side of every square inch of neoprene foam had reduced the material to the thickness of a sheet of Bristol board. With its quarter-inch gas layer the clothing had also lost all its insulating properties. After about 20 hours at 200 feet, I discovered to my amazement that the helium diffused into the neoprene cells and little by little was giving back its original shape to the suit, but helium conducts heat seven times faster than air, and therefore although it reinflates the suit material it restores only a fraction of its isothermic characteristics. Moreover, on my way back to the surface, I made the very first clinical observation of a diving suit suffering from a decompression accident: as the surface crew was lowering my internal pressure, the wet suit started swelling like a balloon (the helium which had diffused very slowly into the innumerable tiny cells of the neoprene could only come out of it again very slowly), and when I sent it out through the lock to make more living space in the cylinder Jay was quite amused to find that my hood would have covered a beach ball.

The dry suits, the waterproof, tight-sealing, thin-rubber one-piece suits which the military frogmen of the Second World War wore on top of woolen underclothes, are not suitable either. The woolen fibers only retain a noninsulating layer of helium around the body; this also is the drawback of the professional "constant volume suit." Ed looked into electrically heated underwear, similar to the garments which the Navy helium divers are currently using, but they were still too unwieldy and too heavy for scuba divers.

I had learned another lesson in the Link cylinder: the ideal diving suit must be quick and easy to put on and take off in an uncomfortable position with no assistance in a very restricted space.

What we needed then was a wet suit made of sponge rubber with intercommunicating insulating air cells and sandwiched between two hermetical layers of latex. Such a suit could be reinflated with a bottle of compressed air, as soon as the pressure flattened it. On paper, nothing simpler, but actually the very different stretch coefficients of the two materials, the difficulties in gluing and the many problems of fit gave the technicians of U.S. Rubber Co. a good many gray hairs. I realized the extent of their problems when I went to their factory in Washington, Indiana, to try on various kinds of armor, or rather to attempt to try them on.

For our bottom to surface communications, the simplest answer was Morse with a special code for urgent or routine messages. General Precision, Inc., was also developing for us means of electronically filtering the "heliumese" language. This language is incomprehensible because the muscles which activate the vocal cords have been trained to make them move in the dense medium of air. When a similar motor impulse makes the same vocal cords vibrate in a different and more fluid medium, the sounds produced remind one of an LP record played on 78 RPM. On top of this, the resonance of the larynx walls is deeply altered by pressure. A bathynaut can "relearn to speak" to a certain extent, by re-educating the muscles of his larynx, and the topside crew can train its ear to interpret these ridiculous human sounds. But electronic devices can break down the heliumese language, more effectively, into several different frequencies to restore only those comprehensible to our ear.

I could also reply by making signs before the TV eye or show it a written message, or I could breathe a few gulps of a mixture richer in nitrogen brought down in a special tank before talking into the microphone.

The most serious problem was that of the breathing apparatus. "To be able to leave my house," I said to Ed, "easily, comfortably, safely, to go to work for an extended period in the vicinity either on the bottom or in mid-water, is obviously the real goal of our whole experiment, and the breathing apparatus which will make that possible will therefore be the key item of our equipment."

There was an easy solution: fill the tanks of a regular aqualung (dorsal or hookah-type) with a suitable gas mixture. An easy solution, yes, but a cumbersome and an expensive one, since at 400 feet a diver would empty a tank of one cubic meter in about three minutes. To have enough autonomy the diver would have to take along a bottle as large as a tank car.

A young American inventor suggested a mixed-gas, self-contained, closed-circuit rebreather, which he had constructed and tested in medium depth with complete success. The partial pressure of oxygen in the two inert gases (nitrogen and helium) was automatically maintained according to the depth by an electronic sensor similar in principle to that of the precision analyzers.

"There is no doubt," I told him, when surfacing after testing his device, "there is no doubt it is the coming device, but not for us I'm afraid. Not today. Too early to put faith in it. With this gadget on my back, I am at the mercy of an electronic breakdown or a malfunction in the CO_2 filter. I know, the chances are one in a thousand, but we cannot take it." Our inventor friend agreed with that, particularly since his rig was designed for dives starting from the surface, and required care, taking apart and adjustments which would be impossible to carry out under pressure.

Our discussions with Ed on this subject always concluded in the same way: "A breathing apparatus," he said, "to be 100 percent safe, must be 100 percent fail safe. Either you get gas, and thereby you know that all goes well because the gas is *always* good, or you do not get gas and you have no choice but swim back home real quick, which is no problem anyway since you are never very far. But you can't entrust your life blindly to a chemical cartridge or to an electronic instrument or even to a manual dosage." And he enumerated again the fatalities: so and so killed by a case of hyperoxemia, another by anoxia, a third one poisoned by CO_2. I fully agreed with him; at the Experimental Diving Unit, every month brought fresh reports of accidents, in Florida, California, Europe, from some Navy frogmen unit or the UDT. The intoxication was always insidious, without any clear warning. Everything was going fine, and then, a moment later, wham, the diver lost consciousness and usually drowned. The investigators might discover a wet chemical filter, or a leak in a tap, or they might not find anything abnormal at all. Now then, the gas which is in the tent, or in the cylinder, is always "good." It is permanently analyzed by reliable precision instruments and its composition is regularly corrected, either by the surface or by a standby diver in the tent. That is the gas, therefore, which must be brought to the diver working in the vicinity. A pump will bring it to him through a rubber hose, and another one will reaspirate the used gas in order to purify and reoxygenate it together with the ambient gas. This hookah-recirculation system, on which we all agreed, gave us around our house an

autonomy limited only by the length of the twin hose, at any rate about 80 feet, which was the distance we could swim comfortably holding our breath in case an incident forced us to return in a hurry.

So I spent many hours under the Potomac or in the swimming pool of the Yard, testing several successive models of a recirculating breathing device I had invented, the vital part of which was made of copper wire and surgical rubber hose.

Our basic Cartesian principle had always been to split up the risks as much as possible and to tackle them one by one.

All the purely physiological dangers would be confronted at first in a dry chamber, gradually, under optimum conditions of control and safety. At sea we would test separately each piece of equipment until satisfied, and then the whole thing first in shallow water, then in medium depth. On the bottom we would be faced only with the environmental problems and all those others which we had forgotten or ignored in spite of careful planning and many sleepless nights.

As to the dry experiments, Dr. Bond had actively pursued the second part of his Project Genesis. He told us about it, one day when he came for lunch on board *Sea Diver*. At the end of 1962, at the Navy Medical Research Laboratory in New London, he had successfully kept three men at sea-level pressure for six days in an artificial atmosphere in which nitrogen had been replaced by helium (helium 79 percent, oxygen 21 percent). In April 1963, he put three volunteer petty officers under a pressure equivalent to being sent down 100 feet, for eight days, and decompressed them in 45 hours (the mixture contained 5 percent oxygen). Now, in September 1963, he had just kept three men in his dry chamber for twelve days under a pressure equal to 200 feet of seawater and had decompressed them without any difficulty.

All this confirmed in a scientific fashion our conclusions of Villefranche and the sketchy medical observations which we were able to record. Bond was now preparing for his next objective, a real sojourn at sea at 200 feet in the "laboratory under the sea" which he wanted to set up next year off Bermuda.[1] Our own objective was 400 feet and therefore we had to pursue the same dry experiments farther and farther down.

The Navy was taking so much interest now in Man in Sea that we felt we were becoming little by little members of the family of the gigantic and almighty U.S. Navy. The Secretary of the Navy had visited *Sea Diver*, the Secretary of Defense had stuck his head into the cylinder, and each day brought its senator, admiral or congressman, not to speak of everyday captains and lt. commanders.

Our stay in Washington was a significant success from a public relations point of view. At the outset, the potential applications of a new model of the cylinder, and of a Spid adapted to the rescue of submariners, had attracted attention. The important message which Link had been shouting from the rooftops for seven years had finally reached the right ears. "How come we only shoot millions toward the moon, when we could also pump millions from the bottom of the sea?"

We had anticipated that we would have to carry on ourselves our own series of dry dives.

[1] In July 1964, Dr. Bond installed four men at 192-foot depth in his *Sealab II*, a horizontal cylindrical house as big as a tramway. The aquanauts lived in it for eleven days. A complete success, this experiment resulted in mountains of important physiological and general information.

To begin with, was my physical condition up to par? Dr. Joseph McInnis, a young Canadian doctor who had been working under Professor Lambertsen at the University of Pennsylvania, to be assigned thereupon to *Sea Diver* as ship's doctor, decided that it was; or rather the results of the electroencephalograms, cardiograms, X-rays from every angle, tests, analyses and countless examinations, manipulations and auscultations decided that it was.

So I was entirely resigned to spend a week far from the world lying in the cylinder on deck at minus 300 feet and another week later at 400 feet. But now the whole Experimental Diving Unit was working with us with its unique facilities where modern helium diving was born and its medical team (headed by Dr. Workman and Dr. Goodman), one of the most competent and prestigious groups in the world, which continues to write diving history every day in the EDU's publications.

It was as a mere spectator, therefore, that I witnessed the trial dive of Koskimaki and Simeone in a large cylindrical recompression chamber. Dr. Robert D. Workman, chief medical officer, was exposing these two volunteers for a period of 24 hours to a pressure of 10 atmospheres, equivalent to 300 feet of seawater, in an oxyhelium atmosphere of 5 percent oxygen (which corresponds to 50 percent oxygen at sea level); the basic objectives were to measure quantitatively the possible variations of their intellectual acuity, and to verify the decompression schedule which he had calculated for us.

First class diver James Koskimaki seemed ill at ease, and his comrade Simeone, next to him, did not look any more relaxed. The present situation was not provided for in the U.S. Navy Diving Manual. The two men bravely kept a set smile while blinking under the flashlights and the pitiless beams of the spots. For them, the experiment was another dry run after many others. For the reporters and cameramen who made them repeat their entrance three times, there was a world record in the making and perhaps, who knows, the promise of some tempting "dramatic developments." . . . Finally, with a big sigh of relief, the two tattooed volunteers climbed for the last time the three steps which led to the caisson. They slid between the small portable stove and the icebox, stepped over a case of lemonade and a mountain of canned foods which blocked the passage between the lock and the main chamber, and finally found themselves at home. Thereupon, they sat down on their bunks and waited. . . .

Behind them, the door was locked—a big circular hatch, similar to that of a submarine. It was eight o'clock in the evening, Tuesday, December 3, 1963. The door would not open again until the weekend.

I couldn't help feeling that those two men were there in my place, there on the other side of the port window, on the side of truth where Navy regulation prevented me from accompanying them, as I, for the first time, found myself on the side of the reporters. Several times a day I came for the news, and when Koskimaki, at 54 feet, in his twenty-seventh hour of decompression finally decided to tell the doctors that his knee hurt since about 80 feet, when he requested, at 30 feet, to be "lowered again" a little because his right knee was becoming paralyzed, I, the spectator, suddenly understood Ed Link's anxiety when on top and why he always makes me take elaborate safety measures which he would never think of taking for himself when he was the diver.

Brought up again at 100 feet on the thirty-fourth hour of their desaturation, and then re-decompressed twice more

slowly (17 minutes per foot instead of 8.25), the two volunteers left their caisson a day later than anticipated but in perfect shape.

This kind of incident is quite normal, of course, in experimental diving; the rate at which the volume of dissolved gas is eliminated from the various body tissues can be calculated, but the theoretical computations must always be verified in actual exposures.

To open up the ways to the great depths with such experiments (the next one at 400 feet was set for the beginning of 1964) was really the raison d'être of the Experimental Diving Unit.

Commander Charles H. Hedgepeth, Officer in Charge, told me the story of the development of the unit. Until 1912, the U.S. Navy had no record of sending a diver farther down than ten fathoms. But that year, a research program, under the direction of chief gunner George Stillson, was begun to verify the safety of the diving tables which Professor Haldane had published five years earlier in Great Britain, and also to improve Navy diving suits and helmets so that deeper dives would be possible.

For three years, Stillson directed systematic tests in water-filled reservoirs and at sea, off Long Island, from U.S.S. *Walke*. Thanks to which, in 1915, when the submarine U.S.S. *F-4* was lost off Honolulu, the Navy divers were able to go down and work at 305 feet—a feat which probably presents an absolute record for a successful salvage operation with air-breathing divers.

A Navy diving school was established in Newport, Rhode Island (it published a first diving manual), and in the 1920's, two new accidents were to demonstrate tragically the necessity of perfecting divers' equipment to increase the depth at which rescue operations could be carried out.

On September 25, 1925, off Block Island, the steamer *City of Rome* rammed the submarine U.S.S. *S-51*, which sank immediately to 132 feet. The salvage ship *Falcon*, on the scene shortly afterward, established that the S-51 was flooded when it reached bottom. Thirty-four men were dead.

Then on December 17, 1927, the destroyer *Paulding* rammed the submarine U.S.S. *S-4* in stormy seas off Cape Cod. Twenty-two hours later, *Falcon* arrived on the scene and a diver went down along the cable of a signal buoy released by the submarine. He knocked three times on the hull. At once, three knocks came from the interior of the submarine as a clear answer to his signal. He knocked again and again came the answer. The diver went up with the good news: "They are alive and they are many, the hammer blows came from several compartments." This time they would be saved.

However, although signals from the submarine were received for several days, in the stormy weather the divers were unable to connect a compressed air hose to the coupling provided for this purpose on the exterior of the *S-4*, and almost perished in the attempt. Finally, on the 21st, as the storm abated, a diver succeeded in attaching the air hose. The compressors started, but it was too late; the men in the *S-4* were all dead. On December 24 the order came to abandon all rescue work.

Perhaps they could have been saved . . . perhaps with more trained divers or a calmer sea. In the spring *Falcon* returned to the scene of the shipwreck. It took two and a half months of work to bring the submarine back to the surface. That year, there were in the U.S. Navy twenty-four

divers, all told, qualified to work at 100 feet. The Navy immediately embarked on a twofold research program: improvement of rescue systems for captive submariners; improvement of deep-diving systems and techniques.

During the 1920's, a number of U.S. Navy divers received unexplained poor ratings. When sent to dive deep, between 200 and 260 feet, they were behaving in a very questionable manner. They did not seem to understand the simplest orders, and did their work completely backward. Their promotion suffered; rated as "unstable" by their superiors, these men who until then had seemed worthy of confidence soon found themselves in the hands of psychiatrists.

However, the divers themselves noticed that this epidemic of "instability," this obscuring of their common sense, appeared only in depth, and their superiors too, at long last, understood that the responsible agent was the air breathed under pressure, not the unfortunate divers.

In 1924, the Bureau of Ships, which at that time was called Bureau of Construction and Repair, joined with the Bureau of Mines to study the effects under pressure of various gas mixtures capable of replacing compressed air.

In Pittsburgh, Pennsylvania, the first experiments on animals in exotic gas mixtures yielded the greatest hopes. Rats, guinea pigs, goats, when subjected to pressures of seven, ten and thirteen atmospheres, remained alert and awake, they ate and played normally instead of falling into a lethargy as they had done when they were subjected to the same pressures in a medium of compressed air. The same dry experiments on men, compressed for very short periods (a few minutes), confirmed these results.

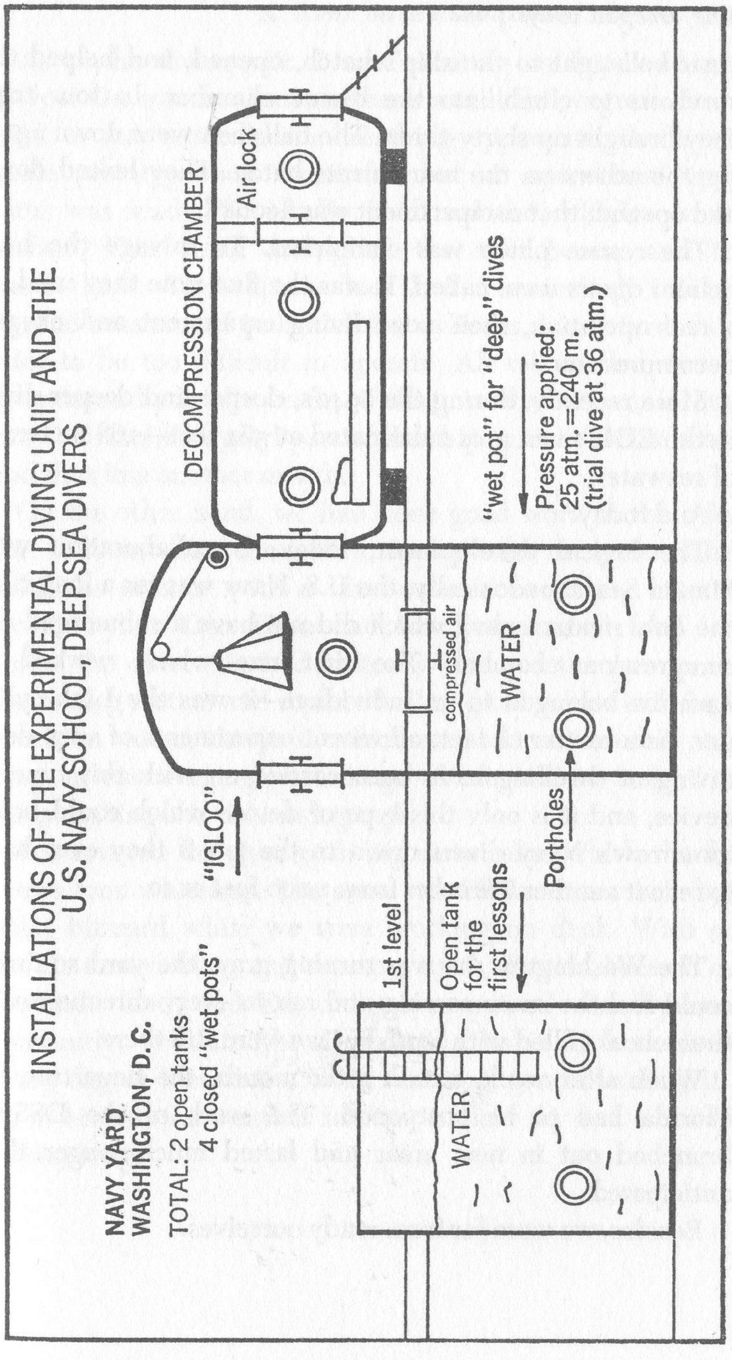
In 1927, in order to continue these investigations, to develop new equipment and new techniques, the Experimental Diving Unit was transferred to Washington, in the Navy Yard where it still operates today. The U.S. Naval School, Deep Sea Divers, was installed under the same roof.

