Y. LE MASSON

AUTONOMOUS CLOSED-CYCLE DIVING APPARATUS

Dec. 1, 1959

Filed July 18, 1956

Image 1 | Masson Closed-Cycle Diving Apparatus

INTRODUCTION | A little bit of history

For many people it was Jacques Cousteau and his adventures on the Calypso or Mike Nelson in the television series 'Sea Hunt' which introduced them to diving. Not me though. For me, it was a bunch of string puppets. I suppose I better explain exactly what that means before I go any further. The string puppets or marionette characters were called; Troy Tempest, Phones and Marina, and they were the main characters in a children's television series created by Gerry Anderson called Stingray. The series aired on British television from 1964 to 1965 and told the adventures of a fantastic submarine named Stingray. To a six year old it was perfect escapism and I became enthralled with the underwater world.

Two years later Stingray gave way to the Undersea World of Jacques Cousteau and I can remember sitting with my parents watching the adventures of Jacques, Jean-Michel, Philippe and the crew of the Calypso as they explored the world's oceans. I always dreamed of putting on scuba gear and seeing for myself the wonderful sea life and vistas that were brought into our living room all those years ago.

Even thought I have spent a great deal of my working life to date involved with the marine and offshore industries, I didn't actually become a certified diver until a few years ago. Not surprisingly, the reality of diving differed considerably from what I remembered from the television images of Stingray and Jacques Cousteau. Certainly the principles of pressure and depth and decompression remain the same but the technological advancements and the explosion in interest in the sport have been incredible. PADI, the Professional Association of Diving Instructors, alone has certified over 5 million divers. Thanks to scuba diving, the underwater world really has opened up for almost everyone. The word scuba has an interesting derivation. It is believed to have been coined by Dr. Christian Lambertsen in 1939 and originated from a project he was working on to design a '**S**elf-**C**ontained **U**nderwater **O**xygen **B**reathing **A**pparatus' for the U.S. Navy. The word 'oxygen' was omitted and the term later condensed to SCUBA and is now used as a word rather than the capitalization of initial letters of the phrase.

Although scuba diving is a relatively young sport, the desire to spend extended periods underwater has probably been around since we evolved to become land mammals. It is almost as if there is some subconscious desire to return to our evolutionary roots. Men and women have been holding their breath and diving for

Image 2 | Stingray

thousands of years. There are depictions of them in ancient drawings, and from archeological artifacts it seems that attempts to fabricate apparatus to extend that time underwater have been going on for just as long.

Possibly the first method to try to allow humans to remain below the water for longer than a few minutes was a form of diving bell. Early bells consisted of a container open only at the bottom, the trapped air being used as a reservoir by the hapless diver until the

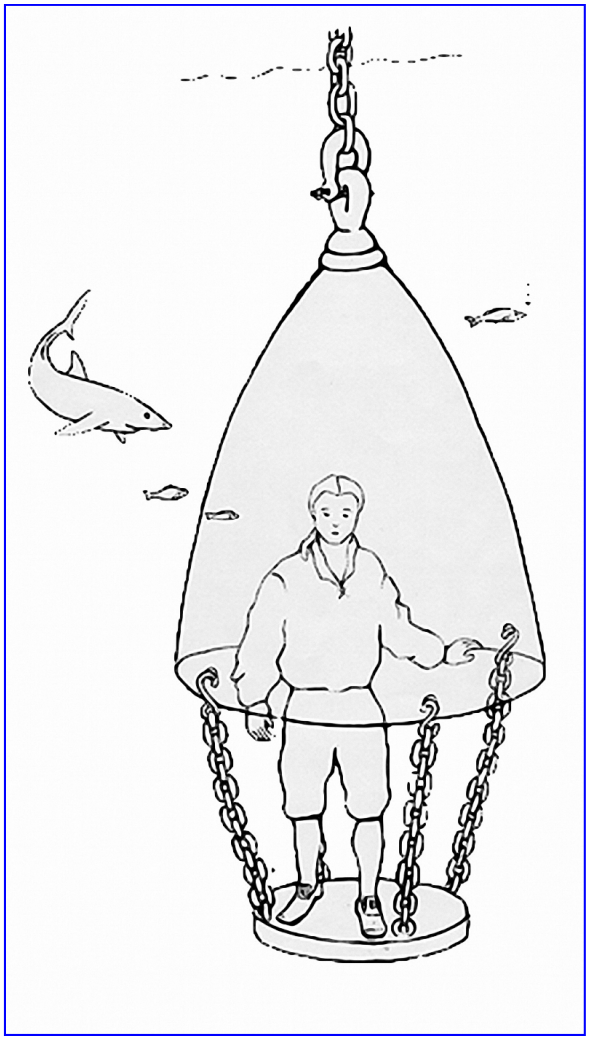

Image 3 | Rudimentary Diving Bell

usable oxygen was exhausted. Though the diving bell in rudimentary form is mentioned by Aristotle, the device was not fully practicable until the early 16th century when Guglielmo de Loreno developed what is considered to be a true diving bell.

