PART 3
THE HISTORY OF DIVING

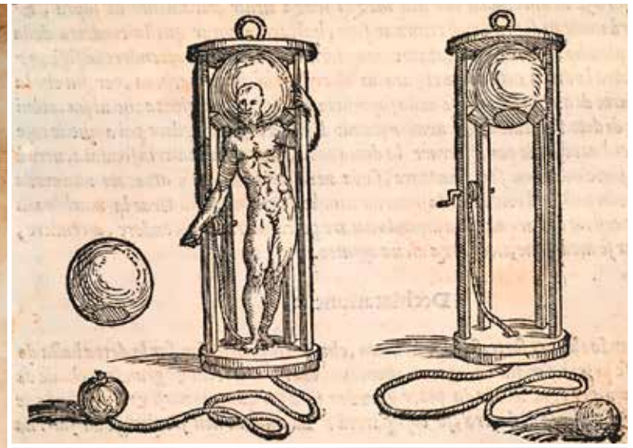
WORDS BY **PATRICK VAN HOESERLANDE**

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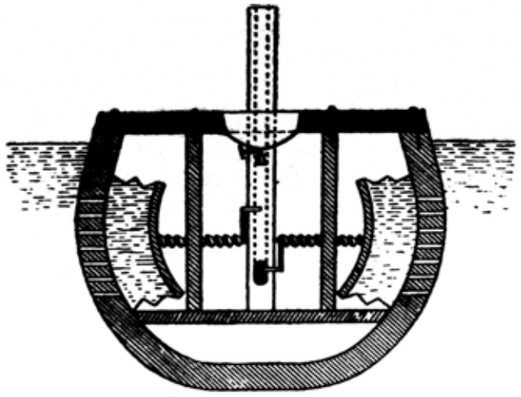
COVER PHOTO: An Experiment on a bird in an air pump by Joseph Wright of Derby, 1768.

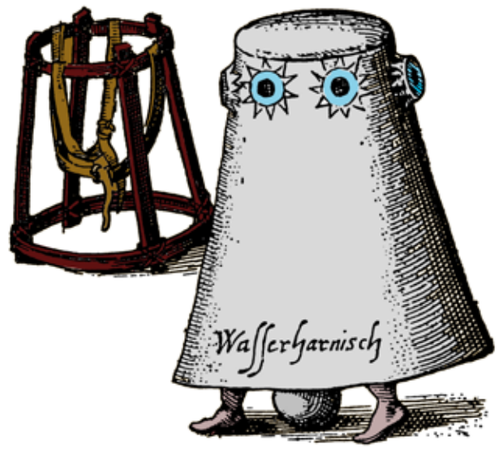
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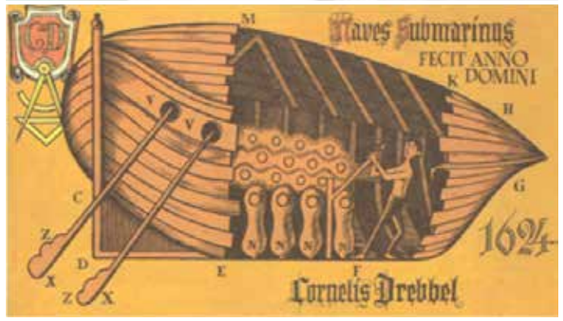












ABOVE: 1538 diving bell for 2 persons by Midjourney – Ivo Madder; Nicholas Tartaglia's diving machine; William Bourne's 'diving chamber', or sumarine.

ABOVE: William Bourne's 'diving chamber illustration; Franz Kessler's walking diving bell; Cornelis Drebbel's submarine on display, and the illustration below.

We ended the previous article in 1531 with the earliest use of a diving bell during the first underwater archaeological research conducted by the Italians, Guglielmo de Lorena and Francesco de Marchi on their discovery of the luxurious pleasure galleys of the Roman Emperor, Caligula. In just a few weeks, they found these sunken ships and their treasures, while others had searched Lake Nemi for years without success.

However, finding the sunken ships and successfully salvaging the treasures did not mark the beginning of the diving bell's heyday.