The EDU facilities were at the time unique: two "wet pots" or pneumatic tanks which can be pressurized up to 25 atmospheres (test pressure 35 atm) or a simulated depth of 800 feet; each of these tanks, installed on the ground floor, is in direct communication with a decompression chamber (with lock) on the first floor, via a circular chamber called "igloo." The decompression chambers can also serve as caissons for experimental diving (see sketch). Here the U.S. Navy Decompression Tables which are now the Bible of several hundred thousand skin divers were developed and painstakingly checked. Here also were developed the helium diving decompression tables which enable a few, a very few, American commercial divers to go and work down to 300 and 400 feet for very short intervals, for the offshore oil industry.

Parallel with the development of the art of air and helium diving, the Navy built different rescue apparatus designed to give captive submariners a chance to escape without waiting for the problematic arrival of a rescue ship.

On May 23, 1939, during her trial sortie, a submarine of the very latest model, *Squalus,* went to the bottom in the North Atlantic. It settled nicely, 240 feet deep on a flat, sandy bottom off the Isle of Shoals.

The next day, the *Falcon,* veteran of the 1925 and 1927 disasters, arrived on the scene with a new piece of equipment: the MacCann Submarine Rescue Chamber. As they had rehearsed it twenty times in the waters of the Anacostia River, two crewmen winched the bell down to the fore turret, along a special cable released by the sub. They bolted



their bell tight to the ship's hatch, opened, and helped the survivors to climb into the rescue chamber. In four trips they brought up thirty-three. The bell then went down again for the others on the rear turrets hatch. They bolted down and opened; that compartment was flooded. . . .

The rescue phase was completed. To salvage the hull, helium divers were called. It was the first time they used, in a real operation, their new diving equipment and oxygen decompression.

More recently, during the 1940's, deeper and deeper dives in the EDU's wet pots culminated at 561 feet—168 meters—of seawater. . . .

And today?

The logical development, today, is collaboration with Man in Sea. Paradoxically, the U.S. Navy was for a long time the only modern navy which did not have a submerged decompression chamber. The first one which worked in America belonged to an individual—it was the Link cylinder. As a matter of fact, all recent experiments of very deep diving or dwelling have been carried on with this type of device, and it is only this type of device which could bring tomorrow's Navy divers down to the job if they ever have to refloat another *Thresher* from 1,000 feet or so.

The Washington sky was turning gray, the yard squirrels could feel the snow coming and ran in every direction with their cheeks filled with food, but we were still there.

Week after week, month after month, the departure for Florida had to be postponed. The work of the DSSRG branched out in new areas and lasted much longer than anticipated.

Besides, we were far from ready ourselves.

As to the diving suit, I was awaiting an improved prototype. On communications there was little progress. In regard to our recirculation breathing apparatus: the homemade prototype was successful, but no operational apparatus was ready. To handle Spid and the cylinder on the surface, Dan Eden multiplied the side booms and the check lines. The captain had had a swiveling U-frame portico constructed to launch the cylinder, but it turned out later to be too difficult to operate. All we needed was an articulated hydraulic crane. Unfortunately, we would have had to demolish a good part of the ship to install it on board, and thus lose another month.

On the other hand, we had done good work in the cylinder. Remembering the walls dripping with ice water, I had lined the interior with a vinyl-covered insulating layer of woven nylon. Dan Eden had installed a small food lock across the cover. He had radically changed the pumps and the mixing system and replaced all original valves with high-precision valves, thanks to which we had succeeded in stopping an encouraging percentage of our helium leaks from the plumbing and the mixing tank.

Ice covered the river with big dirty cakes which the first snows soon whitened. The snow was blown in our face by a polar blizzard while we were working on deck. With our cheeks turned blue, and running noses, Florida became our promised land, and Ed, obliged to put off the departure constantly, got into the aggravating habit of announcing every day at breakfast: "Good morning, good morning, it is 79 in Miami; the weather forecast is clear sky and a hot sun all day long."

8.

DRY RUNS IN FLORIDA

ON January 11, 1964, *Sea Diver* cast off under a whitish sun. The cold was bitterly biting our ears but the clear weather continued during the entire descent of the Potomac.

The following night a severe frost covered the river with two inches of ice, and a snowstorm dumped a foot and a half of thick flakes.

At its southern extremity, Florida ends in a long chain of small, flat coral islands, covered with mangroves. They are the Florida Keys, which stretch over more than a hundred miles of green sea. Today, a long highway bridge connects them with the mainland.

At the most meridional point in Key West, the U.S. Navy maintains an air base, an important radar station, whose big round ears point toward Cuba, and a submarine base where *Sea Diver* went to take its berth on the 23rd after a detour to the Bahamas.

Florida kept its promises: postcard palm trees, warm white sand, sun and crystal-clear water. My first thought of course was to head toward the reefs. What a fairyland! A splendor of tropical fish, coral forests, legions of lobsters, ballets of silver-armored tarpons around the divers, and galleon wrecks with pieces of eight. (Yes! Real ones.) *Grands dieux*, how beautiful it all was!

In Key West, three recruits came to join our team: Clayton Link, Ed's younger son, Dr. Joseph McInnis, and Edward Wardwell.

Clayton, a fun-loving, hard-working fellow, is the most pleasant of companions and a remarkable diver. Just graduated from college, he had come to lend us a hand before serving in the Navy. Joe McInnis, M.D., the Canadian lumberjack type, was thirty years old, a swimming champion and an excellent underwater cinematographer. Professionally, he has specialized for several years in diving medicine, he has worked also in the Department of Pharmacology of the University of Pennsylvania under Professor Christian Lambertsen, who is an authority on hyperbaric physiology. Our Man in Sea project owes much to Professor Lambertsen.

Joe brought news about our white mice which left me astounded. I had gotten acquainted with them on my arrival in Washington, when they were living in tagged canary cages or aquaria in the aft laboratory of *Sea Diver*. One could read their records: 13 hours at 1,400 feet (420 meters), 2 hours at 2,000 feet, 8 hours at 2,000 feet, 1 hour at 3,000 feet, etc., together with the date of the simulated dives through which Ed Link and Dr. Joan H. Membery had made them go. They were all bursting with good health, and yet, when Ed had compressed in oxyhelium the first mice, bought in a Washington pet shop, many had predicted that they would die at about 2,000 feet. With Mrs. Link I had moved the whole caboodle of diving mice and their small experimental

caisson (a cylinder 36 x 18 centimeters, tested at 2,800 psi) to the University of Pennsylvania at Philadelphia, where the same animals, Joe McInnis told me, had been compressed four hours long at 4,000 feet in an oxygen-helium mixture (O_2 21 percent surface equivalent).

Four thousand feet! That is 1,200 meters of depth; that is 121 atmospheres. And the mice ate, digested and moved about normally. They quivered a bit in walking, and some of them closed their eyes, but 48 mice, in small successive groups, had survived this pressure without any damage (three mice died in a technical accident, not connected with the experiment itself), and at last report, their offspring too were in the best of health. It was bewildering. Where, then, was this fatal threshold which was thought to be somewhere around 100 atmospheres, or 3,000 feet, and which mammals were supposed not to be able to cross without serious damage to their bones and tissues? And, would man . . . perhaps . . . someday?

Joe brought along something else, the prototype of the first high-pressure analyzer ever constructed, which the EDU had tested for us with complete success. Up to now, the existing gas analyzers worked on gas samples taken to the surface, at atmospheric pressure, from the circuit of a chamber or a diving bell. The little stainless-steel cylinder with two dials on one side and a big round screw on the other, which Joe brought us swathed in cotton like a newborn baby, was going to give us, on the bottom, a continuous direct reading of the percentages of oxygen and carbon dioxide present in the cylinder or the tent. We could even transport it in the water. This time, our autonomy on the bottom was complete. Incidentally, the price of this new instrument, the Beckman analyzer, specially constructed for us in California, and which wasn't any bigger than a coffeepot, was very difficult to believe. Out of curiosity, I tried the weight of the object: sure enough, I had guessed right—this thing had cost more than its weight in gold.

But the most important thing that Joe brought us was his own self, for Joe is one of those doctors who instill much more confidence in their patients and their entourage, with the radiance of their own personality, than modern medicine justifies.

The third recruit, Lt. Commander Edward Wardwell, had been given the job to relieve the Captain of all administrative responsibilities, bookkeeping and planning. Edward is an engineer and a former submarine officer. He was on the nuclear submarine *Skate* during her trip under the Pole. His experience and technical knowledge were going to be invaluable to us.

With the Villefranche veterans—chief engineer Daniel Eden and the faithful chief cook Jannis Margettis—and four new crew members, our topside manpower was complete. Only one very important person was still lacking—my companion for the dive. And come to think of it, where were we finally going to do this dive?

"Well," said Link, "you know I have been thinking of Bermuda. But when touching there on my return from Europe, I studied the bottoms and found out that the area would not do at all. The Bermudas are the emerged summits of a gigantic chain of volcanic underwater mountains. There are practically no depths of 400 feet, no flats at any rate. The bottom drops vertically, from the coral plateaus straight to the abysses."

Well, then, Ed, where?

"Next week I am leaving to reconnoiter the "Tongue of

the Ocean" with an echo sounder. You know, it is this kind of an underwater fjord which penetrates deeply into the Great Bahama Bank. There we should have all kinds of depths, and, above all, be completely sheltered from rough weather. The only thing I fear, from studying the maps, is that the slopes may also be too abrupt."

They were indeed. When Ed returned from his three-day prospecting cruise, he had decided on a slope south of the North Bahama Channel. West of the Berry Islands, he had detected on his sounders the very depths which we needed with a reasonably flat bottom and a fair shelter from the islands.

In Key West Harbor, Joe supervised from topside our first night under the sea. Clayton and I had furnished and equipped the tent, which had been sitting for a month on the bottom. Long before we settled in it, all the fish in the port had settled themselves around it, and Bates Littlehales, the charming photographer of the *National Geographic Magazine* who fed them sausage, was keeping permanent watch to prevent Jannis, the cook, from using these "extras" as material for a fish fry.

The first days, a very stubborn remora had even been taken; it had patiently waited for this fat black shiny whaleshark to finally go ahunting.

The first night under water was very calm—a good dinner, good wine, good coffee, a good rest. The only noises were the thousand little cracklings of the barnacles which covered Spid, and the long beep-beep of the sonars when a ship was leaving port.

Weighing up the experiment showed an ineffective carbon-dioxide scrubber, short circuits everywhere, a slippery floor and so forth, but also sufficient comfort, pleasant temperature, and a complete peace of mind.

Nevertheless, it was an incident that took place several days later which was the most significant to us. One quiet Saturday, Dan Eden looked me up in my home. For some unknown reason, he told me, big clusters of bubbles had been rising from Spid since morning. I dived to discover the interior strewn with glass splinters, and realized what had happened: we had forgotten in the tent a tightly corked, half-full bottle of milk. Fermentation of the milk had caused it to explode, and three sharp pieces had pierced the rubber through and through. I made immediate repairs, but the incident was enough to make up our minds to get rid of that tent, and Ed immediately ordered a new neoprene bag, a quarter of an inch thick, internally reinforced with four layers of nylon fabric. This time, my dwelling would be as strong as a heavy-duty truck tire.

The course of events proved us right. During the second series of trial tests at Looe Key, Spid, which was bobbing in the waves on the surface, suddenly exploded like a child's balloon which has touched a cigarette. A *psschtt* and no more tent, only the nylon line stretching, becoming thinner and vibrating like a guitar string, and *Sea Diver* taking a heavy list on starboard. Just then, there was nobody inside. The Captain had gone out, I had not gone in yet. The descent would have been a rough one. . . .

The only thing left to do was to recover the frame and the ballast tray, which we had to empty first, bucket by bucket, all day long.

The cylinder had transformed itself into an autonomous unit. Appendages projected all over it, inside, outside, on top, underneath and all around. They were gas tanks, pressure reducing regulators, a scrubber, hookah pumps, external searchlights, pivots, spare batteries, and so on. Almost every day, Dan bored another hole in it and added a tap or a switch. To make more room inside, I removed hatch C which had become superfluous now, since we were going to use a multiplace deck decompression chamber.

The final device that was to complete the system was the portable, inflatable, rubber underwater-workshop-diving-bell which we used to call the "igloo." It had been loaded in Washington, in separate pieces, and there is its great advantage: instead of taking as much space on board as an adult elephant, the igloo can be dismantled when not in use into eight pieces (that make up the circular ballast tray) and a big, flat sack, all quite lightweight and easy to put away.

It required a day's work to assemble the pieces—it was the first time; with practice we could do it in two hours—and then another whole day to lug the lead ingots and raise and lower the igloo to find the optimum ballast weight. Thereupon, Ed and I, still dripping, found ourselves walking dry, in an inky blackness, on the mud and heaps of debris which litter the bottom of the port. When I switched on my flashlight, we were ready to work, ready to weld two pieces of pipeline together, or to repair a damaged telegraph cable maybe, or the head of an oil well. Tomorrow, in dry surroundings, under igloos similar to ours, it will be the hands of aquanaut workers which will do the actual work, but thanks to TV, the eye of the specialists will be watching them from topside, and the brain of the engineers through the intercom will direct each phase of the operation.

I have retained other memories from these months spent baking under the sun in Key West: the cormorant that swooped around me 30 feet down in the green water, fascinated by my bubbles; my comic efforts to get into the isothermic suits which arrived one by one from the factory, and especially to get out of them without tearing both ears off. The first one was too small, the second too big, the third one too small on top and too big on the bottom, but the neck was invariably too narrow for my head. It wasn't the manufacturer's fault; the material was too stiff. Above all, I remember the day I had just laid down on the dock 400 feet of air hose, then looked back—*sacredieu,* how long 400 feet are!

The multiplace deck decompression chamber and the new Spid (puncture proof but, alas, smaller than the first one) were awaiting us in Miami, where *Sea Diver* was to go in dry dock. Two teams of sandblasters were taking the hull in cross fire amid the hubbub of the compressors and the deck was invaded by electricians, mechanics, welders, painters, and carpenters. After dinner, executive officer Ed Wardwell would pin up, from one corner of the lounge to the other, the heavy folios of his daily program, for a general discussion—like a housewife putting her bedsheets out to dry.

At eight o'clock, he pushed everybody into the lounge, pounded the table with his fist, and waved the first banner. "All right," he said, "tonight we'll be brief." ("Whew," everyone muttered, "yesterday we were still discussing at midnight.")

"We'll start off with the deck chamber: Dan?"

"Well," said Dan, "the chamber itself will be ready for the pressure tests in three days—this valve was missing, that gauge had to be changed, such and such queer joint was lost,

Wardwell took notes to place orders—but the mating with the cylinder will take at least eight days." The connecting clamp was the big item.

Link interrupted. "Yes, and then the cradle must be aligned better. The sliding blocks ought to be raised a third of an inch."

"How about the control panel?"

"Ready there," Joe answered. "Everything O.K. but the mixing unit is not."

The duration of the job was estimated as best as one could. They argued firmly; time went by. Then, on to the next item: "The cylinder?"

"Ready, except the batteries for the analyzer." It was Dan again. "The hoses withstood the hydrostatic test at 25 atmospheres. Still have to go through the helium test though."

"Good, how about the Spid, Robert?"

"Well, I have applied the first three coats inside, but I am waiting for a reply from the manufacturers before putting on the white one. According to instructions, the paint may be toxic. I don't dare use it without their go-ahead. I will get an answer tomorrow. Otherwise, the port windows are ready to screw on, and the suspension eyes are fixed. The retaining net? Yes, finished. Tested? Yes, yes, it works."