Early attempts at increasing the pressure in the bell were largely unsuccessful until 1771, when John Smeaton invented the air pump. A hose was connected between the air pump and the diving barrel, allowing air to be pumped to the diver. However, increasing air pressure in order to keep water at bay, both underwater and in mine shafts brought with it a new set of complications. In 1670, Robert Boyle observed a gas bubble in the eye of a snake that he had put under atmospheric compression and then quickly decompressed. This was the first recorded observation of decompression sickness. Boyle concluded that the bubble was a consequence of previously dissolved gas. This conclusion manifested itself as Boyle's Law, which states that at a constant temperature, the volume of a gas is inversely proportional to its pressure. This basically means that a gas will compress proportionately to the amount of pressure exerted on it.

It was almost two centuries later that Boyle's discovery was applied to humans. In 1841 a mining engineer reported observing pain and muscle cramps among coal miners working in mine shafts where compressed air was used to force water from the tunnels. Like the snake in Boyle's experiment, the miners apparently suffered no ill effects while under pressure. However, after they left the pressurized regions of the mine, they were beset with muscular pains and cramps. It wasn't until 1876 when nitrogen was implicated in this "Decompression Sickness". Decompression sickness later became known as "The Bends". The bent posture of afflicted individuals approximated the 'Grecian Bend', a fashion posture assumed by women of the period caused by wearing corsets, crinolettes and bustles. Although the term "The Bends" is often used to describe decompression sickness, it is only one manifestation of the condition. Other symptoms can be itching skin and rashes, joint pain, nervous system failure, paralysis and death.

Years later, workers constructing the tunnel beneath the Hudson River or working in the pressurized caissons for the Brooklyn bridge supports also came down with decompression sickness. Almost one quarter of the workers died in these construction projects. When affected workers were treated by recompression and relatively slow decompression, the death rate dropped dramatically. This treatment was effective because increasing the pressure forced the nitrogen bubbles to re-dissolve into the blood stream and body tissues. The slow decompression allowed the dissolved nitrogen to circulate to the lungs and be exhaled under normal breathing.