FIRST MULTI-PERSON DIVING BELL

The next practical conquest of the deep came sometime around 1538. In that year, two unknown Greeks (although some believe that one of them may have been the Italian Lorena) gave a demonstration in Toledo, Spain, in the presence of Emperor Charles V and more than 10,000 spectators. Sitting on planks mounted in the diving bell, these 'Greeks' slowly lowered themselves to the bottom of the Tagus River. To enhance the dramatic effect, but probably also to avoid being in complete darkness, and as an indication of the presence of sufficient oxygen, they lit a candle. The fact that the candle was still burning after an hour underwater seemed to amaze the audience the most.

Despite the successful outcome of this demonstration, the diving bell itself was not yet a success. However, that did not mean that others did not attempt to build a diving bell.

UNUSUAL DESIGN

In 1551, the Italian Nicholas Tartaglia (1499/1500-1557) designed the 'Diving Machine'. The diving apparatus of this mathematician, accountant, and engineer resembled a huge hourglass. A wooden frame held a glass sphere in place, into which the diver had to put his head. Inside, the diver could breathe and had a good view of the underwater world. The whole thing, together with a very heavy weight, was lowered down on a thick rope. At least, that was the intention. An impractical and peculiar design, about which little is known.

FIRST RECORDED DESIGN OF A 'DIVING CHAMBER' OR SUBMARINE

In 1578, William Bourne (1535-1582), an English mathematician and former gunner in the Royal Navy, drew the first recorded plans for underwater navigation. His design was a completely enclosed boat made of wood bound in waterproof leather. This enclosed boat could dive and move forward under the water's surface using oars. Borne's submarine design was based on ballast tanks that could be filled to submerge, and blown to return to the surface. The same principle is still used in modern submarines.

Diving chambers offered a solution for working in turbulent waters as diving bells were unable to do so due to the risk of capsizing, which would result in certain death for the inhabitants. William Bourne published a book in 1578 entitled 'Inventions or Devises'. This visionary work contained more than a hundred ideas relating to maritime and military matters and provided practical solutions to many problems, either by proposing techniques (devices) or inventions. Among other things, he explained how to make a telescope (Hans Lippershey is usually credited with making the first telescope in 1608, as he was the first to apply for a patent for it). With his 'Device 18', he proposed two methods by which a ship could submerge itself underwater and then rise to the surface, while providing air to its occupants. What he proposed was (in modern terms) nothing less than a submarine with water ballast tanks and a snorkel. Bourne described how these ballast tanks should be built and operated. In principle, this amounted to internal watertight chambers on either side of the boat, with holes drilled into the side of the boat. This allowed water to enter for diving and was expelled using screw-operated 'pistons' to rise again.

"… you must have one mast, and must be of sufficient bigness, that it must have a hole bored through the one end unto the other… for the hole that goeth through the mast must give you air, as man cannot live without it." Bourne even came up with a watertight hatch: "… then for the hatch or skotel, that you must go in or out, you must have leather round about it, that you may bring that together as a purse mouth, and so with a small screw, you may wind it so close together, that being in the bottom of the water, there shall no water come in…" It would take another 200 years before water ballast tanks or a snorkel were first used in a functional submarine.

This diving chamber was never built, and although we know that the principle was followed in the construction of the first submarine some four decades later, for almost a century and a half, no one seemed to show much interest.