"And the divers' equipment?" Edward asked, taking a side step toward the next folio.

"The last suits received will do," I said. "Finally I had to have it cut out with a separate hood, and a Velcro fastener in front. Otherwise there is no way to push the head through. I have tried out the whole outfit—it works. As for the recirculating hookah, it works very well, but I still have to try it out under 13 atmospheres before passing judgment. At any rate, I will make a homemade ordinary hookah with my own single hose regulator and 50 feet of hose to have a spare on the bottom."

"Gas analysis, Jim?"

Dr. James Dickson, the last to arrive of the newcomers, was the very likable boss of Joe McInnis. Taking off his glasses, he replied, "Everything is under control. We will be ready before the chamber is."

"Perfect, and what have you decided on the physiology side for the last dry dives?"

Jim cleared his throat, summarized the tentative program agreed upon; then requested a modification. The Captain disputed, Joe expressed delicate shades of thought, I inclined toward other views, Dan offered alternatives, Edward arbitrated, and the evening session dragged on.

Having finally reached agreement on a compromise, we passed on to logistical support. "Look," said Wardwell, taking out of his file a letter with an official heading, "I have excellent news. The net tender *Nahant* will be at our disposal for as long as we want her. She is an antisubmarine net layer. In fact, it is almost an ASR without a McCann bell and without helium diver. They will locate for us the most favorable spot with their echo sounder. They will lay anchors and buoys for our four points mooring, and all we will have to do is enter it. Moreover, they will carry on board the 168 bottles of helium which the Key West base allows us."

"A hundred and sixty-eight," Jim calculated rapidly, "that is . . . an ample safety margin. So much the better; we won't go through the suspense of Villefranche again."

"Well, how about communication and TV?"

Nobody replied. Link had reason to believe that General

Precision Co. was ready to supply the underwater TV. Hadn't they confirmed it? No. "Well." Wardwell made a note. "We'll go after them."

"And where will we put it?" There was a very long discussion—Ed would ask for supplementary specifications —and little by little, we arrived at the various electrical circuits. Here the discussion became very technical. I had no opinion; I was the only one. I looked at my watch: it was 11:10.

The next to the last sheet: putting the cylinder into the water and taking it back on board. This was mainly a discussion between Dan, Wardwell and Ed, based on little sketches and matchstick booms. Our lateral booms were all ready. Wardwell made a note to purchase so many single, double and triple pulleys, nylon lines and slings and chain lengths. "Oh," we sighed in chorus, "if only we had a hydraulic crane."

And so we came to the last sheet in the far corner of the lounge—to the critical point, to the always reopened discussion: how to launch and then fish up again the inflated Spid and the cylinder in 400 feet of water with their hoses, their cables, their wires, their safety lines and their chain—without entangling everything right away, or flooding the inside of the tent. As on every previous night, I waved my drawn-to-scale sketches and step-by-step handling plans. Everyone deftly reverted to his own point of view, unchanged since yesterday. Theories supported with a heavy fire of contradictory examples clashed. Sometimes we argued in circles a bit. In the heat of the discussion it happened that one or another forgot his position and suddenly found himself in the opposite camp. It would go on like that until half past eleven and then the Captain would rise. "Well, well, we'll decide about that later. It is time to go to bed now. We have a long day tomorrow." That at least was undeniable.

Finally the Captain had his way as always and everything went along smoothly.

I was still left with one serious problem—the choice of a companion diver. For I had to admit this time that I needed one. The internal equipment was much too heavy for one man, and, besides, the final objective was to send to the bottom a team of workers who could relieve one another around the clock if need be.

The problem in this case was one of human relations between two men sharing a small living space under difficult circumstances and in continual proximity. Similar conditions, aggravated by discomfort, are found on small yachts, and it is a well-known fact that ill feelings on board have wrecked more cruises than have the reefs. . . . I had suggested a Belgian cave diver, Marc Jasinski, a friend of many years of whom I was sure. Link finally decided in favor of Jon Lindbergh—one of the sons of Colonel Charles Lindbergh, hero of the first transatlantic flight in 1927—a former cave diver himself, ex-UDT and one of the top commercial divers in the world. He is one of the very few along with his associate Dan Wilson and the other divers of Offshore Divers, Inc., of Santa Barbara, California, to go and work from the West Coast offshore oil rigs in a routine manner between 230 feet and 400 feet, a depth where they made dozens of dives, each lasting about twenty minutes.

The morning of Jon's arrival, we began a series of dry dives in the cylinder on deck, and I knew right away that Ed could not have made a better choice than this big, dark, smiling lad, thoughtful, very calm, and a perfect gentleman.

Sea Diver, refurbished and spick and span, was floating again on the Miami River. At night one could sometimes hear the bellowing sound of a manatee which came to the surface to breathe alongside the ship; during the day, we could see turtles swimming downstream, their heads up like periscopes. And the tourist boats, going up the river every two hours, loaded to the gunnels with kodaks and pink straw hats, had officially scheduled us in the grand tour of the local sights, which entitled us to the detailed comments of the old guide, between the construction price of the Dupont Plaza Hotel (in millions of dollars) and the number of stories of the Municipal Jail (the tallest jail in the world).

I had my share of the bends the night before we left, after a simulated dive to 400 feet. It was a stupid accident caused by extreme heat and poor ventilation. To check on the behavior of certain pieces of equipment, Jon and I had to make a detailed dry run in the chamber under 13 atmospheres of oxyhelium.

All morning long, under a burning sun, I had worked in the cylinder to connect up all the equipment to be tested. We had been forced to take off its white awning to have access from outside to God knows what connection. When I touched the aluminum, it burned my fingers. The interior was a Turkish bath; we wallowed in the perspiration which poured in rivulets from our bodies.

At eleven o'clock, when Jon had locked hatch B behind us, the doctors raised the pressure. At first, one atmosphere of oxygen and then eleven of helium, very fast, as fast as the gas would get in, so that the stay be short and decompression brief also. I had a thermometer under my eyes. I saw the needle start almost immediately. From 86°, the outside temperature, it veered regularly toward 120°. I was gasping; sitting in front of the gas inlet I was receiving blasts of fire right in the face. Very soon the needle hit 120°. I had stopped perspiring. I felt my brain was melting. At every breath I could feel new waves of flames penetrating the recesses of my lungs. What I was breathing was unmixed helium, no oxygen. My legs were wobbly. I decided to ask topside to slow down the compression. But, what the hell, we were almost at 400. Now, we were there. The reverberations of outside voices came to us as in a dream from some other world. With trembling hands, point by point I completed the program agreed upon: test of the pumps and the hookah with the X valves, then with Y valves; comparison and notes in a soaked notebook, inflating of the suits, switching scrubbers on and off. Then I made a sign to Jon, and he relayed the Morse dash dot, dash dot—"All equipment checked, ready to decompress."

As soon as the temperature decreased with decompression, I felt alive again. Thirty seconds, and a few degrees later, I was in top shape, but I had taken my pulse at the worst time: 120 per minute. That, I said to myself, is very bad; my blood must have carried dissolved gas twice as fast as normal, and spread twice the amount all through my body. Before crawling from the cylinder into the deck chamber, I told topside and we consequently prolonged the last decompression stops on pure oxygen. It was insufficient.

I went out without mishap, in the late afternoon. But that evening between nine and ten o'clock, an acute pain flared up inside my right ankle. When it died down, I went to bed, perplexed. A mistake. At four in the morning, a fierce pain

woke me up which now burned the leg from knee to ankle and I had to wake up Jim Dickson, the Captain and Dan to have it treated in the deck chamber.

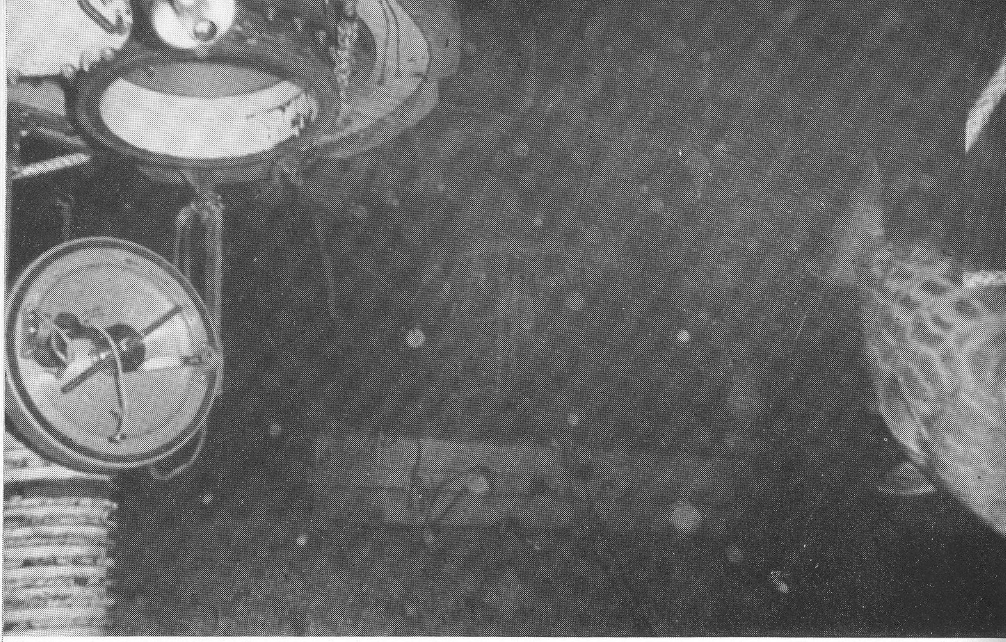
It was quite annoying, since that accident could make the outcome of our saturation dive questionable. If I ran into decompression trouble now, we would never be able to say with certainty whether it was merely the usual recurrence of that first accident or whether it was the fault of the desaturation schedule itself. Fortunately Jon, who was in the far end of the cylinder, in the back where he had not suffered from the heat so much, would be the standard of measurement.

Filled by now with its oxyhelium mixture, it floats alongside *Sea Diver*.

When the ballast tray is loaded with lead ingots, Spid will sink to the bottom.

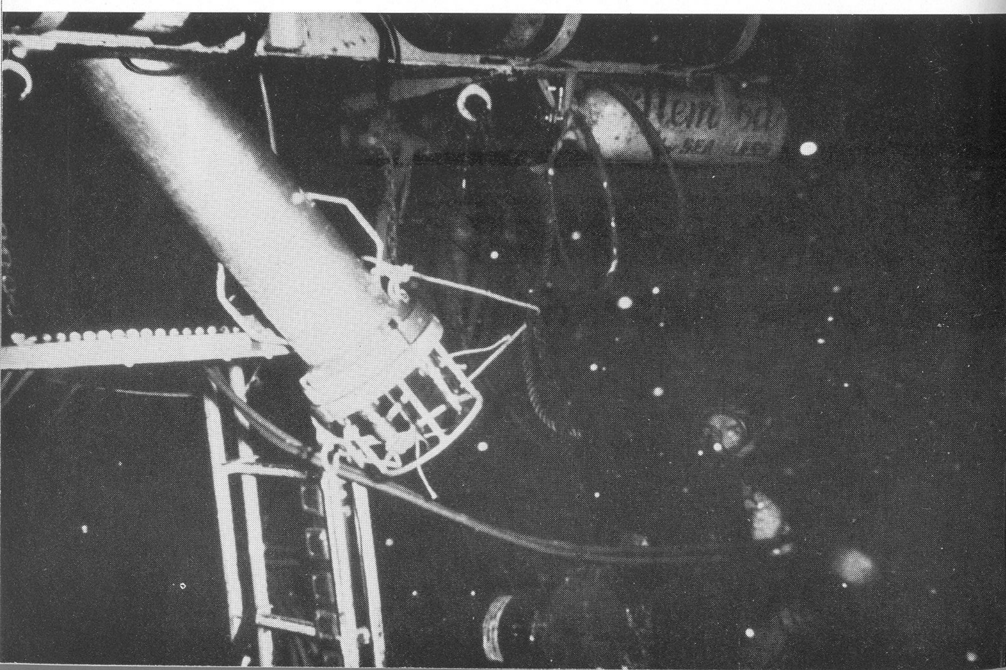
My companion for the "big dive" will be Jon Lindbergh, a remarkable diver and a perfect gentleman. Here he gets the feel of the cylinder hatches.

Last rehearsal. We spend 5 hours at 70 feet in the crystal-clear Bahamas waters; everything works as planned.

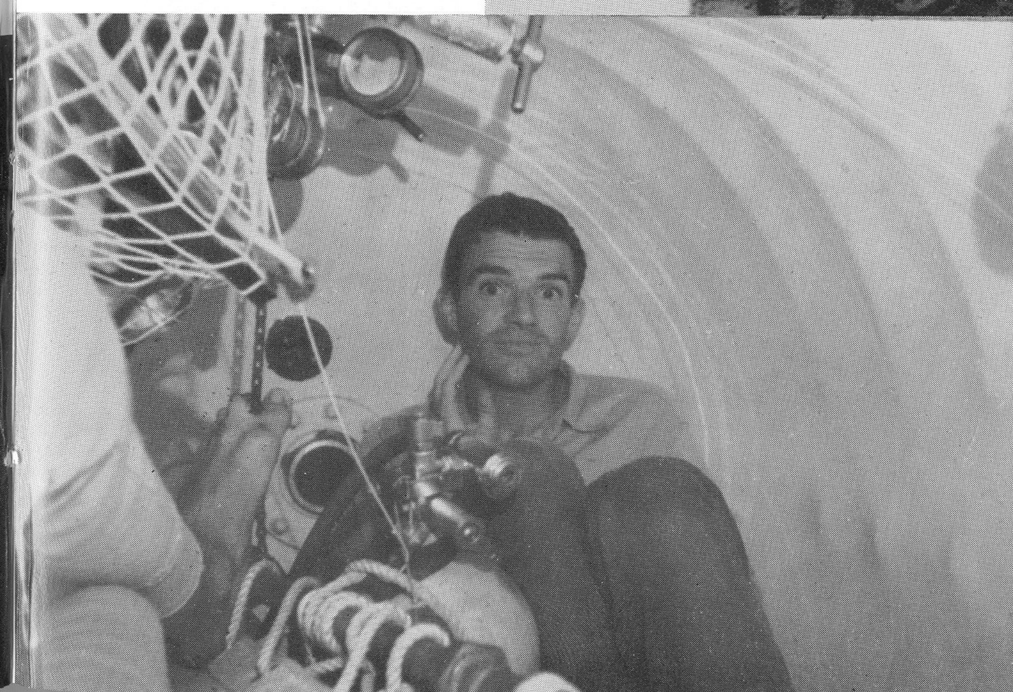


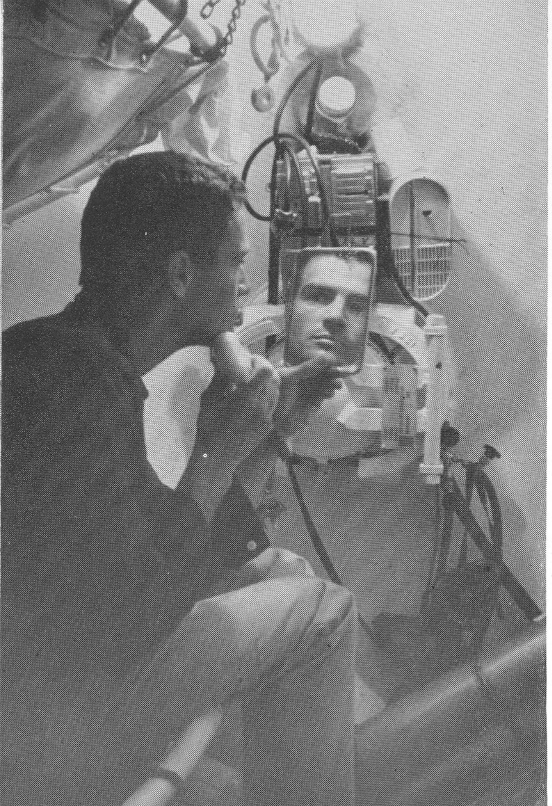
432 feet under the waves. These are the deepest pictures ever made by a diver. The cylinder has taken us down to our home. Huge groupers fraternize with the visitors.

But they stir up the sand, bump clumsily against our legs and cloud up the water as I try to photograph Jon.



Every day, after working 3 or 4 hours in the water, we return home to find dinner, comfort, warmth and safety.