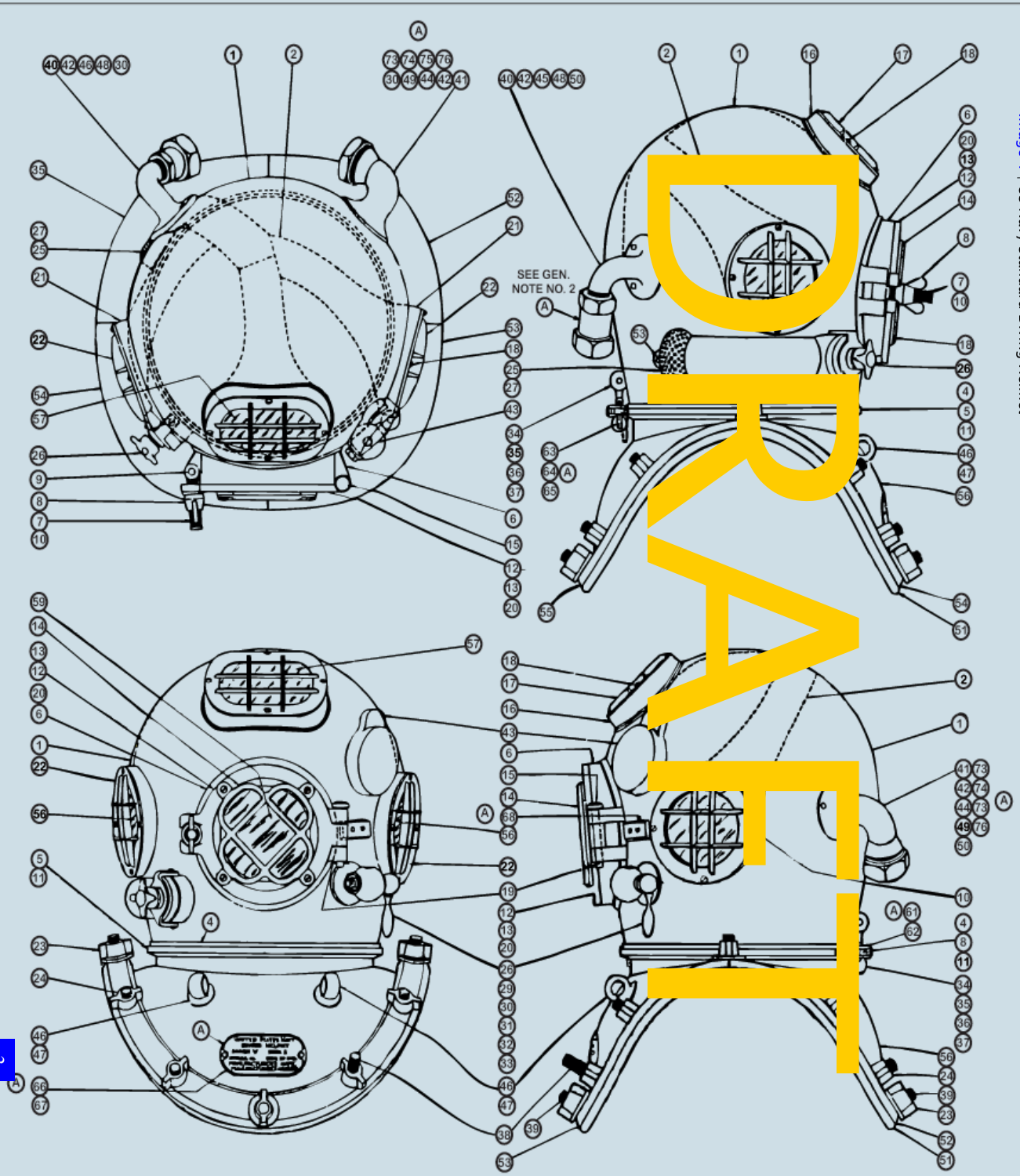

Image 4 | US Navy Standard Diving Helmet

REVISIONS

REV.	DATE	DESCRIPTION	APPROVED
A	11/14/41	APPROVED BY CAPT MARK V. HELMKAMP U.S. NAVY SUPERVISOR OF DIVING "NOT A CERTIFIED DIVING APARATUS"	
B	11/14/44	LOCKING DEVICE AND GEN. NOTES NO.'S. 1, 3, 4. AND 8 ADDED. ALTERED LEGEND ON NAME PLATE ALSO ON NOTE NO. 1 TO 11 ADDITION OF NEW SHEETS NO.'S 2 AND 10 TO SET. PAGE NUMBERS CHANGED FROM 007 TO 008. TITLE ALTERED TO COVER ADDITIONAL SHEETS. CORRECTIONS MADE TO DRAWING, ADDED PCS 13, 74, 76, & 78.	
C	12/14/44	PC 77 ADDED TO GENERAL NOTE NO. 1	
D	7/29/47	PLAN NUMBER CHANGED FROM BU.NO. 417976 TO BU.NO.S9400-921583.	
E	12/15/56	PLAN NUMBER CHANGED FROM "STANDARD PLAN" TO "HULL STANDARD PLAN."	