WALKING DIVING BELL

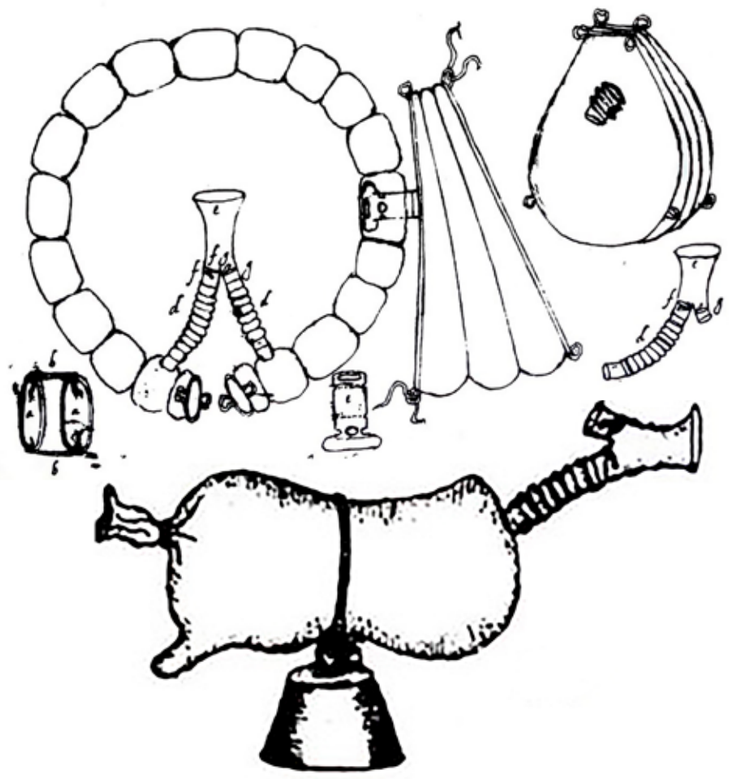
The diving chamber may not have been popular, but the diving bell slowly began to gain ground. In 1616, the portrait painter, inventor, and alchemist Franz Kessler (1580-1650) designed a one-person diving bell. In his model, the diver sat in a frame on which a heavy, bell-shaped metal casing rested. The diver could view his surroundings through a series of small holes. The whole thing was slightly heavier than neutral buoyancy, so that the diver could walk along the bottom without much effort. However, walking was not without risks, because the slightest misstep could cause the whole thing to tip over, trapping the diver under the heavy structure and probably resulting in drowning.

THE 'FIRST' SUCCESSFUL SUBMARINE

Various sources mention the submersible rowing boat that Cornelis Drebbel designed and built in 1620 as the first successful submarine. Meanwhile, you have read that, if we are to believe the writings of the Swedish historian Olaf Magnus, the Greenlanders had already achieved this in 1505 with a similar concept. Nevertheless, Drebbel deserves to be mentioned.

Drebbel, a Dutch inventor and naturalist who lived in London for much of his life, built two successful experimental submarines between 1620 and 1624. When building his submarines, Drebbel adopted some of William Bourne's ideas. Drebbel's third boat was made of wood covered with tight-fitting sheets of greased leather and could accommodate twelve rowers and eight passengers. Oars protruding from the sides of the boat through flexible leather seals propelled the boat through the water. Amazingly, the vessel could dive to a depth of 20 metres (3 bar!) and travel 10km. It made several hour-long trips from Greenwich to Westminster at an average depth of 4 metres under the surface of the River Thames.

Drebbel was also the first to effectively address the oxygen problem during the dives with this submarine. How he did this is still a matter of debate. Some believe that the submarine had two tubes with snorkels, which were kept above the water with floats, thus supplying the submerged vessel with air. Others believe that Drebbel created oxygen by heating sulphur



ABOVE: Two of Fleming Valangren's breathing devices from 1631.

and potassium nitrate. Either way, atmospheric pressure prevailed inside the submarine.

According to tradition, Drebbel even took King James I on a test dive in his submarine, making the latter the first monarch to travel underwater. Despite consistent, successful dives and the royal passenger, the submarine never aroused enough interest in the navy to investigate how this new type of boat could be used in battle. We would have to wait a long time for that.

FIRST KNOWN INSTANCE OF AIR BEING PUMPED TO A DIVER AND THE FIRST DESIGN OF A SNORKEL

In Spain, a country that was virtually constantly at war during the sixteenth, seventeenth, and eighteenth century, inventors were particularly busy. Spanish archives are full of early SCUBA designs, some promising, others downright ridiculous. In 1631, during the Dutch domination of the high seas, Spain was drifting toward bankruptcy because Dutch ships were capturing many Spanish ships carrying treasures from the New World. To remedy this situation, a desperate King Philip IV offered 10,000 ducats to anyone who could make usable SCUBA equipment. According to spies, there were sometimes as many as 500 ships in the ports of Amsterdam and Rotterdam. Relying on this information, King Philip planned to send divers to one or both ports during a storm to cut anchor cables so that these ships would collide with each other. Because the Dutch had sentries on all their ships, the plan could only work if the divers were not discovered. A special commission was appointed to study the designs that poured in from all corners of the Spanish Empire. None of the designs were deemed feasible, and the plan to deal the Dutch a stormy death blow had to be abandoned.