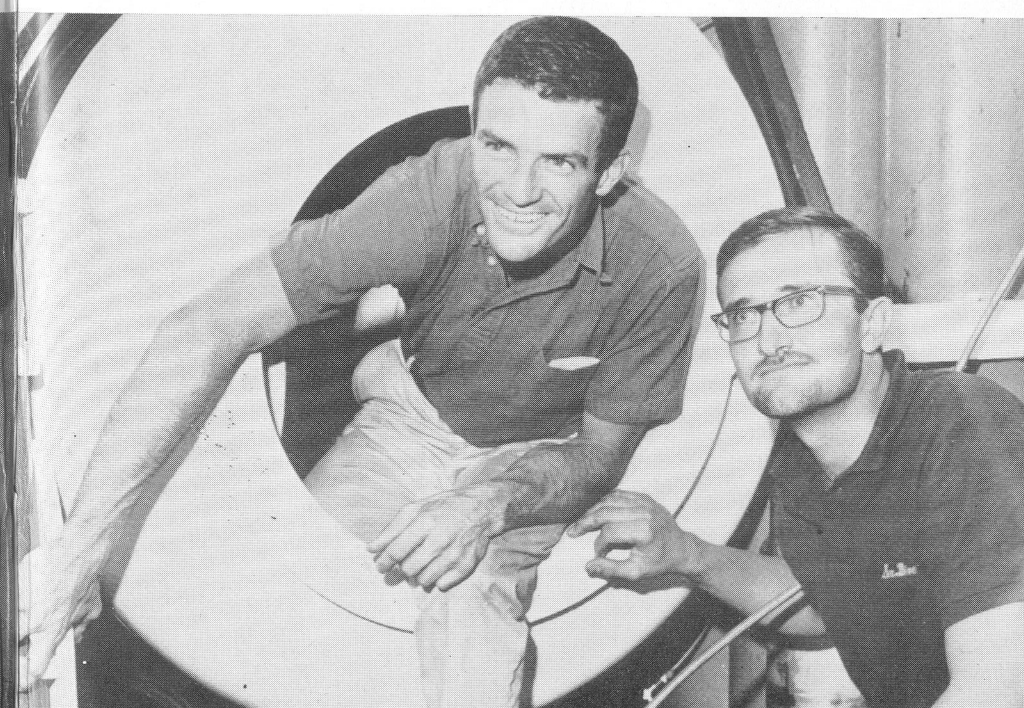


Back on deck, with 96 hours of decompression ahead in the roomy deck chamber, Jon returns to civilized practices.

Dr. Joseph McInnis checks on our pulmonary functions as we breathe pure oxygen to hasten the elimination of dissolved helium from our tissues.

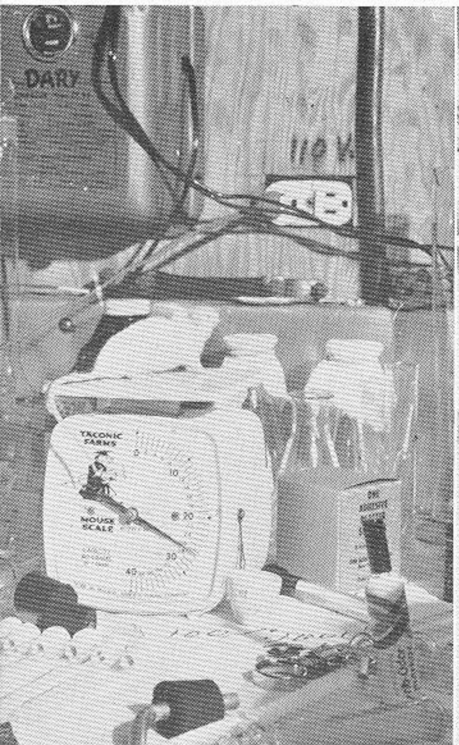
Night and day, our medical team monitors our breathing mixtures and allows our internal pressure to rise progressively.

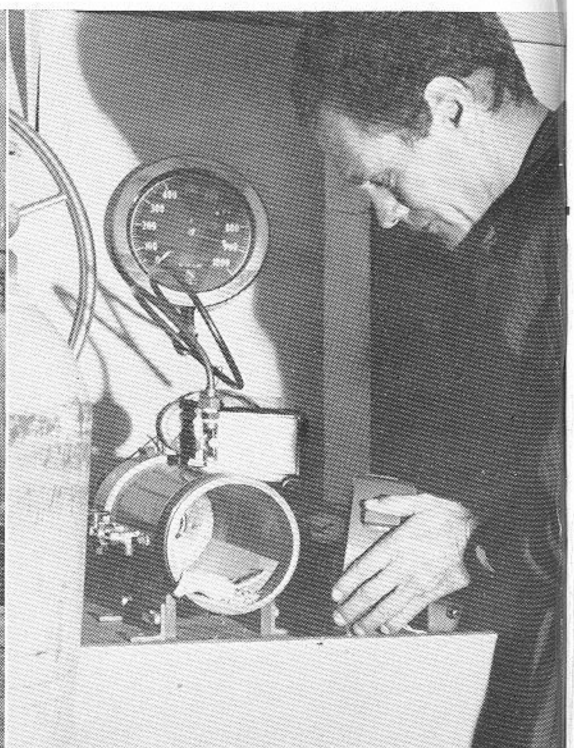
The deepest, longest dive ever made is over. For the first time in a week, we are going to breathe God's fresh air again. This success actually opens to human colonization the greater part of the world's continental shelf.



These white mice, petted by the Links, have lived in a pressure chamber at the incredible depth of 4,000 feet. After being saturated by the oxyhelium mixture they were breathing, they were safely decompressed. Ed Link has started this series of experiments which were reputed impossible.

One cannot of course extrapolate such results from a mouse to a mammal the size of a man, but still, could not one ask oneself, if one day, divers . . . possibly . . . ?





9.

THE DEEPEST DAYS

HANDKERCHIEFS fluttered good-byes on the evening of June 15. *Sea Diver* made her way eastward across the incredibly blue ribbon of the Gulf Stream, moored in front of Bimini where Wardwell went in the outboard to attend to custom matters, and headed for the Berry Islands, at the northeast tip of the Great Bahama Bank.

Quite pleasant, these bare islands, hardly inhabited, with their blue horizons dotted with white schooners. Water was pure crystal where translucent jellyfish drifted like gelatin orchids, dragging their inoffensive pink filaments. The bottom swarmed with bewildering polychromatic fish, fearful mako sharks occasionally looked up at you and giant black rays would slowly fly by just below you.

Off Great Stirrup Cay, on the edge of North Providence Channel, the U.S. Net Tender *Nahant* caught up with us, on time for the rendezvous. Then our auxiliary boat, *Sea Hunter,* arrived (formerly *Sea Diver I,* it is the converted shrimp boat on which Ed and Marion had begun their underwater career). The *Widgeon,* Link's personal flying boat, was to join us later with a party of VIPs and civilian observers.

A normal day's work on board *Sea Diver* lasts ten hours. Now, the mechanics, engineers, electricians, doctors, divers and sailors were working fourteen hours a day and "Captain Link" sixteen hours, under a sun of molten lead. The dress rehearsal duly took place at a depth of 70 feet in the most limpid water I have ever seen. In five hours, Jon and I equipped the tent completely. Everything worked; we could not believe it. Topside, as on the bottom, every one of the complex phases of the operation developed perfectly.

At the same time, *Nahant* drew up for us on their echo sounder a detailed map of the 400-foot depths. All day long we could see its coleopterous silhouette come and go on the horizon. Small, big, small, big, small, big, while it methodically combed the depths with its ultrasonic beam.

At night, Lieutenant Leon Mills, Commander of *Nahant*, unfolded for us on the bridge the long rolls of electrolytic paper. It came out badly the first times: "You see," he said, "almost everywhere a regular slope falls at a 30° angle from 350 to 450 feet. I know that's too much to suit you. All I found is this plateau, which is somewhat flatter, but its maximum width is 150 feet only, and the length 600 feet."

"I'll buy that," said Ed. "Let's not be fussy; when we have to work on an oil well head, we won't choose our slope."

But the next day, the news was better. *Nahant* radioed: "All well: we have found another plateau 200 yards by 200. Gentle slope from 390 to 420 feet. It is beaconed, we will drop the four anchors as soon as you are ready."

Ready? But *sapristi!* We really were.

Sea Diver was going to moor fore and aft on the berth prepared for it, and Spid, fully inflated, its ballast tray loaded with watertight containers, slowly descended to the bottom,

preceded by a trio of pilot fish and followed by a barracuda which was playing with the bubbles.

Jon and I were too busy on the bottom to keep a diary, and too preoccupied living those precious moments. But by assembling my notes scribbled on the walls of the cylinder, on the roof of Spid or on a carton of flash bulbs, and the tape recording of the experiment, I have been able to put together a montage of the complete film of the longest and deepest dive ever made.

June 30 The sun, at the porthole over my bunk, wakes me up at seven o'clock. The weather is perfect, just enough breeze to make one realize he is in the tropics. On deck, Dan is already working. He has discovered new helium leaks, and is trying to fother them, while Jon and I foresightedly stuff ourselves with bacon, eggs and marmalade.

9 o'clock The cylinder has just gone overboard. It floats alongside almost entirely submerged in a calm sea, as blue as the sky. Clayton puts the analyzer batteries, which must remain vertical, in their watertight case. My flippers, my mask, my cameras, have been ready in a corner since yesterday. It's getting closer. One can feel it from something floating in the air, from a certain expression on the face of friends. Everybody is on deck, the observers, the sailors of *Nahant*, our *National Geographic* friends, looking through the viewfinder, and Jannis who wants us at all costs to have a final cup of coffee with chocolate biscuits. The television screen shows us very distinctly the bottom where the ballast tray has settled. No tiger shark in sight, only two or three tiny fish, the same ones as yesterday. Our control gauge is positive—the tent has not lost a single gram of pressure overnight. It is ready to welcome us; everything looks fine down there.

Ed shakes hands. "There, Robert, everything is ready this time. Good luck to both of you." We have another round of handshaking. My last sight of the surface will be that of Marion Link, very moved, waving us a last good-bye. Then we stick our heads in the tepid water. Jon undogs hatch A, which spits a flood of bubbles and swings outward wide open, and we climb one after the other into our elevator, which I lock tight behind me. We have just closed our door to the world—for a whole week we won't breathe God's fresh air again.

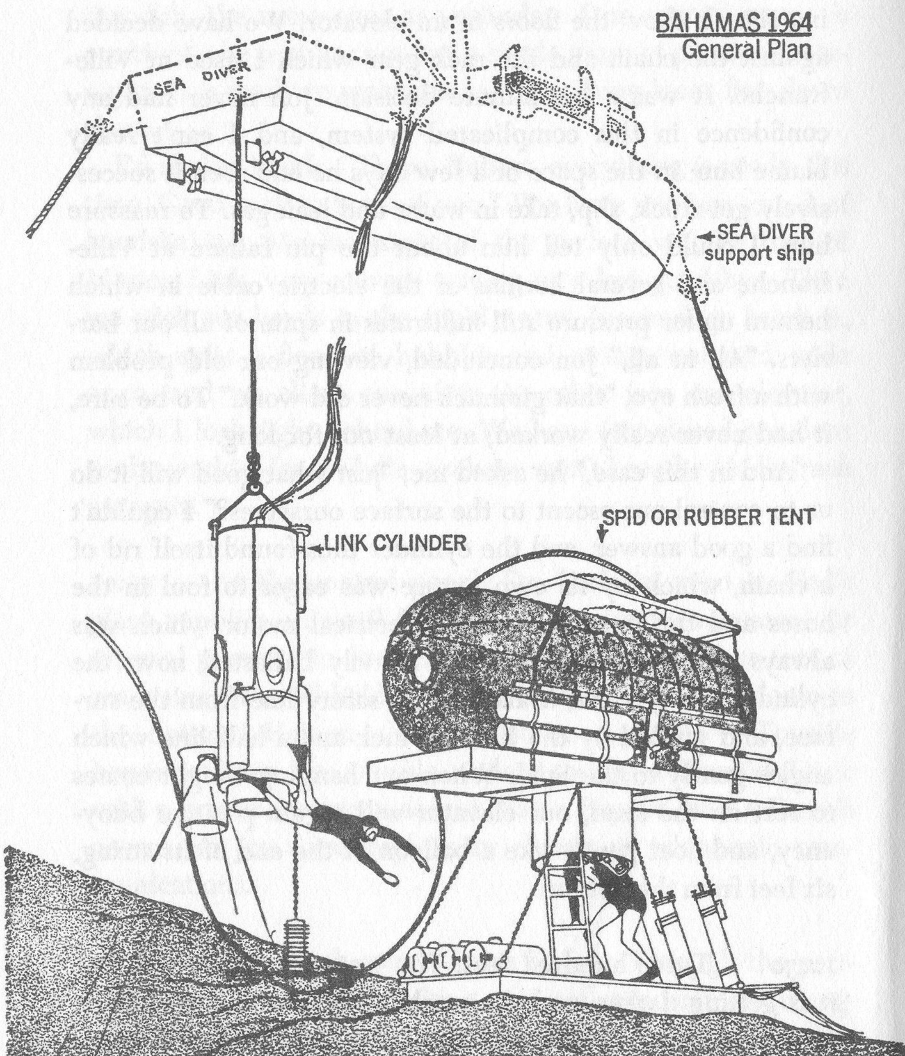
10:45 At the control panel, Dr. Dickson, who in God's place supplies air until further notice, slowly increases our internal pressure to five and a half atmospheres, 150 feet of sea water. We will hold to that pressure all the way down to the bottom. Helium already distorts our voices. Topside hopes to have less trouble understanding a Donald Duck with a proper American accent than a Popeye with a French accent, so Jon Lindbergh is in charge of telephonic communications.

11:50 The depth gauge shows 60 feet. Through the porthole, I can see a diver working on our electric cable. I recognize Ed at his regulator. From the first sketch to the last check, he insisted on supervising everything himself.

12:15 The cylinder descends so slowly that only the creeping depth indicator needle reveals it, just as the blinking signals show the floors in an elevator. We have decided against the chain and the rack gear which I used at Villefranche. It was a last-minute decision. Jon never had any confidence in this complicated system, and I can't really blame him; in the space of a few days he had seen it successively get stuck, slip, take in water and leak gas. To reassure him, I could only tell him about the pin failure at Villefranche and several hernias of the electric cable in which helium under pressure still infiltrates in spite of all our barriers. "All in all," Jon concluded, viewing our old problem with a fresh eye, "that gimmick never did work." To be sure, it had never really worked, at least not for long.

"And in this case," he asked me, "just what good will it do us to control our ascent to the surface ourselves?" I couldn't find a good answer, and the cylinder thus found itself rid of a chain, which by its own nature was eager to foul in the hoses and the lines, and of an electrical motor which was always asking for shorts. More heavily ballasted now, the cylinder slowly sinks, braked by its safety line from the surface, and guided by the braided inch-and-a-half line which angles gently to the Spid. When our hanging weight comes to rest on the sand, our elevator will regain positive buoyancy, and float gently like a balloon at the end of its string, six feet from the bottom.

12:30 Three hundred feet. The water is still limpid, but it is getting darker, and the washday blue of the surface is tainted with gray. Joe McInnis calls us: "Stopping circulation for a few minutes to take samples." Even though the cylinder is 100 percent autonomous, the doctors insist on verifying our gas mixture regularly with their surface instruments, more accurate than our Beckman.



"Oxygen: one ninety; CO_2 four point five." Jon, when reporting to Jim "Topside" Dickson, articulates as if talking into the ear trumpet of a deaf old gunner. Since our interior pressure is still only 150 feet, he gets his message across. Topside confirms a little later: "Oxygen here one eighty-eight, Co_2 four point seven. All's well on top, the weather remains fine."

12:34 "The Spid," Jon shouts victoriously into the mike. He saw it first. It seems to stand nicely on a grayish bottom, mottled with vague darker spots. It warms the heart, this view of a little house in a landscape more lunar than terrestrial.

12:40 I call surface: "Hold it, we are descending plumb on the tent. If we continue we will land smack on top of it. You'll have to slacken the nylon line to get us farther away from the tent."

And I watch the white rope unwind, slacken, and deposit its big, threaded biconical lead weight on the bottom, 20 feet from the tent. Our terminal is in place.

"O.K., resume lowering."

12:58 Good, the needle is on 400. But . . . are we still going down?

1300 "On the bottom." A big smile lights up Jon's face as he reports. The depth gauge at the top of the cylinder reads 415 feet. If I add 11 feet, the height of the cylinder, and 6 feet for the chain of the hanging ballast, that puts us at a depth of 432 feet. I must mentally convert feet into meters to fully realize the depth in which I find myself: 130 meters! *Diable*, the captain of the *Nahant* has been generous.

1315 Through the long "umbilical cord" which connects us with *Sea Diver* the doctors send us helium to increase the internal pressure gradually to 14 atmospheres. Once in equal pressure, we will be able to open our double door. The gas we now breathe is a cocktail of 4 percent oxygen, about 5½ percent residual nitrogen and 90.5 percent helium, which positively prevents us from producing any intelligible sound. Filled with the absurdity of the situation when scribbling messages to Jon on the vinyl lining, I begin to regret we didn't learn deaf and dumb sign language.

1330 The needle of the interior pressure gauge has slowly caught up with that of the depth gauge. They could hardly go any farther. Our diving suits are flattened and wrinkled like old parchment. I blow them up, piece by piece, from a small tank of compressed air. Up there, I had taken the precaution to open my camera housings, my light meter case and the diving flashlights. Now they are in equal pressure and I may close them again to take them in the water. I am glad I did, since our three spare electric bulbs have just exploded with a boom like thunder, spraying us with ground glass. I had tested, in the chamber, three of the "heavy-duty" type and they had held up perfectly, but I put them away so carefully in Miami that I was never able to find them afterward.