GENERAL NOTES

1. PC. NO. 1 & 68 SHOWN ON SHEET NO. 2 BU.NO.S9400-921591
" " 2 & 3 " " 3 " " " -921584
" " 4 TO 11 INCL. " " 4 " " " -921585
" " 12 20 " " " 5 " " " -921586
" " 21 39 " " " 6 " " " -921587
" " 40 50 " " " 7 " " " -921588
" " 51 55 " " " 8 " " " -921589
" " 56 59 " " " 9 " " " -921590
" " 60 " " " 7 " " " -921588
" " 61 65 " " " 6 " " " -921587
" " 66 67 " " " 9 " " " -921590
" " 68 70 " " " 10 " " " -921593
" " 71 72 " " " 8 " " " -921589
" " 73 77 " " " 7 " " " -921588
2. DIVERS AIR AND EXHAUST VALVES SHOWN ON BU.NO.S9400-921580 SHALL BE FURNISHED AS PART OF HELMET CONTRACT.
3. WELDING LENS FACE PLATE SHOWN ON BUREAU NO S9400-921582 SHALL NOT BE FURNISHED AS PART OF HELMET CONTRACT.
4. FOR DIVERS DRESS SEE BUREAU PLAN NO'S. 583407 AND 583408.
5. METHOD OF FASTENING ATTACHMENTS TO HELMET SHELL AND COLLAR:
THE HELMET PC.1 AND THE COLLAR PC.56 ARE TINNED IN WAY OF THE FAYING SURFACES OF ALL PARTS INTENDED FOR ATTACHMENT.
THE WINDOW FRAMES PCS. 6, 21, AND 16; THE AIR DUCT PC.2; THE TELEPHONE CUP PC. 43; THE PAD FOR WELDING CLIP PC. 68 AND THE SCREW RING (FEMALE) PC.4 ARE SECURED TO THE HELMET SHELL PC. 1 BY TINNING AND SWEATING TIGHT. THE SCREW RING (MALE) PC. 5 IS SECURED TO COLLAR PC 56 IN THE SAME MANNER.
THE GOOSENECKS PCS. 40 AND 41 TOGETHER WITH THEIR WASHERS PC. 42 ARE FIRST TINNED AND AFTER SECURELY FASTENING THEM TO THE HELMET PC. 1 BY COPPER RIVETS, THEY ARE SWEATED TIGHT.
THE COLLAR RING PC. 51 IS FIRST FORMED TO FIT THE COLLAR SHELL PC. 56 AND BOTH ARE TINNED. THE SKIRT OF THE COLLAR SHELL IS THEN WORKED NEATLY AROUND THE OUTER EDGE OF THE RING AND THE TWO SURFACES SWEATED TOGETHER. BEAD PC. 71 SOLDERED ON TOP OF RING.
THE OUTLET EXHAUST BODY PC.25 AND ITS THREADED WASHER PC. 27 ARE FIRST TINNED. THE AFTER END OF THE VALVE BODY IS SECURELY COPPER RIVETED TO THE HELMET SHELL PC. 1 AND THE THREADED WASHER PC. 27 IS SCREWED ON AND SWEATED TIGHT. THE WHOLE BODY THEN SWEATED TIGHT.
THE BALL SPIT COCK PC. 28 AND ITS THREADED WASHER PC 32 SHALL BE SECURED IN THE SAME MANNER.
THE SAFETY LOCK BRACKET PC. 34 AND THE WASHER PC. 37 ALSO, THE EYELETS PC. 46 WITH THEIR WASHERS PC. 47 SHALL BE FIRST TINNED, THEN RIVETED UP AND SWEATED TIGHT.
THE STUDS PCS. 36 AND 39 SHALL PASS THROUGH THE COLLAR RING PC. 51 AND THE HEADS SHALL BE SOLDERED TIGHT ON THE INSIDE OF THE COLLAR SHELL PC. 56.
THE NAME PLATE SHALL BE SECURED BY BRASS RIVETS MADE WATER TIGHT BY SOLDERING ON THE INSIDE.
THE SOLDER USED CONSISTS OF MIXTURE OF EQUAL QUANTITIES OF LEAD AND TIN.

THIS PLAN SUPERSEDES BU. NO.417976.

N

DRAWN BY: Fred K. Orr, JR. (USN) E. T. Ellsworth
EXAMINED BY: Thomas D. Smith (USN)
IN CHARGE OF: T. B. Gay
PRINCIPLE ENGINEER
DATE:

HULL STANDARD PLAN

NAVY STANDARD DIVING HELMET

MARK V MOD. I

GENERAL ARRANGEMENT

10 SHEETS SCALE 6" = 1 FOOT SHEET I

NAVY DEPARTMENT

BUREAU OF SHIPS

WASHINGTON, D.C. APRIL 6, 1948

Mark V. Helmkamp
FOR CHIEF OF BUREAU

BU.NO.S9400-921583 REV D

Around the same time that decompression sickness was beginning to be understood, Charles Anthony Deane patented a "smoke helmet" for fire fighters. Not surprisingly the helmet was also used for diving. The helmet enclosed the wearers head and was held on with weights, with air being supplied through a connecting hose. Deane marketed the helmet with a "diving suit". The suit was not attached to the helmet, but secured with straps. Augustus Siebe later sealed the Deane diving helmet to a watertight, rubber suit. This suit was used during the salvage of the British warship HMS Royal George in 1834 - 36. The improved suit was adopted as the standard diving dress by the Royal Engineers and was utilized extensively when the Royal Navy established the first diving school in1843

During the next 60 years a number of improvements in the diving suit were made, including the innovation of using a compressed air tank on the divers back which connected to a valve and a mouth-piece. The diver still used a hose attached to a surface pump to replenish the tank, but it was possible to disconnect and “free swim” for several minutes relying on just the air reservoir in the tank. Also great strides were made in the understanding of decompression sickness and the methods used to try to mitigate their effects. This culminated in the US Navy testing dive tables published by Haldane, Boycott and Damant in 1912. The tables were derived from a paper on decompression sickness by the three men in 1908 called; "The Prevention of Compressed-Air Illness".

It wasn’t until 1917 when the first true diving helmet was manufactured. The U.S. Bureau of Construction and Repair introduced the now familiar Mark V Diving Helmet. This helmet became the mainstay of underwater work and a standard piece of U.S. Navy Diving equipment. It was used for most of the salvage work carried out during World War II.

Two years later in 1919, Professor Elihu Thompson, an electronics engineer and inventor, reasoned that decompression sickness might be avoided if the nitrogen in the diver’s air mixture were diluted with another gas. He suggested that helium would be a suitable gas for deep diving. Helium is tasteless, odorless, colorless, normally nontoxic, and the second most abundant element in existence. Helium is also the only substance that never solidifies under normal pressure, even at absolute zero. Quite literally, hell will freeze over long before helium does. The problem at the time was that helium was incredibly expensive so very few people were able to test Thompson’s theory. However, a series of experimental dives were carried out on the U.S.S. Falcon, which included at least one dive to 150 feet using a heliox mixture. Following a discovery that helium was present in vast quantities under the American Great Plains, as a constituent of natural gas, the United States attained a virtual monopoly on the world's supply of helium. In fact, for many years the USA produced over 90% of the world’s commercially usable helium. This new found abundance dropped the price of helium to a few cents per cubic foot.

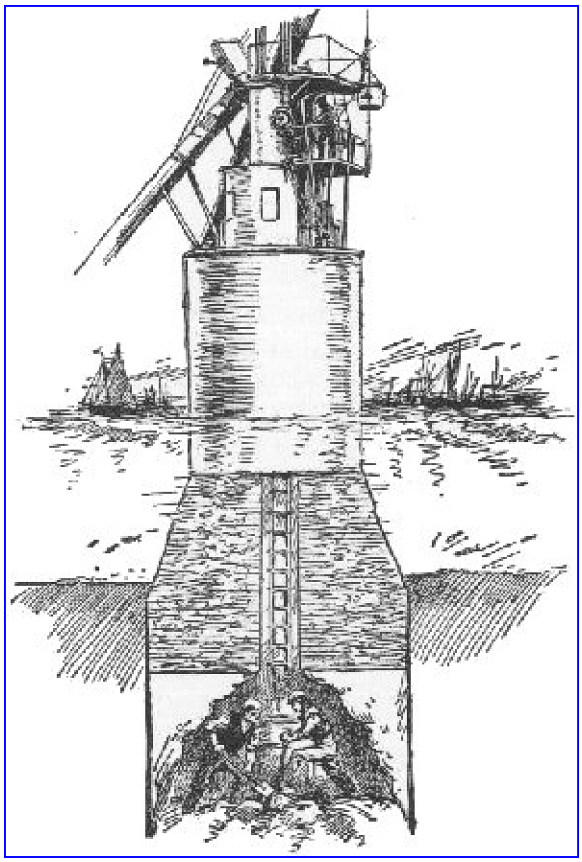

Image 5 | Pressurized Caisson

The US Navy begin examining the potential for deep diving using helium and oxygen as a breathing gas mix and by 1925 a research laboratory had been established in Pittsburgh to carry out lab animal experimentation using various gas combinations. This work established that animals and humans breathing an 80 % helium / 20% oxygen mix could be decompressed at between 1/6 and 1/4 the decompression time of that using air. The bonus was that divers using an 80 / 20 mix could function "clear headed" at depths where air breathing divers were incapacitated by nitrogen narcosis.

Image 6 | Diver on USS Walke -1914

Thompson's also came up with the idea for a re-breather. Although it took many years and the development of high efficiency absorbents before his postulations became a reality. Thompson suggested that since the helium was not consumed by the metabolic process of breathing, it could be recycled and used continuously during the dive. All it took was the mechanism to remove the carbon dioxide exhaled by the diver.