1345 Topside gives us the green light: "You may transfer to the tent whenever you wish." Jon secures the IN and OUT gas valves, and starts the CO_2 scrubber, which begins

its familiar purr. I undog hatch B, pull it upward and fasten it tightly. Dash-dot-dot-dot-dash-dash-dash Jon signals, B.O. —that means B open, then hatch A, which finally opens on a brown bottom of coarse sand. And Jon signals on the sending key: dot-dash, dash dash dash, "A open." I slide into the water from where I hear Jon's dash dot dot, dash dash dash, "Diver No. 1 out." The water feels cool, even at 72° F. Visibility is excellent, 150 feet maybe—I glance around, looking for the antipathetic fish which I have been told to expect. Nothing in sight. Three days ago, some sailors on the *Nahant* caught a 15-foot-long tiger shark on a butcher's hook baited with a 5-foot shark and it took the ship's boom to hoist it aboard, but, fortunately, that monster did not seem to have a twin brother.

Our spotlights pierce the gray water with two emerald beams, and awaken on the sand glimmering splashes of sleeping color. Seen in profile, the tent is leaning like the tower of Pisa; it is tilted at 25° on a bottom which slopes down as far as I can see, but it is perfectly habitable. It appears so tiny, my little black bubble in this immensity, that the old sailor's prayer comes to mind: "Oh Lord, thy sea is so big and my Spid is so small." It is hardly more than 20 feet away from the cylinder, so close that I decide not to use the rebreathers for our comings and goings. That is how I wanted it to be. Whatever happens, we will always get back to our elevator, even without flippers, mask or light. A diver who has come from the surface or even from an undersea house settled at 85 feet and who suddenly finds himself in difficulty at 350 feet is not very likely to make it back. But here we have our return ticket in our pocket.

A deep breath and let's go. Seen from below, the water surface inside the entry shaft of the Spid is a mirror of fluid silver. My head breaks through it as soon as I set foot on the ballast tray. Inside, the gas tastes like mountain-fresh air. I climb the ladder. Everything is in order. First operation: I must connect the Beckman analyzer to its watertight batteries. Good, the little black needles come alive and slowly take the position I expected; oxygen, 4 percent; carbon dioxide, 0.25 percent. All is well. I sit down on the side of the well from which a Blue Grotto light is rising. At last, I am here. Ten months of working like a beaver, delays, dogged effort, but now I am here. How calm this other world! How silent! How peaceful. . . .

Full of optimism, I have not put on my wet suit. The cold makes me shiver. Well, let's pull ourselves together, and act quickly.

1405 Fearing an inundation, we have taken a useless precaution by securing all our instruments, electrical connections and internal gear in watertight containers, attached to the ballast tray. So much the better. But now we must get them unpacked and connected as soon as possible. I swim back to the cylinder to get dressed; in sliding into my isothermic suit, I feel as if I were going into a hot bath. We both return to the tent; I pass the first container to Jon. He removes our central power station connected to the generators by its cable. It is an octopus of big, black wires with waterproof plugs, carefully labeled. First he makes contact with the surface: dash dot dot, dash dot dot—"Both divers in." On top, they congratulate us. Then he switches on the light. The light bulb glows. We look at each other, beaming. We won. It burns five seconds and goes out. We look at each other in consternation. Is the game up? Is it merely the bulb? If it's the current—that would be serious. To go on working, I

light a diver's hand lamp. Immediately, a noise like a gunshot splits our eardrums. The "sealed beam" bulb of the lamp had just imploded, spraying the other half of Spid with thousands of sharp fragments. Fortunately, I brought along six cheap flashlights from some discount store which were not waterproof, thus not affected by the pressure. I plug in the radiator. Let's see: Nothing? No, no heat at all. Without light, without heating, without warm food, things don't look terribly good.

1410 Standing in the narrow access well, with water up to my waist, I wrestle with a 5-foot-long aluminum cylinder. It houses a big cartridge of granulated barium hydroxide and the turbo-ventilator which will continually drive the surrounding gas through the compact crystals so they will combine with the carbon dioxide produced by our respiration. At last, I have got hold of it. Its top is out of the water, the sill leaning on the last bar of the ladder. I open the vent and wait for a *psst.* Nothing happens. Catastrophe! Jon makes a long face. That can mean only one thing. Yes indeed. I take off the cover: everything is flooded. The motor and ventilator are useless. A thick white paste, bloated with craters, spills over the container. Our situation is not exactly brilliant—that apparatus is vital to us.

I glance at the Beckman; the little needle already points to 12, twelve millimeters of mercury, that is 1½ of CO_2. Our minutes here are numbered. Let's fetch the spare filter quick. It is carefully tied up in a corner of the ballast tray. I cut ropes and more ropes of nylon, sisal, and cotton. This time the container is in ¼-inch sheet iron. It seems to weigh a ton, as I thrash around on the bottom trying to drag it behind me. "Containers made for human beings, not for a team of horses." That will be the first item on my list of necessary improvements. Jon hands me a line. He pulls and I push, I grasp, I lift, I pivot and I maneuver. I come back to the entrance well to breathe more and more often, more and more heavily. At last the monster is in place, but I am completely out of breath. Our disordered efforts have raised the level of carbon dioxide to 1.8 percent.

Now we discover that the cover has no pressure-equalizing valve. The surface crew has put on the wrong cover! I calculate rapidly: on every square centimeter of this iron disk with a 10 cm radius, there are 14 kilos of external pressure and one kilo of internal pressure, so differential pressure is nearly four tons. . . . We won't try to pull it off. What we try to do is to cut or pry off the O-ring between the cylinder and its cover. No luck. I break a screwdriver and Jon snaps a scissors blade.

A glance at the Beckman analyzer: 2.8 percent carbon dioxide. We begin panting now, we are breathing too fast. The symptomatic lead bar impinges on my forehead, and the pounding of my heart resounds through my whole body. I make a sign to Jon: "Let's get out of here," and we return to the cylinder, to the refuge, to the light, to the heat, to the pure air, to the antechamber of the world of men.

1430 I consider our condition: no scrubber, no light, no heat, possibly no electricity at all. The outlook is very, very bad. I write with a grease pencil on the cylinder wall: "In any case we will stay here 24 hours." From the upper level, Jon signals his agreement. A whole day at 432 feet in the cylinder—that would at least be a partial success.

In Morse code we report to topside. Link answers: "Wait one." I picture the powwow up there; Ed, Dan, Wardwell, Captain Wilson, all discussing. As Dan likes to say: "There are perhaps problems that have no solution, but personally I have never encountered any."

And then: "If we send you a line, can you attach it to the flooded container? We have a spare motor, we shall repair and send it down to you again."

Dash-dot (affirmative).

"Very well. We are sending you a line, along your safety line."

1500 I have received the line, and dragged the container up to the cylinder. I have attached it and sent it back up. Now the flooded apparatus is on the surface in the hands of the electricians.

1600 We wait and munch a few biscuits. Jim Dickson calls us: "According to my samples, you now have over 2.8 percent CO_2 in the tent. You can tolerate that fifteen minutes, no more if you move around." He is right; as soon as we reenter Spid, the carbon dioxide level will climb rapidly. At 4 or 5 percent we will have to get out fast, otherwise we shall be overcome by asphyxia, and down here, no rescue is possible. Those fifteen minutes will decide either the success or the semi-failure of the entire operation.

1700 Still waiting. It is getting dark.

1825 Clang—the new air purifier which topside has just announced lands on top of the cylinder. I rig myself and leap into the water. Brrr, I shiver, and I swim for the new container up there and drag it toward the tent. The gas inside is heavy, and sticky in the mouth. With my heart pounding, I open the tap of the equalizing valve. *Psst*, the surrounding gas rushes into the container. The scrubber has arrived dry. Jon's face lights up with joy, but we have no time to celebrate. Six minutes have passed already. The little black needle has started to the left again far into the danger zone. We take off the cover, Jon pulls the heavy interior cylinder to him, I set it down in its cradle, I plug it in, the motor purrs, gas circulates, we have won! An outburst of joy answers from topside.

1930 We are installed under the tent. Wardwell has sent us spare electric bulbs in the scrubber container. Since they are smaller, they withstand the pressure. On tonight's menu: carrot juice and corned beef, canned water, fruit salad. The pressure has crushed and crumpled the tin cans, but their contents are intact.

2300 Dash dot dot, dash dot dot dash dot dot—BKI, "Beckman readings unchanged." I have taken the first watch of our first night at 432 feet. I have wrapped up my head in towels and put on close-fitting woolens to fight the helium chill. I watch the instruments and the water level in the entry well. The radiator does not work, nor the air conditioner, and Jon shivers on his cot in his three inadequate sweaters. Still, the thermometer registers 76°. Through a porthole, I watch in amazement thousands of sardines dancing a gastronomic ballet with the shrimp in the beam of our projectors. Topside, the medical team takes turns at the control panel; through the eye of the closed circuit TV aimed straight at my face, Big Brother is watching us. . . .

July 1, 0200 I lean over the well, and my heart suddenly rises. A huge black silhouette moves slowly against the ladder. Could it be the brother of the Nahant shark? Yes? No? No, I got a better look this time. It is only a peaceful grouper which nibbles on our garbage and on some spoiled ham which we have thrown in the water. It is as big as a boar; it must weigh 200 pounds.

0900 Breakfast. I have not slept well because I shivered too much, but as soon as we move around, the temperature becomes bearable.

1000 To work. I send the other container up to have a spare scrubber ready. We test our breathing apparatus: on a leash at the end of our 50 feet of hose, we take turns exploring around. When I put my mask close enough to the coarse sandy bottom I can see it is teeming with life, sponges, worms, minute royal blue fluorescent fish which I would like to bring back to make into a ring or earrings. Is that why they are called "jewel fish" in Florida? Chunks of dead coral, scattered all about on the bottom, swarm like beehives with little flabby creatures. Sometimes, from the far end of a hole, a big round, yellow eye looks at you. The breathing apparatus works perfectly. The big grouper follows us everywhere. It sucks my feet when I descend the ladder and it accepts all our caresses.

1330 Link on the intercom: "May I congratulate you for being the first men to have lived a whole day at 432 feet depth."

1530 I leap up to the cylinder to make our routine checks: everything is in order and I inform topside . . . dash

dash dash, dash, dot, dash. Jon joins me to try the breathing rig of the cylinder. We won't have another opportunity to use it.

1600 With parts and tools sent from the surface, Jon succeeded in repairing the air conditioner. The electric radiator gives us more trouble. It sputters as soon as we connect it. It makes sparks and bites my fingers when I touch it. Perhaps, if I hadn't let it drop so awkwardly into the access well, when pulling it out of its container yesterday . . . ? Too bad. The air conditioner gives us sufficient heat. After three hours in the water, it is a real pleasure to come back to a warm, cozy, and almost dry little haven.

2200 On the agenda: experiments in voice communication. Question: Below what percentage of helium in the windpipe can one make oneself understood at 400 feet? Lindbergh takes three deep gulps from a bottle filled with 25 percent helium and 75 percent air. His voice remains nasal and distorted, but I understand him clearly and the surface does too. He takes the opportunity to dictate a telegram to each one of his children on the West Coast: "I live in a little house on the bottom of the ocean. It floats like your balloon at the end of a string. Through the window I see thousands of silverfish and a big grouper follows me on my walks like a poodle. A little while ago I gave him some ham. . . ." The wonderful story of Ondine which has become reality. The radio up there will relay to four little children of the twentieth century a modern fairy tale, and, no doubt, they won't be astonished.

It's my turn. Now I take three deep breaths from a bottle of pure compressed air. The air is so dense that when I push

the BYPASS button I can see it flow from the regulator's mouthpiece like a thick fog. On the third gulp, the tent begins to swing back and forth, circles of light flare up and drift slowly before my eyes and cumuli pile up under my skull. I feel my face twisting into ludicrous grimaces, I am drunk as a lord. I drop the mouthpiece: now I know what narcosis is. It is the first time it has happened in my whole career as a diver.

2315 I am on watch. Every half hour I transmit to topside the figures I read on the dials of the analyzers: BKI, "Beckman readings unchanged."

Why am I vaguely disappointed? I am here, at last, here where I had so much trouble arriving, where so many people had so much trouble keeping me alive, and it is not what I was hoping for. I expected the great adventure of my life. I expected the exaltation of effort and danger. Not at all. It happens exactly the way I predicted it would, swaggering a little bit of course, to the reporters in London. It is routine, the humdrum life with its little works, the meals at a set time, the little problems which all have their little solution. But I should not regret it. After all, isn't that the real success of our operation?—this normal development of a well-prepared program without really narrow escapes. A more thrilling, "heroic" adventure might not have had a tomorrow. What we are doing today others, nonspecialists, will do just as calmly tomorrow. That is what matters, not the state of my soul. . . .

The second of the 1,000-watt spotlights of the cylinder which burned night and day goes out. Burned out, no doubt. Our interior light brightens immediately. Ten seconds later, the water in the access well is boiling. All the sardines which were whirling in the bright beam have now come around to the lesser light. They jump out of the water frantically and race on the surface and twist and turn like mad creatures. At once I see why: the water teems with tiny shrimp which turn round and round like mosquitoes, pursuing an invisible plankton, no doubt.

2335 A staggering blow shakes Spid. Jon wakes up, startled by the bang. What is happening? Another bang. We hold on to the cots. "The grouper." It is the giant grouper, charging the sardines in the well. With his enormous mouth wide open, he bores like a bulldozer, and gets entangled in the well, which is too narrow for his colossal body.

July 2, 0400 The grouper wakes us up ten times during the night. It is a real earthquake. Plankton, shrimp, sardines, groupers. The only ones lacking to complete the cycle are sharks. But if their size is related to that of the groupers around here, I prefer not to meet them at midnight. . . .

0900 At breakfast, Jon tries to tell me something. I look at him vacantly without understanding a single sound, while he repeats and articulates and repeats again. I can't get accustomed to these difficulties in communication. Finally, I hand him a scratch pad. He writes: "Weather on the surface excellent. Jim signaled dead calm. Sunrise on the surface 0510, first light here 0520."

0940 Getting dressed to spend our daily three or four hours in the water. To forestall a telephone breakdown, I have devised an emergency system—a plastic mustard dispenser ballasted with a lead pellet at the neck. I write a note

on a sheet of paper and slip it inside, then I need only drop the dispenser in the water with its opening down. But one can't anticipate everything. I raise my eyes to follow the ascent of my small red and yellow plastic bottles which bump along upward, sputtering their bubbles, only to see voracious packs of amberjacks rushing to pursue them. It is the first time I happen to look up. There is a whole carousel of king mackerels and jacks far above the tent and barracudas and other steel-gray fish which I can't name, all twisting and turning tirelessly. Are they attracted by the noise?

Topside calls: "Four dispensers with messages received."

"See, jacks don't really care for the taste of plastic."

Now, I take photographs of Jon; he breathes from the recirculating hookah, rearranging our gear ballast tray. It had to be done. We used the tray for a garbage can, and the sight of the debris-strewn bottom is no credit to the first colonists who came from above.

I used GE1 and M3 bulbs, the only ones small enough not to be crushed by the pressure. Immediately, the flashes attract around me half a dozen giant groupers. But where the deuce do they come from? It's a desert as far as I can see. No way to photograph them; they press against me in spite of the strong kicks I give them to get rid of them. They nudge the lens, bump into my legs and fill up the whole field of my viewer with their bovine bodies while their ping-pong paddles stir up opaque sandstorms in front of me.

Yesterday, while raising an arm too high, I tore my diving suit from shoulder to waist. Now deflated, it floats around me like a nightgown, weighed down by water, useless, and my teeth chatter helplessly. But I must continue, bones frozen or not. If they come out, my pictures will be the deepest pictures ever taken by a diver. After a roll of color film, I go and fetch my second Calypso-Phot, this one loaded with black and white, and begin to shoot again. But now, this is it, I can't go on, it's too cold, my fingers can no longer grip the flash bulbs. I dash toward the cylinder. I climb and turn on both radiators at once. Well, that doesn't help. To stop trembling like an epileptic and recover my energy, here as well as in caves, I know what I need: sugar. I return to the tent and greedily swallow six big spoonfuls of powdered sugar. My trembling hand spills more on the floor, but thirty seconds later, my composure returns and I stop shivering.

1330 We ate with big appetite: tomato juice, frankfurters, apple sauce, biscuits and Cheshire cheese, bananas and oranges. The thermometer registers 80° (27° Centigrade), and we relax, full, warm again, happy and content. Topside calls us—it's Ed with a ceremonious voice: ". . . Er, Robert and Jon . . . you . . . you have spent two days and two nights at 432 feet, and all our tests have succeeded. What we wanted to prove, is proved by now. Bravo! But now that the demonstration has been made, we'll gain nothing more by extending your stay. So pack up everything, and get ready to come up."