An interesting historical footnote has the famous escapologist Harry Houdini obtaining a patent on an inherently safer diving suit in 1921. The objective of Houdini's diving suit was to allow a diver to extract themselves from the suit while underwater in a situation where the air supply failed. It also allowed a diver to don his suit without needing assistance. It accomplished this by being formed in two halves, with a locking joint in the middle. In an emergency the diver could reach this joint and release it, and then escape from the suit.

The next great technological leaps happened in the 1930s and 1940s. Guy Gilpatric pioneered the use of rubber goggles with glass lenses for skin diving and by the mid 1930s, face masks and snorkels were in common use. The patent for fins was filed in 1933 by Louis de Corlieu and his simple invention increased the efficiency of movement underwater tremendously. 1933 also saw the first time that a diver could be freed for hoses and lines for extended periods of time thanks to Yves Le Prieur combining a demand valve with a high pressure air tank.

However, undoubtedly, the single most important invention which allowed a human freedom underwater didn't appear until 1943. That is when Jacques Yves Cousteau and Emile Gagnan designed a spring loaded diaphragm regulator open to the sea. The regulator ensured that air would always be delivered at a pressure equal to that of the surround water and hence the diver could breathe comfortably. Cousteau called the invention the Aqua Lung. Over the years there have been refinements to the original design but that original piece of equipment revolutionized diving.

Although the Aqua Lung allowed unparalleled freedom of movement underwater it did not remove the necessity for decompression stops if the diver remained underwater for extended periods. The joke among scuba divers is that that there are two ways to avoid decompression sickness: "don't go down, or don't come up". The "don't go down" part is easy, the "don't come up" bit is more difficult but 'Saturation Diving' effectively takes care of it. Saturation diving allows humans to live and work at sustained depths for days, weeks or even months at a time. The technique uses the principle that after about 24 hours at any working depth, a diver's

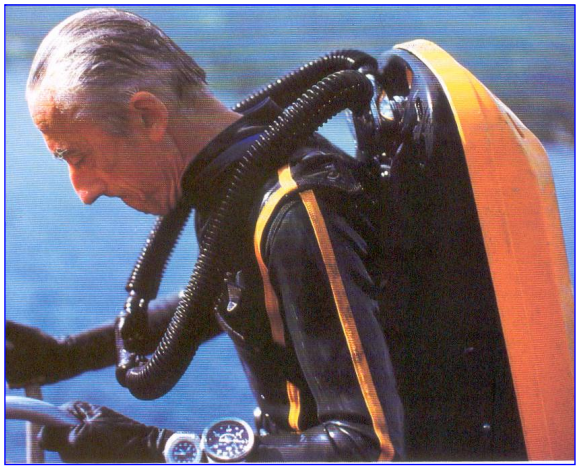

Image 7 | Jacques Cousteau

body becomes saturated with dissolved gas. Once the body is saturated, decompression time is the same regardless of how much time has been spent underwater. The dive team is only compressed to the working pressure once, and decompressed to surface pressure once, over the entire work period.

Although the first intentional saturation dive was done in 1938, the technique did not really begin to be fully tested until the early 1960s when the 'Man in the Sea' and 'Conshelf' programs began. Despite the fact that Ed Link's initial 'Man in the Sea' experiment lasted only 8 hours, Albert Falco and Claude Wesley lived for seven days in the first 'Conshelf' which was basically just a large cylinder submerged in 10 meters of water.

With the advent of the Aqua Lung and saturation diving, humans could now effectively live and work underwater for considerable periods of time. However, they were still limited to relatively shallow depths. It is a immutable law that not only does your bottom time decrease the deeper you go but the water pressure acting on your body increases also. It is a simple relationship which dictates that a diver will experience an increase of one atmosphere of pressure approximately every 10 meters of descent.

In order to allow exploration but not necessarily work at depth, bathyspheres and bathyscaphes were developed. The difference being that a bathysphere is unpowered and tethered to a surface vessel whereas the bathyscaph is free diving and self propelled. The first bathyscaph was invented by Auguste Piccard and built in Belgium between 1946 and 1948. Propulsion was provided by battery-driven electric motors. He composed the name bathyscaph using the Greek words bathys ("deep") and skaphos ("ship"). In 1960, Piccard's second bathyscaph, the '*Trieste*', carrying Piccard's son; Jacques, and Lt. Don Walsh descended to the deepest point on the earth's surface, the Challenger Deep, in the Mariana Trench. They reached a depth of 35,813 feet (10,916 meters), a record which has remained unbroken.

Probably the most famous of all bathyscaphes or submersibles as they are now known, is the DSV Alvin. It is owned by the US Navy and operated by the Woods Hole Oceanographic Institution and was commissioned in 1964. Alvin was involved in Dr. Robert Ballard's exploration of the wreckage of RMS *Titanic* in 1986. Alvin,

Image 8 | 1-atm dive suit used to explored the Lusitania wreck in 1935

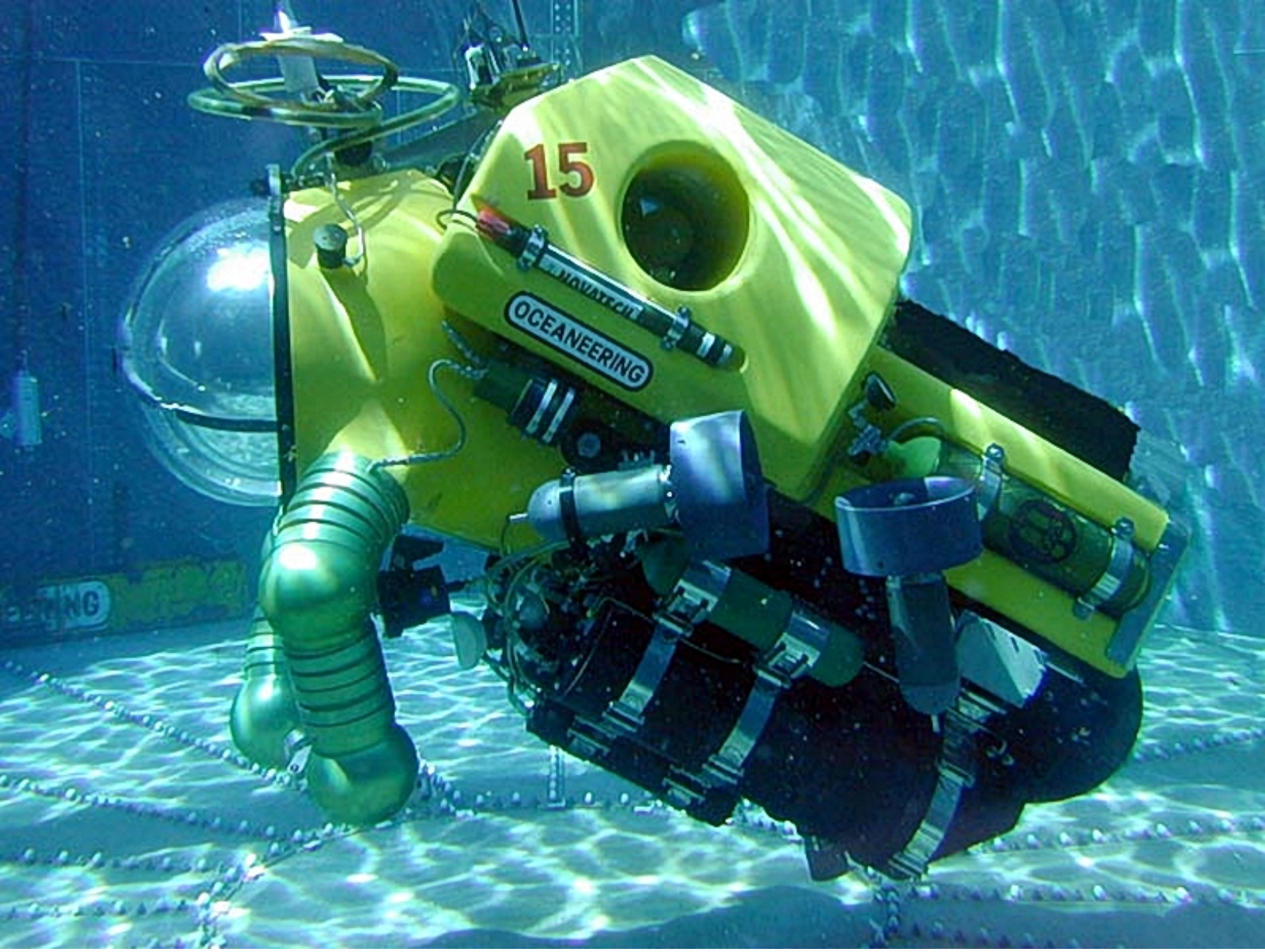

Image 9 | WASP suit

which launched a small remotely operated vehicle, named Jason Jr., was able to conduct detailed photographic surveys and inspections of the Titanic's wreckage.