We stare at each other, nonplused. The first night, when shivering with cold under our useless sweaters, we may have been willing to obey orders to come up without much discussion, but now that the air conditioner works, and we are installed and organized, and have made friends and got into our daily routine, no need to consult each other: we would gladly spend the rest of the week here.

It is the voice of reason, however, and we have to obey. But while bolting the container tops in our little house, our

hearts are filled with the kind of nostalgia which overcomes you when you close for the winter the shutters of a summer cottage.

Then comes the routine of the ascent, just as in the rehearsals: our comings and goings with the instruments, the elevator sealed, the order to topside—dot, dash, dot, dot, L for lift—the needle of the depth gauge coming back to familiar figures, the water luminous again, the glare of sunlight through the porthole, and the big, white ship close by, the cylinder afloat, swiftly dancing on the surface and lying down under our backs to put us on deck, horizontally; and finally, the happy faces of the Captain and all our friends who stick an eye to the porthole, their hands making a sunshade, to get a look at us in our box, and the smile of the cook when he promises a steak dinner to celebrate our return to civilization.

"Mating with Deck Decompression Chamber accomplished," the telephone tells us. "You may now switch."

It is 3:15 P.M. Jon opens hatch B, unlocks the DDC's door and crawls into it on his stomach. I follow him and straighten up, enjoying the simple and forgotten luxury of stretching my limbs.

At 3:50 o'clock, Jim lowered the interval pressure from 432 to 399 feet. With one atmosphere of difference between the partial pressure of the helium dissolved in us and the pressure of the gas which our blood would encounter in our lungs, our desaturation had just begun.

My cameras and housings were open. For them as for us, we had planned on a regular linear resurfacing at a rate of one foot per eleven minutes in line with Dr. Workman's successful dry exposure at 400 feet at the EDU.

But it would be longer after all, Joe explained to us. "First, you were 32 feet deeper; second, you have worked harder and under much more strenuous conditions of comfort, and then, too, we did not have the means of controlling your percentages of inert gas on the bottom with as much precision as they did in the caissons of Washington. We are going to decompress you at one foot per twelve minutes, you will breathe oxygen on and off from 50 feet up, but just as an extra precaution, not to cut down your time."

I picked up a pencil: "Twelve minutes per foot, that amounts to five feet per hour. Five feet times 24 hours equals 120 feet per day. In other words, to resurface from 400 feet will take us 400 divided by 5, equals . . . er . . . equals 80 hours, or . . . let's see . . . 3 days and 8 hours."

Well, that is worth the trouble of sitting down.

Jim Dickson's voice in the intercom: "Robert, look starboard." Through the porthole of our decompression chamber, I saw our little rubber house slowly emerge from the blue water. The potbellied roof came first, sleek and shining, then the green and orange bottles glistening with color under the Bahama sun, and finally the access well, like a trouser leg, inflated by a muscular thigh.

At the exact moment when the base of the well emerged, the sausage collapsed, lacking the counterpressure of the water; what the hoisting boom unloaded on the deck was just an empty sack, a dead and flabby skin.

I wrote in my notebook: "1630 o'clock, all's well that ends well, both divers recovered, all equipment on board, not a single bolt lost, complete success."

I took pictures also: Jon taking our first iced drinks out of the air lock, and then in the evening Jon attacking his

steak, a plate on his knees, Jon shaving, and finally, Jon falling on his bunk to make up for a few forgotten hours of sleep. Then I climbed on the bunk above, and stayed such a long time that the next day our friend Wardwell suggested the name of the project be changed from Man in Sea to Man in Bed.

I learned that July 3 was a Friday. All cables and anchors recovered, *Nahant* left us after a polite exchange of foghorn blasts. She had assisted *Sea Diver* like a big, attentive brother—how could we have gotten along without her? I was glad to know that the crew would spend the Fourth of July with their families after all.

Tonight we listened to the tape recording of the dive. It was the same story but seen from the other side of the mirror, and once more, I realized that experiments of this kind, just like cave diving, are much more frightening for those who wait and worry on the surface than for those who are down below active and happy.

At 4 A.M., July 4, Jim woke us up. "You have arrived at 200 feet. Please get up and try out your joints." Frequently, it is the joints where the first bubbles materialize, so we will watch ours closely. As perfectly ridiculous as the actors of the silent movies, we solemnly gesticulate, facing each other. Toes, ankles, knees and hips, fingers, wrists, elbows and shoulders: everything works without creaking. Henceforth, every three hours we shall go through the same sophisticated mime's dialogue.

A very tired *Sea Diver* was heading back for Miami at low speed when we "reached 100 feet," then, on the 5th at about 2:30 in the afternoon, the skyscrapers of Miami Beach traced in the porthole their tourist-poster silhouette, and at 4:00 we were tied to our berth in the Miami River. Little details betrayed our ascent: a plastic bottle inflated; I could whistle again; our voices gradually resumed their human tone.

At 4:30, we strapped rubber masks on our faces to breathe pure oxygen. The amount of dissolved inert gases driven from the tissues and blood to the lungs in which it diffuses and from which it is then eliminated is proportional to the difference in partial pressure between the dissolved inert gas and the inert gas present in the lungs. If there is no inert gas at all in the lungs, the difference is maximum and the elimination quickest.

I felt a first slight pain at 33 feet, about 5:00 P.M. It was internal, somewhere in the right knee and leg. I was expecting that. Bubbles always display a regrettable tendency to show up again in the same parts of the body where they have appeared before, following any dive too close to a first decompression accident. When the inside of my leg began to burn, I notified Jim Dickson, who brought me back to 50 feet, and the pain vanished. But now, both of us had to resume the ascent at the rate of one foot per quarter hour only. We both were in the same boat, and poor Jon, free of any symptoms, now saw his purgatory prolonged for almost a whole day when he could probably have been through as planned, just as the first guinea pigs did at the Experimental Diving Unit.

Joe had himself locked in with us that evening, to tap my knees, look into my eyeballs, listen to our breathing, take our pulse and blood pressure. At this point I felt a strange tingling in the end of my fingers which interested him a great deal, but which gradually faded away while we finished our last hours of desaturation on our cots.

At midnight, the caisson was ventilated with compressed

air only. In the morning Jim announced: "There, see, your heads emerge." Indeed, we were only in five feet of imaginary water and at eleven o'clock, the oxygen mask still glued to our face, we were "wading" in two feet of theoretical seawater.

An Argus in shirt sleeves with a hundred round black eyes and a hundred electric ears, a squad of press photographers and reporters was watching for our exit. "One more, go out, hold it, go back in, please smile now, once more. . . ." And the first question: "Mr. Lindbergh, what is your favorite food for breakfast?"

"In token of appreciation," as the master formula engraved in the metal has it, the Mayor of Miami gave to each of us a golden key to the city. But he did not know that the key he presented us in its blue velvet jewel box opened much more than the doors of his city. It was the key to a world where air keeps pure without machines, where the sun warms and caresses your naked skin, where man can speak to man; to a world, above all, where somebody was waiting for me, her blue eyes beaming between her blond locks.

10.

THE BEGINNING

So, we have succeeded again. We have proved once more that our theory is sound. *Man can work efficiently and live in safety on the continental shelf.*

We will repeat the demonstration deeper, first at 600 feet and later, if it is proved possible by the preliminary dry runs, at 1,000 feet, the greatest depth of the continental shelf.[1]

But while we continue to push deeper and deeper, it is up to our engineers to make our equipment routinely operational at depths already conquered. In order that our efforts be truly useful, it is essential that our equipment be mass-produced and readily available. We must perfect our

[1] The original Man in Sea project has now been taken over from Mr. Edwin A. Link by a new company, Ocean Systems Inc. (an affiliate of Union Carbide and General Precision Inc.) which will carry on, on an industrial basis, the pioneering of the depths started many years ago on a shoestring budget. Ed Link, an owner of the new company, is its chief oceanologist adviser. Jon Lindbergh is marking off the Pacific Coast for the offshore oil industry as a manager of Offshore Divers, the operating branch of Ocean Systems Inc. in Santa Barbara, California (Dan Wilson, General Manager). Our experience with S.D.C.s and bottom dwellings is already playing a vital part in giving better diving services to the oilmen in charge of offshore operations. The author has been retained as an adviser and development engineer and is working with the team of mathematicians, biochemists, physiologists and physicians of the Diving Research Group of Ocean Systems who are presently engaged in computing and experimenting in a decompression chamber new and deeper decompression tables.

crude prototypes, do away with homemade articles and gimmicks, develop suits which won't rip, replace grenadelike light bulbs, appliances which short-circuit, waterproof containers which leak and weigh a ton, bulky TV cameras, capricious analyzers, dollhouse-sized Spids, etc., etc. . . . A long and complicated way to go.

The undersea workers of tomorrow will have a choice between three types of vehicles. First, for short deep dives, an autonomous diving bell which will bring a team of three specialists to its underwater job site, then serve as their operational basis for a few hours and finally take them up so they can be decompressed inside, on deck. The top compartment of that bell will remain at sea-level pressure and accommodate a customer's supervisor or an engineer who will be able to check visually and direct by phone the work of the divers. That same bell may be used also in a different fashion. If a particular job requires repeated short dives, tying in an oil well for instance, or welding elements of a pipe line, then the divers will remain under pressure for as many days as necessary, working from the bell and slipping back to a comfortable deck decompression chamber between calls or at night and will be decompressed, once and for all, at the end of the week. Second, for all jobs that require a permanent presence on the bottom, all around the clock, an enlarged Spid with an igloo next to it to allow colonists or scientists to settle down for several weeks or maybe months. And, three, there are plans for a double-lock submarine which will take the divers anywhere they have to work, will "spit" them on the job and swallow them again in a special pressurized compartment for a decompression *intra muros*.

But today, it is imperative that we concentrate on the tools and devices which will enable us to work fast, dry or wet, on the bottom. What is irreplaceable down below is the human brain; the hands are weak and should trigger only, not push or pull. We need power tools to bolt, to saw, to pickle, to punch out, to bore, to core, to excavate, and to transport loads. We need to be able to weld and paint and dynamite and pour concrete, for we aren't going to settle on the bottom to twiddle our thumbs, or make movies. . . .

"So, you did it," a Miami reporter asked, "but just what good will it do to be able to live on the bottom of the sea for two days or two months?"

What good will it do? About three billion earth dwellers jostle each other this year on our little planet. In 1978, there will be four billion, and six billion in 2000, we are told. And already, two men out of three are hungry when they wake up in the morning, and they know they will still be hungry in the evening when they go to bed, and hungry tomorrow and all the tomorrows until the day they die.

While the sea potentially contains all the proteins which they lack, 10,000 men die every day from undernourishment. Half a billion men drag themselves around, weakened and enervated by an inadequate diet. The UNICEF predicts that 50 million children will die from malnutrition in India during the next decade. Today, 100 million children are almost defenseless against infectious diseases because they suffer from Kwashiorkor. And yet enormous sources of food fill the oceans.

Last year fishermen hauled 45 million tons of fish, crustaceans, mollusks and edible mammals from all the seas of the world; that is twice as much as they did ten years ago, but it still represents only 1½ percent of the overall food consumed by man and it is estimated that the sea could produce well over 100 billion tons of potential human food a year.

Should fishing techniques be industrialized? The Soviets have done just that; they are widely engaged in fishing with electricity, and with submerged lights inspired by the Mediterranean lamparos. They invented the fish suction pump and built new huge trawlers, true floating factories which harvest and process fish night and day, in all seasons on the North Atlantic banks, under the very nose of old-fashioned American craft-fishermen. Many nations follow their example, especially the Japanese, and apply to catching fish the most modern techniques, including echo sounders, sonars, and television. But to perfect fishing techniques is nothing more than going from hewn stone to polished stone.

The solution is not an accelerated extermination which would rapidly convert the continental shelf into a desert. Let us not forget that after the four years of the Second World War, during which there was no fishing, the catch of the British fishermen in 1945 was more than three and a half times greater than in 1939. The solution is in organized breeding of fish.

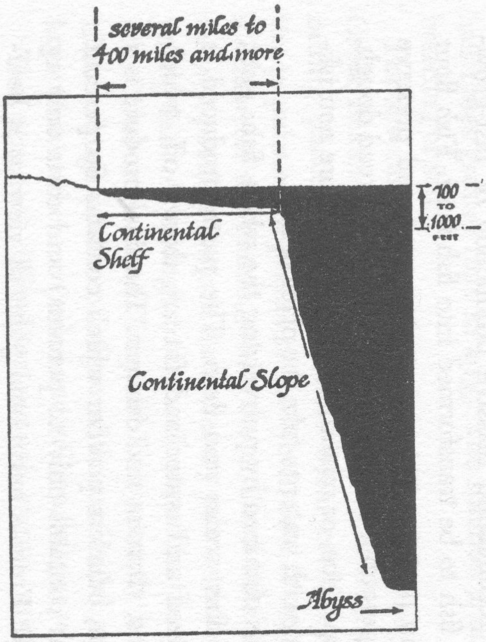
For several years the Fisheries Laboratory of Lowestoft, Great Britain, has been studying the problems involved in raising plaice. A 12-square-mile basin could hold the entire population of plaices of the North Sea. It would serve as a larder for the nation, while the artificial hatcheries would make it possible to stock the sea every year with many million young fish, old enough to be well armed in the struggle for life. Other scientists in England have recently begun to fertilize a huge prairie of algae with reinforced nitrates, and hope to raise there someday one million fish per year.

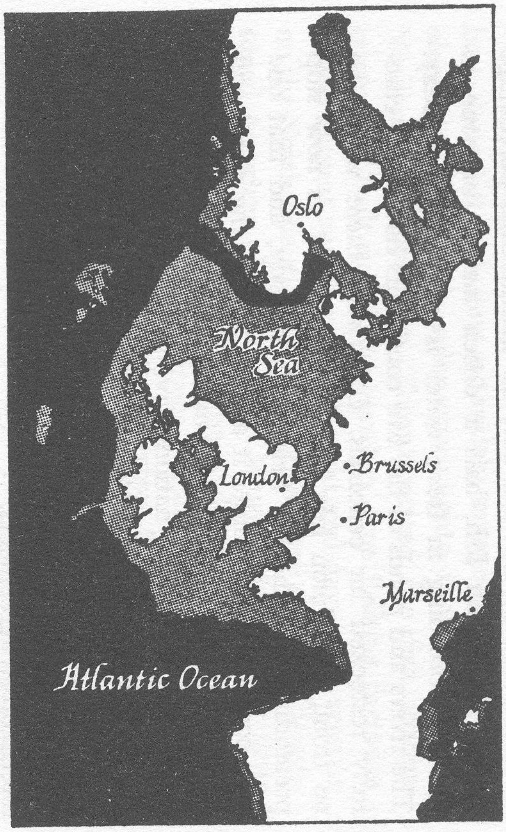
The practical difficulties are, of course, enormous, but they must be overcome. The biological waste in the seas is staggering. An average fish lays two or three million eggs in

the course of its life, but only an infinitesimal percentage evolve into adult fish, half a dozen maybe, or none at all. Fish breeding in fresh water is commonplace today. The rivers and ponds of the five continents have been carefully restocked for centuries. Otherwise, there would be no trout, no salmon left in most rivers. Let us now stop pretending that the sea belongs to nobody, and that one may consequently plunder it at will. Just as the rivers and ponds belong to the bordering owners, the sea belongs to all mankind. The whaling nations have already recognized that concept; they limit the catch by mutual agreement, protect the threatened species, and set up reserves. Tuna fish, salmon, and other "noble" species are likewise protected by international agreements.

The "noble" fish must be husbanded. In addition to restocking with choice species for direct consumption, the FAO experts now recommend massive production of fast-growing common fish to be transformed into fish flour. Fish flour is very rich in proteins, it is easy to transport and preserve without refrigeration, and it can be mixed with bread dough, added to soups, rice, or manioc to make them more nourishing, or diluted with water to take the place of milk.

This meal is obtained by pulverizing the whole fish: guts, bones, head, fins, scales and flesh. The paste produced is then deodorized and water and fat are drawn off, which leaves proteins, vitamins and calcium. The final product is a light, tasteless, odorless powder which contains 80 percent protein (meat contains only 20 percent) and costs only 15 cents a pound. From a nutritional point of view, it is beefsteak for 3.75 cents a pound. Scandinavia, France, and South Africa are producing it industrially. In the United





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Between England and Europe: another submerged Europe. It is the continental shelf.

The Continental Shelf around the Bahamas (a cross marks the place of the historic dive of *Sea Diver*).

States, where one ton of meal is extracted per 5 tons of fish, the Food and Drug Administration insists on treating fish meal as "aesthetically unfit for human consumption" because it contains the whole, uncleaned fish, when at the same time it accepts bones and skin gelatin and nongutted sardines.

The children of South America are much less fussy about the whole matter. The fish meal experimentally served as an additive to the diet of young victims of the Kwashiorkor disease restored their strength in a very few days. After three weeks, they were all in good health for the first time in their lives, in as good health as the children of the rich who obtain the amino acids of their animal proteins from milk, eggs and meat.

The investigations of the Marine Biological Laboratory of Elsinore, Denmark, are concerned with fish breeding in the sea. Professor Gunnar Thorsen is studying the growing rate of Baltic fish on the sandy bottom where they dwell in correlation with the amount of food available and the role played by predators. He aims at protecting and fattening up the fish stock in the sea. His plans call, first, for selecting the most resistant, most docile, most palatable species, those which grow the quickest with the least amount of food, what we might call the chickens, the cows and the pigs of the ocean —and here he has a 10,000-year handicap on the land cattle breeders—then, for limiting or destroying the parasites which attack eggs and larva (starfish and asterias) and for aiding the development of plankton, the basic food of all crustaceans, mollusks, animalcules, and small fry on which adult fish feed. Danish fish are all undernourished as a result of their laziness, quite an important discovery. If a massive

amount of food is put within their reach, they will eat much more, and thus grow faster than if they have to search for their pittance bit by bit over a wide area.

"What good will it do," the reporter wanted to know, "for someone to go and live on the bottom of the sea?" Well, it will enable tomorrow's farmers of the deep to watch their finned cattle, their clawed cattle or their shelled cattle, to take care of them and to feed them twice a day in their underwater ranches.

Next to his grouper pens, his turbot pastures, his king-crab corrals, his lobster hutches and his oyster beds, the peasant of the depths will clear and plant a square of sea bottom, and reap his undersea harvest of seaweed and algae.

Chinese, Japanese, and Hawaiians have always consumed great quantities of various kinds of seaweed. They eat it fresh or cooked, or preserved or seasoned. In Japan, hundreds of small factories process algae to extract *kanten* which clarifies the national *sake* and which housewives add to their soups, sauces and pastries. A kind of tapioca called *kombu* is made with other algae. In the lagoons as on most sheltered shallow flats on the coasts of the Nipponese islands, huge plantations regularly maintained and harvested produce the *asakusanori* alga, extremely rich in vitamins. For most algae contain as many vitamins as salads, and the vitamin D found in codliver oil is but a concentrate of vitamins absorbed by the algae-eating fish and retained in its liver.

More vegetation grows under the surface of the oceans than on land, and also more animal life. Biologists have studied and classified two thousand different varieties of algae, from which the future "old salts-peasants" will pick the wheat, the coffee, the vine, the carrots and the cabbage of the sea bottom. And here again, the land farmer enjoys a 10,000-year lead.

For centuries Britons have burned laminaria to make fertilizer out of the ashes. In Norway, soap and marmalade ingredients are extracted from algae. In California 150,000 tons of kelp were converted last year into 13 million dollars' worth of algine. Scots use algae derivatives in manufacturing transparent paper and synthetic tissues. In Morocco and Spain they turn seaweed into agar-agar. The agar-agar or gelose is a gelatin recently extracted from the gelidiaceae, a sort of pink algae of Spain, Biscayne and Morocco, which was formerly known only in Japan. The French industry uses it in drugs, food, preserves and cosmetics, as well as for fabric finishing and the pasting of paper. The salangane swallows of China agglutinate it to their saliva to make the peculiar glue with which they cement their nests to the rock and which the world's gourmets guzzle with delight in their bird's-nest soup.

The appreciable market value of the agar-agar resulted in installation of several factories for the processing of gelidiaceae algae in Bilbao and San Sebastián. In 1963, a processing factory was opened in France.

But an organized, expanding industry cannot be content to pick up, at the end of the summer, the algae that have died, wholesale on the beaches, since they lose most of their quality in fermenting—nor can it obtain sufficient algae by sending down a few sickle-armed frogmen, or by merely harvesting from the surface with air-lift-equipped boats, as is done in Morocco, when the sea permits it. Although most seaweed grows only in shallow or medium depth—because they live by photosynthesis—the wheat of the waves, like

the wheat of the furrows, will have to be cultivated, fertilized and cared for by the farmers of the sea, living on the bottom.

"What good will it do?"

For Jon, who watched the very first offshore ventures of the oil industy in California and was now hurrying back home where new contracts awaited him for deeper jobs on undersea well heads, the answer was simple.

All land oil fields have been found in areas which were covered up by the ocean during the geological times. Mineral oil, produced by the putrefaction of organic matter cast up on ancient lagoons and marine animals buried in the depths, is stored up in the sedimentary rocks—limestone, sandstone or gravel—of these vanished seas.

But the inland fields are not inexhaustible. Their production is at the mercy of local politics, royalties and transportation costs make it expensive, and transport can be paralyzed by war. British and American companies have not forgotten the Suez crisis. Besides, exotic fields are not the richest, nor the most profitable in the long run. It was therefore only logical to prospect at home for the possible fields which the seas still cover up today, and since the world market for black gold is far more solvent than the market for protein, progress here has been phenomenal.

The first wet-footed derricks were built in the shallow marshes of Louisiana and in Lake Maracaibo in the 1920's. In later years, derricks have multiplied there like living forests of steel. But these were shallow waters and all work was conducted from the surface. As oilmen raced toward greater depths, they had to find ways to adapt methods of prospecting, drilling and extracting to the watery milieu.

Most of the preliminary prospecting, can be done on the surface or from the air. After the general geological study, the prospectors resort to various geophysical methods to locate the eventual anomalies created by the presence of oil pockets in one or the other field of force. These fields of force may be natural, such as the gravity field, for example, which is measured with gravimeters, or the magnetic field, the weaker zones of which are detected on magnetometers, or they may be artificially created: After dropping an underwater depth charge, prospectors can measure on their seismographs or geophones the different speeds of propagation of the explosion's shock waves through the various strata of the bottom. The results are ultimately translated into graphs and reported on the geological map of the bottom where certain special configurations indicate the probable presence of oil.

American oilmen call the Gulf of Mexico "the playground of hurricanes." Nevertheless, that is where several oil companies began to drill shortly after the war. In 1959, the American Petroleum Institute summarized their problem in this way: "To construct a drilling platform in a depth of 70 feet, more than 30 miles offshore, to construct it high enough and strong enough to withstand hurricane waves 30 feet high and winds which can blow at 150 miles an hour, install living quarters for 40 men, be ready to evacuate them in a hurry if the storm signal is given by the weather bureau and be willing to invest a million dollars in a platform before even beginning to drill, knowing that at that point there is still no certainty of success whatever. . . ."

Beginnings were discouraging. Of the 71 drilling operations first carried out off Louisiana, 44 did not produce one drop of oil. Out of the first 16 drillings off Texas, only one

produced, but so little that it has since been abandoned. Nevertheless, the proximity of known fields on land and a wise long-term policy spurred the companies not to neglect any possible area. Up to now, they have poured over five billion dollars into the Gulf of Mexico alone. But their success today is in proportion to the expenditure.

In 1958, the Gulf Oil Co. had the first "deep" permanent platform set in 200 feet of water, 60 miles offshore; it drilled one mile deep under the sand. In 1962, higher and larger rigs were planted in 330-foot depths off the coast of California. Today off North Africa, drilling crews work in 600 feet of water, but the new rigs are afloat and mobile. They drill in one area, then are towed somewhere else.

The first of these new type rigs appeared off El Segundo, California. It was a square, floating platform which was towed from one potential area to another. To drill, it would lower to the bottom its four legs, which slide across each of its corners, then having gotten a firm foothold in 200 feet the platform would crank itself up the legs, 30 feet over the waves.

Technical progress in this field has been so rapid that these first attempts are obsolete. Seamen, by now, are getting used to the spectacle of such newcomers as football-field-sized platforms driving their legs into all seas, of strange-looking drilling ships, of derrick-carrying catamarans and of floating islands being towed back and forth before they submerge like icebergs on their stabilizer buoys and begin operations.

Technical journals are filled with stories of conflicts between oil companies fighting over the entire span of the continental shelf for concessions which no authority, whether provincial or national, state or federal, is quite sure it has the right to grant. White geysers of foam spring from the Timor Sea, off Borneo, off Australia, in Alaska and in the Arctic seas, in the Mediterranean and in the Gulf of Biscayne as prospecting geologists drop their depth charges. On the whole west coast of the United States, there is such a rush to the deep waters (400 feet) that Wilson and Lindbergh can't always find enough divers to meet the demand.

Skeletal steel silhouettes of drilling rigs have been growing and multiplying for seven years off the west coasts of the Japanese archipelago. The Canadian lakes are being tapped. In front of Baku, the wells of the Caspian spew forth rivers of black gold, and since 1960 the Soviet Petroleum Agency has been carrying a large-scale geological survey under the depths of the Sea of Azov in order to locate and map the exact prolongations of the Caucasus oil fields. Numerous English, American and Scandinavian groups, the French Bureau de Recherche de Pétrole, a consortium of German industrial concerns and the Dutch Koninklijke Nederlandse Aardolie Maatschappij are prospecting and drilling the North Sea. No valuable strike has been made yet but the Dutch have found nearby, on dry land, the richest natural gas field in the world. In the Gulf of Sidra, in Libyan waters, an American group is drilling today at a record depth of 600 feet.

Technology progresses by leaps and bounds and as fresh needs arise, new methods, new instruments, new types of rigs, are invented, proposed, tested, adopted and constructed every day for undersea prospecting and for deep-water drilling and exploitation. But there is nevertheless a restraining factor, a hurdle against which the oil people continue to stumble. Everywhere in the world prospectors and operators

wrestle with the same problem: how to get longer and more efficient services from their divers in deep water.

They tried to get around the problem by replacing the eyes and arms of men with remote-control instruments and with more and more sophisticated machines which therefore broke down more and more often and got more and more costly; the Mobot is a good example. Manufactured for Shell Oil Co. by Hughes Aircraft, it is the only robot which has really been operational. It was a real monster, 14 feet by 5 feet, and was supposed to swim with its twin screws, to run on two wheels, hear with its hydrophone and sonar, see by television, steer with its gyrocompass, turn screws, bolt, open valves and operate specially adapted tools with its two grippers. But always there were problems that Mobot couldn't handle. The oil technicians admit today that machines are not the answer. The physical presence of man can no more be replaced on the bottom of the sea than in outer space.

About the Man in Space project of NASA, the Astronaut John Glenn wrote: "It is man's capacity to understand quickly, to analyze and establish relations in the framework of one same experiment which yields the most profitable results in this kind of explorations."

And in March 1963, J. H. Clotworthy had this to say in New Orleans before the assembled members of the American Petroleum Institute: ". . . In spite of all the techniques which make it possible to put mechanical and electronic equipment on the bottom of the ocean at great depth, it will be necessary in many cases that men be present at the bottom."

Oil experts estimate at about 400 billion barrels the reserves of crude oil lying under the continental shelf, and the gas reserves are almost impossible to evaluate. To tap such a formidable supply of energy, man will have to work on the bottom, on well heads, on pipelines, on separators, with their brains, with their eyes and with their hands. And in order to be able to work down there efficiently and safely, they will have to live under pressure.

It will be necessary for another reason too. The green waters of the Gulf of Biscayne and the yellow waters of the North Sea become mountainous in the winter with storms more frequent than breezes. No platform will ever be safe. Several years ago, in the Gulf of Mexico, a "Texas tower"—a radar warning station, constructed like modern drilling platforms—was broken down by heavy seas and knocked into the waves with its crew.

Hurricane Hilda smashed nine platforms and two drilling vessels into bits; forty wells were completely wiped out in two hours from the surface of the Gulf. Millions of dollars in investment were lost in minutes. In bottom-based installations, in the rubber dwellings of aquanaut workmen living on the bottom to work and maintain undersea well heads, to attend separators and to man pumping stations, Hilda would have passed by unnoticed.

"What good will it do?"

The oceanographic vessel *Challenger* undertook, from 1872 to 1876, what was to be the first round-the-world oceanographic cruise ever made by scientists. From the bottom of the Indian Ocean its dragnets brought up black nodules containing 30 percent manganese and appreciable quantities of cobalt, copper, and nickel. Some were the size of a hen's eggs, others like cannonballs, others like cooking

pots. Most of them, we are told, resembled "potatoes cooked in their jackets."

In the nineteenth century, these metal balls had aroused some polite interest in academic circles as "scientific curiosities." Found today in all seas of the world, they may become another "black gold" and give rise to a new and gigantic industry.

The Institute for Marine Resources of the University of California has studied the eventual profitability of extracting and processing the nodule deposits of the Pacific coasts and depths. For millennia the components of these nodules have been carried to the sea by the rivers, underwater volcanic eruptions and sunken springs. Now, since water is saturated with dissolved iron and manganese, the considerable amounts of these metals which flow into it every day are immediately precipitated in the form of colloids and sink to the bottom. Once on the bottom, these substances agglutinate into nodules through molecular electric attraction, it is believed, instead of forming a uniform stratum. Around the Hawaiian Islands the deep-sea currents which carry off plastic muds have left a hundred thousand tons of these nodules resting on each square mile of the bottom. There are a thousand five hundred billion tons of it under the Pacific alone, according to Dr. John Mero, the apostle of underwater minerals at the University of California. Once they have been dried, they contain on the average 24 percent manganese, 14 percent iron, 0.4 percent cobalt, 1 percent nickel, 0.54 percent copper, 0.06 percent zirconium and 0.05 percent molybdenum (maximum percentages found are 50, 26, 2.3, 2, 2.3, 0.12 and 0.2 percent).

The market value of these metals oscillates between $45 and $100 per ton (1961 prices). Would industrial extraction and processing be economical? In an often quoted report, Dr. Mero figures that the return on investment would be excellent: 50 percent per annum—and that the cost price per ton would be 75 percent of the standard present cost price of the metals, provided 5,000 tons per day could be dredged. Others, armed with these figures, insist that the United States import today 96 percent of the manganese they use and 78 percent of the cobalt, 91 percent of their nickel, 25 percent of their iron ore, as well as three dozen other strategic products.

What makes the industrialists' heads spin is the fact that the reserves of these precious metallic nodules beneath all seas are actually forming more rapidly than they could be consumed by the whole world, at its present rate of consumption. Are Dr. Mero's figures too optimistic? Skeptics will soon know, since he has left the University of California to go into private industry, associated with a company which specializes in dredges and hydraulic pumps.

The day may be close when we will see, quoted on Wall Street, the stocks of Captain Nemo.

Another industrial pilot project, that of a California company which considers extracting fertilizers from the continental shelf, could have enormous repercussions on the agriculture of the underdeveloped countries.

Excellent chemical fertilizers are made from phosphorite, a natural phosphate of calcium. The world production of "terrestrial" phosphorite is 40 million tons per year. As a matter of fact, under the largest part of the continental shelf which skirts California, Australia, South America, Japan, Spain, South Africa and Chile, at depths often less than 300 feet, oceanographers have discovered enormous quantities of this mineral in the form of large brownish nodules.

The Collier Carbon & Chemical Co. obtained in 1961 an official concession from the Department of the Interior on 30,000 acres of the Forty Miles Bank off San Diego, California. The company engineers reportedly plan to scrape the bottom with hydraulic dredges and fish up the nodules (5,000 tons per day) to bring them to their factory, which could then turn out each ton of fertilizer at a much lower cost than the price paid in California for phosphates imported from other states. From an investment of 3 million dollars, John Mero expected in 1961 a net annual return of 27 percent.

Still, the extraction projects of Collier have been temporarily shelved. Technical difficulties? No doubt, and enormous ones, but it is encouraging to remember the real commercial success of the Freeport Sulphur Co. in Louisiana, the installations of which, resting on piles seven miles offshore, pump all year long the sulphur of marine deposits, after they have been dissolved and melted by a jet of boiling water. The investment here was 30 million dollars.

The Japanese, since they depend on imports for most of their basic raw materials, have a special interest in discovering new fields along the coast of their own country. In Ariake Bay, the Hyawata Steel Co. has been extracting small quantities of iron ore mixed with sand since 1960. Recently, the company increased the production to 30,000 tons per month by putting on stream new giant dredges. The reserves are estimated at 36 million tons, according to the very first explorations.

In Labrador, private companies are engaged in drawing up a map of the fields of ferruginous sands, using acoustic echo sounders. The same device is used by the British, who explore for coal along their eastern shores to try to follow the tracing of any underwater prolongations of their exhausted coal mines.

For millions of years, rivers have been pouring diamonds in the seas. Particularly on the western coast of South Africa gems have been stopped en route, others lie in the estuaries or on underwater terraces which happen to be presently submerged. Volcanic chimneys opening under the surface may likewise have expulsed fabulous quantities of precious stones.

The Collins Marine Diamond Ltd., which holds important leases on the bottoms of Southwestern Africa, has found two offshore placers of importance with an estimated reserve capacity of nearly 30 million carats. It would seem that further surveys will probably increase this figure, but when one bears in mind that the reserves of the De Beers Consolidated Diamonds are 15 million carats and that it possesses a virtual monopoly on the distribution of diamonds, one can readily understand why this company has just financed the operations of Collins Marine Diamond Co. to the tune of two million pounds sterling.

The results need no commentary. Air lifts—a kind of compressed-air suction pumps—raise the diamond-filled gravels up to the surface and dump them in three specially equipped ships where a complicated filtering system retains the gems. The field presently being exploited is located in less than 100 feet of water. For the first five days of work, production was 2,100 diamonds with a total weight of 1,038 carats. Today, production has reached an average of 1,000 carats per day, 1,000 carats of jewelry diamonds of the very highest quality.