When it comes to beating the phrase “don’t go down or don’t come up” there is one other method which also originates from the late 1960s, and that is to use an atmospheric diving suit (ADS), the most famous of which is the JIM suit. The JIM Suit is designed to maintain an interior pressure of one atmosphere no matter what depth or water pressure it is subject to. By maintaining one atmosphere the diver doesn’t need to decompress, there is no need for special gas mixtures, and there is no danger of either nitrogen narcosis or decompression sickness.

The first JIM suit, invented by Mike Humphrey and Mike Borrow, was completed in November 1971 and in trials reached depths in excess of 400 feet (121 meters). It was expected that the offshore industry would beat a path to its door, but the reception was strangely cold. It was not until 1975, when Oceaneering acquired exclusive rights to the application of JIM suits in the oilfields, that the suit achieved success. Oceaneering now operate a number of atmospheric diving suits including the WASP IV, designed by Graham Hawkes, which can operate at depths of 700 meters.

One of the other indispensable items used by the early divers was the dive watch. Nowadays most dives are timed using a dive computer but many people still wear a dive watch as a back up. There is some debate as to who produced the first dive watches, and it is no surprise that “big names” like; Blancpain, Omega, Panerai and Rolex all vie for the claim. However, general consent seems to indicate that the Omega Marine introduced in 1932 probably takes the prize.

Image 10 | DOXA SUB 300T with Helium Release Valve

One of the innovations of the dive watch was the graduated bezel which allowed a diver to set the time he entered the water and hence have a more accurate indication of his time spent subsurface. That type of bezel remained constant until 1967 when Doxa, along with producing a dive watch with large luminous markers and a bright orange dial, released the SUB 300 which incorporated a Non Decompression Dive Table in the bezel.

In 1969 Doxa introduced a dive watch with a Helium Release Valve (HRV) to the general public. Both Doxa and Rolex, who hold the patent, worked together on the development of the HRV. While Doxa worked with Jacques Cousteau and Claude Wesley, Rolex enlisted the help of Comex divers to test their HRV equipped Submariner. They released the HRV Sea-Dweller in 1971.

So what is the big deal about having a HRV? Is it really necessary and what does it do? Well, if you are a saturation diver, then yes. If you are a normally aspirated diver, then no. What it does is allow trapped helium to be vented from the watch as the diver decompresses.

Saturation divers breathe a mixture of gases which include helium. Because of its molecular size, helium is able to bypass the water tight rubber seals and invade the inside of a watch. Consequently during decompression the gas will expand and unless it is vented, the buildup of pressure can blow the crystal off the watch. In order to allow continuous venting of the helium, a simple non return valve was incorporated into the side of the case.

Thanks to technology and the inventiveness of a number of very clever people through the ages, we really have come a long way with regards to exploration of the underwater world. Man, is now able to live and work and play beneath the waves with relative ease and safety, but we have really reached a plateau and the next steps seem like the stuff of science fiction.

Fish breathe underwater because they have gills which extract oxygen from the surround water. What if we could develop artificial gills to do the same thing? There is ongoing research to try to do such a thing. In 2001 an inventor developed an underwater breathing system that literally squeezes oxygen directly from seawater, doing away with the need for compressed air tanks. His hopes are that one day reduce the size of the apparatus, taking it down to a small, lightweight vest for divers.

Many people saw the James Cameron movie; *The Abyss,* in which a scene shows Ed Harris seemingly breathing through the use of a liquid. There was also a scene showing a rat submerged in and breathing fluorocarbon liquid. For Ed Harris it was pure movie magic but the rat was for real. There has been a great deal of research done on what are called Perfluorocarbons. These have been investigated for decades as an oxygen rich liquid which could fill the lungs and be breathed, instead of air or oxygen gas. Unfortunately, while limited success has been achieved with mice and rats, it is still not feasible for larger mammals, but, who knows, maybe one day. By the way the rat survived it's movie experience.

No matter what technological marvels appear in the future to make diving and underwater life safer and more practical, one thing is for sure, after several million years away, it looks like we have now come home.