After several months' work, the wealth of the deposits was estimated at not less than two carats per ton of gravel, which is far superior to that of terrestrial deposits. It was no

doubt by coincidence that the Prime Minister of South Africa declared soon afterward that the government of his country felt the moment had arrived to extend the limits of the territorial waters of the Republic from three miles to six miles.

Even the inexhaustible red clays of the great depths are rich in aluminum, copper, cobalt and nickel, and the muds rich in silica and calcium. Whether or not they can be exploited depends on technological progress. In the United States, the Bureau of Mines of the Department of the Interior, realizing how fast the reserves of minerals are becoming exhausted on land—the figures are frightening—is investigating and evaluating underwater deposits, studying possible techniques of underwater recovery and preparing special metallurgical methods.

Every day that goes by, the continental shelf yields a new secret and unveils a new treasure. Pharmacologists are studying more and more closely an entirely new class of antibiotics and drugs that can be extracted from sponges and marine organisms. Tin is found and sampled under the mud bottoms of the Gulf of Siam and Indonesia. In Alaskan waters, the Shell Company is dredging the coastal sands of Nome, in an attempt to extract gold and platinum.

Some scientists believe that once the suitable equipment has been perfected, all metals found on the continental shelf will be industrially extracted at 50 to 60 percent of the actual cost prices on land.

But once again, to perfect this "suitable equipment," to install it on the bottom and operate it, it will be necessary in many instances that men settle, work and live on the bottom of the sea.

That is what our project, Man in Sea, will do. . . .

Industry is becoming aware of the promise of the sea. Today, all major American and European corporations are getting their feet wet, setting up their own research teams and launching new subsidiaries to specialize in the study of this new potential gold mine: the continental shelf.

But where should we begin? Industry, by its very nature, is interested in quick-return enterprises and suffers in this respect from the technological lag which Link has been denouncing for years.

President Kennedy wrote: "The safety and the well-being of the United States and the world demand that we learn much more about the ocean."

"Compared to the efforts of other branches of science, the progress of the sciences of the sea has been slow in the United States," the Report on Oceanography of the National Academy of Sciences admitted in 1962. This is true not only in the United States!

How far has basic underwater research proceeded?

Not far. Most marine maps are as inaccurate as the geographic charts of the eighteenth century. Chemists, physicists, geologists, meteorologists, biologists, all oceanographers are just beginning to wonder what questions they should ask themselves.

But at least the work has begun and governments are devoting increased funds to pure oceanographic research.

Joint enterprises of enormous scope are being carried on with great success: for example, the International Expedition in the Indian Ocean, or the International Cooperative Investigations in the Tropical Atlantic, organized by the Intergovernmental Oceanographical Commission of the United Nations.

France just created a Commission for the Exploitation of the Oceans, endowed with adequate funds.

The Kennedy Administration presented to Congress a new 10-year program for oceanographic research (1963-1973), the budget for which will amount to 2 billion, 300 million dollars, to be apportioned among the Navy, the National Foundation for Sciences, the Bureau of Fisheries, the Geodetical and Coast Services, Public Health, the Atomic Energy Commission, and other agencies.

Fifty-six percent of this enormous sum is allocated to basic research. Now, in the most important sector of this research, the study of the first step on the staircase of the depths of our continental shelf, the investigators will have to be able to live on the very bottoms they study so they can observe and work and learn—for a long time, night and day, winter and summer.

"I see also means I understand," Jacques Piccard reminds us, "and the eye is nearer to the brain than the TV camera."

"I am convinced," writes Commandant Houot, "that the observer himself must penetrate the environment which he wants to study. Only man can take full advantage from all the possibilities of the moment."

"Machines alone will not be able to do the work which needs to be done," says Dr. René Engel, Chief of the section of Oceanic Research of the Naval Ordnance Test Station. "No machine can react to an unexpected situation, and it is precisely for that reason, to find the unexpected, that we explore the unknown."

"And after all," another scientist said, "man is still the only 150-pound apparatus with servo mechanisms which can be produced on a mass basis without any intervention of specialized personnel."

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And the 1960-1970 program of the Oceanographic Committee of the National Academy of Sciences of the U.S. (National Research Council) concluded: ". . . for a great variety of experimental and exploratory problems, the investigator would ideally like to be able to descend to the bottom of the sea, walk around, observe and gather specimens . . . and there make use of the greatest number of the techniques he has learned on land."

Isn't that word for word the ambition of our Man in Sea project? Isn't that precisely what our underwater houses, our working bells and our tools are meant to be used for?

What Jon and I accomplished in the Bahamas was not to "beat a record." There is not a more meaningless word, under the sea, than the word "record." What good is it to remain on the bottom deeper and longer than somebody else, if it is just to sit on a stool?

What we have accomplished is different and it is only in the light of what the sea promises man for tomorrow that one can really understand the meaning of our adventure. We have lived on the continental shelf in questionable comfort, but in safety, and we have worked on the bottom for many hours every day. We worked—this is the measure of our success—we worked a long time, efficiently and safely, we worked on the bottom like a plower on his field, like a chemist in his laboratory, like a public servant in his government office, we worked where surface-bound divers were not even able to reach and look.

We paid for our two days on the bottom with four days of decompression. But since we were saturated, if we had stayed two weeks or two months, the decompression time would have been the same.

The Conquistadores did not make the Americas prosperous; they came to pillage, and so do today's divers and fishermen who rob the sea. The undersea colonists, the aquanauts, will be the pilgrims of the sea. Without looking for quick plunder they will cross the "last frontier"; they will go down and clear the continental shelf and they will leave behind them more riches than they found. They will build a new colonial empire—not overseas—but under the sea.

They will succeed; we have already succeeded.

RECORD-BREAKING DEEP DIVES

Date	Depth	Bottom Time	Type of Breathing Gear	Gas Breathed	Divers Name & Organization	Place	Duration of Decompression	Remarks
1915	305 ft.	Many working dives 10 min. and more	U.S.N. Air Hard Hat gear	Air	U.S.N. divers	Honolulu, Hawaii	U.S.N. Tables	Salvage of U.S.S. F4 - Exceptional feat
1930	343 ft.	?	Hard Hat, Royal Navy	Air	H.M. Royal Navy	?		
1937	420 ft.	?	Modified Hard Hat	Helium/Oxygen	Max Nohl	Lake Michigan, USA	?	
1943	210 ft.	1 minute	Scuba (Cousteau-Gagnan prototype)	Air	Frederic Dumas	Marseille, France	—	First deep Scuba dive
1945	305 ft.	Bounce	Scuba (Cousteau-Gagnan)	Air	Frederic Dumas	Marseille, France	?	
1945	533 ft.	A few seconds	Modified Hard Hat	Hydrogen/Oxygen	Arne Zetterström, Eng.	Sweden	No decompression due to topside mistake	Topside tender, unfamiliar with winch mechanism, mistakenly brought diver straight up. Zetterström perished from explosive decompression effects after dive. Otherwise successful.
1947	400 ft.	?	Scuba (Cousteau-Gagnan)	Air	Maurice Fargues (Gers)	Toulon, France	None	Fargues died. Probably due to extreme narcosis (lost his mouthpiece)
1948	547 ft.	5 minutes	Hard Hat	Helium/Oxygen	William Bollard, RN	Loch Fynn, Scotland (HMS Reclaim)	8.30 H in S.D.C.	Bollard suffered serious bends (Hemiplegy)
1949	560 ft.	A few minutes	Semi-open circuit Hard Hat	Hydrogen/ Helium/Oxygen	11 U.S. Navy divers	Wet tank plus decompression chamber EDU Washington, D.C.	?	Wet tank dives, not in open sea.
1953	270 ft. +	—	Scuba	Air	Hope Root	Miami, Florida, USA	—	Root, probably under serious narcosis, kept swimming down; never surfaced.
1953	385 ft.	15 minutes	Semi-open circuit Hard Hat (Helium helmet)	Nitrogen/Helium/ Oxygen	All U. S. Navy qualified deep sea divers	—	±3 hrs. 30 min.	385 feet is the maximum normal operational depth for all USN qualified deep sea divers (Helium)
1954	315 ft.	—	Scuba	Helium/Oxygen	Clarke Samazan	Catalina, California	—	Samazan suffered serious bends.
1958	309 ft.	Bounce	Scuba	Air	Eduardo Admetlla	Alicante, Spain	—	
1958	610 ft.	4 minutes	Hard Hat	Helium/Oxygen	George Wookey, RN	Norway (HMS Reclaim)	11 hrs. 30 min.	
1959	435 ft.	A few seconds	Semi-open circuit Scuba	Air	Falco-Novelli-Olgiai	Naples, Italy	75 minutes	Record setting air dive using Scuba. (Own partially recirculating Scuba regulator)
1959	400 ft.	4 minutes	Hookah in crude bell	95% N_2 - 5% O_2	Hannes Keller	Zurich, Switzerland	1 hour	Keller was lowered to depth in a crude diving bell. Did not do any work or any movement.
1960	520 ft.	Bounce	Hookah in crude bell	"Secret" mixture	Hannes Keller	Zurich	30 minutes	-idem-
1960	833 ft.	—	Hookah	"Secret" mixture	Hannes Keller	Gers Wet Pot, Toulon, Fr.	48 minutes	Wet pressure tank dive.
1961	740 ft.	—	Hookah	"Secret" mixture	Hannes Keller Kenneth McLeish (Life)	Lago Maggiore, Switzerland	45 minutes	Both divers in crude bell.
1961	717 ft.	10 minutes	Hookah	"Secret" mixture	Hannes Keller	Gers Wet Pot, Toulon, Fr.	140 minutes	10 minutes of work at 717 feet - unprecedented.
1961	1000 ft.	5 seconds	Hookah	"Secret" mixture	Hannes Keller	Gers Wet Pot, Toulon, Fr.	48 minutes	In wet pressure tank.
1962	833 ft.	Several minutes	Hookah	"Secret" mixture	Hannes Keller	Bangol Bay, France		Real open sea dive with diving bell of USS Tringa.
1962	300 ft.	1 hour	Experimental	Successive secret mixtures	Hannes Keller Peter Small	Santa Catalina, California	105 minutes in S.D.C.	Open sea dive - Bottom time remarkably long, decompression remarkably short - Keller all right, small bent.
1962	1000 ft.	3 minutes	Experimental	Successive secret mixtures	Hannes Keller Peter Small	Santa Catalina, California	In S.D.C. Scheduled decompression made impossible: accidents	Absolute world depth record - down and up in S.D.C. Atlantis - At 1000 ft., Keller reportedly left S.D.C. and swam under - Equipment failures caused improvisations which led to death of Peter Small. (Apparently decompression sickness due to loss of consciousness and slowed metabolism.) Keller's "methods" apparently not in cause.
1962	480 ft.	Bounce	Scuba	Air	Richard Burch Roger Hutchkins	Aldros Island, Bahamas	?	Divers lowered and lifted seated on wooden structure - no work performed.
1962	450 ft.	10 minutes	Open circuit Hookah	87% Helium - 13% Oxygen	6 Royal Navy divers	Tenériffe, Canary Islands	133 minutes	Divers swam and worked around S.D.C. - S.D.C. rated with DDC on deck of ship.
1963	306 ft.	Bounce	Scuba	Air	Constantino Zimbron-Espejel	Acapulco, Mexico	?	
1963	309 ft.	1 hour	Hookah (open circuit)	Helium/Oxygen	Pierre Graves Sogetram	Villefranche/Mer, France	4 hrs. 22 min.	One hour in the water - light work - Decompression in S.D.C with various mixtures
1963	500 ft.	?	French Navy Mix-Gas unit	?	Gers divers	Toulon, France	?	Classified information.
1963	500 ft.	15 minutes	Open circuit Hookah	90% Helium - 10% Oxygen	12 Royal Navy divers	Tenériffe, Canary Islands		Divers in open sea around S.D.C. Decompression in DDC.
1963	500 ft.	15 minutes	Helium Hard Hat	Nitrogen/Helium/ Oxygen	Dick Garrahan, Ernie Harmon, Purdy Laferriere (USN divers)	Decompression chamber EDU Washington, D.C.	3 hrs.+	Wet pot dive.
1963	300 ft.	20 minutes	Closed circuit, automatic oxygen sensor (Krasberg-Emerson)	Nitrogen/Helium/ Oxygen	USN divers	Decompression chamber EDU Washington, D.C.	—	Remarkable autonomy.
1964	Approx. 330 ft.	Several minutes	Experimental closed circuit	"Secret" mixture	C. Colombo	Swiss lakes	?	Colombo successfully achieved several deep dives in lakes. He died in 1964, during an experimental dive due to failure of his "secret" equipment.
1964	400-533 ft.	About 20 minutes	Semi-open circuit Hard Hat	Nitrogen/Helium/ Oxygen	Commercial divers	California - Libya	3 to 6 hours	Working dives for oil industry.
1964	600 ft.	4 hours	Chamber atmosphere	Helium/Oxygen	HMRN volunteers	Decompression chamber Portsmouth, England	40 hours	Simulated dry dive. Bottom time remarkable.
1964	800 ft.	2 hours	Chamber atmosphere	Helium/Oxygen	HMRN volunteers	Decompression chamber Portsmouth, England	51 hours	Simulated "dry" dive. Severe bends at 390 ft. Decompression difficult.

WHO'S WHO ON THE OCEAN FLOOR (August 1965)

Date	Project Sponsor	Name of Project	Depth	Duration	Location	Type of Dwelling	Aquanauts	Gas
Early 9/62	Dr. Edwin LINK	MAN IN SEA	200 ft.	26 hours	Villefranche (Medit.)	LINK cylinder (3' × 11') Aluminum	Robert STÉNUIT	3% Oxygen 97% Helium
Mid. 9/62	Cmdr. Jacques-Yves COUSTEAU OFRS	CONSHELF #1	30 ft.	7 days	Marseille France (Medit.)	"DIOGENE" (Horizontal Cylinder 8' × 16')	Albert FALCO Claude WESLY	Air (No narcosis & no decompression required)
6-7/63	Cmdr. Jacques-Yves COUSTEAU OFRS	CONSHELF #2	34 ft.	1 month	Shaab-Rumi Reef (Red Sea)	"STAR HOUSE" four 8 ft. diameter cylinders horizontally assembled in a star-like pattern.	Prof. VAISSIERE Claude WESLY Albert FALCO Pierre GUILBERT Pierre VANONI	Air " "
			85 ft.	7 days	Shaab-Rumi (Red Sea)	"DEEP HOUSE" (Vertical Cylinder 7½' × 16'	André PORTELATINE Raymond KIENTZY	Air/Helium
6-7/64	Dr. Edwin LINK	MAN IN SEA	432 ft.	49 hours	Berry Islands (Bahamas)	SPID (Submersible Portable Inflatable Dwelling) a rubber tent 7' × 4'φ	Robert STÉNUIT Jon LINDBERGH	4% Oxygen 96% Helium
7/64	Dr. George BOND (USN)	SEA LAB I	192 ft.	11 days	Argus Tower (Bermuda)	"SEA LAB I" - cigar shaped steel horizontal capsule 35 ft. long by 12 ft.φ	Robert THOMPSON Robert A. BARTH Lester ANDERSON Sanders MANNING (All USN)	16% Nitrogen 4% Oxygen 80% Helium
1964?	USSR Group	?	45 ft.	4 weeks	Black Sea	?	?	?
8/65	Ocean Systems	MAN IN SEA	650 ft. (simulated)	48 hours	Tonawanda N. Y. (Linde Labs)	Experimental pressure chamber	Robert CHRISTIANSEN A. NOBLE	4% Nitrogen 1.85% Oxygen 94.15% Helium
9/65	Dr. G. BOND O.N.R. - S.P.O.	SEA LAB II	215 ft.	15 day and 30 day periods	La Jolla (California)	Steel cylinder 57 ft. × 12 ft.	Several teams of 10 men headed by Scott CARPENTER	16% Nitrogen 4% Oxygen 80% Helium
10/65	Cmdr. Jacques-Yves COUSTEAU OFRS	CONSHELF #3	315 ft.	24 days	Villefranche (Medit.)	Steel sphere (2 stories) on 4-legged supporting barge	André LABAN Jacques ROLLET Philippe COUSTEAU Christian BONNICI Raymond COLL Yves OMER	1% Nitrogen ± 2% Oxygen ± 97% Helium

Notes on Chart on Pages 212-213

RECORD-BREAKING DEEP DIVES

Since this book was sent to the printers, the staff of the Admiralty Diving Unit, working from H.M.S. *Reclaim*, off the French Mediterranean coast with a Submersible Decompression Chamber, has carried on a series of record-breaking deep dives: 18 dives of one hour at 450 feet; 18 dives of one or two hours at 500 feet; several dives of one hour at 600 feet. Severe bends, successfully treated, slowed down the course of operations and led to the cancellation of the 800-foot dives previously tried out in the Alverstoke dry chambers.

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