Although no design was found suitable for the operation, there were a number of very interesting proposals, including three submissions by the Flemish inventor, Florencio Valangren. The first was a long breathing tube, similar to designs already devised by other inventors, but unusable for more than shallow snorkelling. However, his design had an original touch: an exhaust valve at the bottom of the tube to easily evacuate exhaled air. The second design was also a tube, but the end was connected to a bellow above the surface. This is the first known case of air being pumped to a diver, more than 60 years older than Papin's proposal. The device allowed a diver to work in deeper water. According to Valangren's accompanying letter, similar devices were in use in Flanders and the Netherlands, mainly for repair work on ships.

The third design, the only very primitive design of a SCUBA, consisted of a large bag made of animal skin that was pumped full of air by bellows and dropped to the seabed with weights. Attached to the skin bag was a tube with a mouthpiece that could be opened by the diver when he needed to breathe while swimming freely in the water. The letter stated that this device, like the tube-bellow combination, was in use. There is no reason to doubt this: with an air bag made from cowhide and lowered to a depth of 6 metres, a trained free diver could stay there for fifteen minutes.

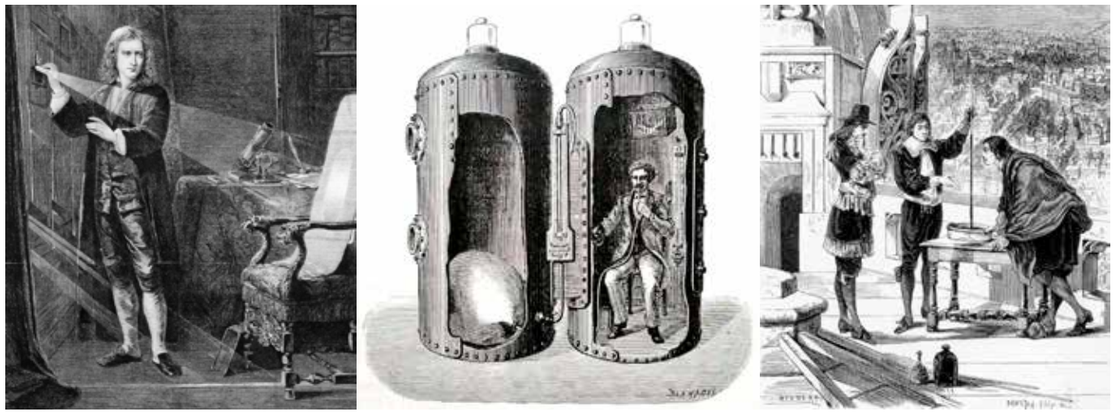
Another anonymous invention sent to Filip was even more interesting, as it took the development of SCUBA equipment a step further. It consisted of a tubular air reservoir worn like a belt and probably made from animal intestines. At one end was a mouthpiece and at the other a bellow that allowed the diver to draw air from the surface without assistance. The air reservoir was too small to hold much air, but an experienced free diver could dive for up to ten minutes before having to refill the air reservoir.

THE FIRST AIR PUMP

Until then, a bellow was the only way to get air to a diver. A bellow can move a large amount of air (a popular feature amongst blacksmiths), but its flexible walls means it can't build up much pressure. This limits the depth at which a diver can operate. To open the gates to greater depths, we needed the inventiveness of Otto von Guericke (1602-1686), a German scientist, inventor, and politician. In 1650, he succeeded in building the first effective air pump. This air pump was used in the Magdeburg experiment, in which horses failed to separate two hemispheres held together by a pressure lower than the ambient pressure.

WIND-UP SUBMARINE

In Rotterdam, a Frenchman named De Son decided to build a submarine, and in order to attract investors, he claimed to have an invention. The power of advertising must have been limited at that time, because De Son had to build his submarine largely at his own expense. The submarine was about 24 metres long and 2.5 metres wide. It was made of wood, reinforced with iron beams. At the front and rear, there were large iron rams for attacking enemy ships. Propulsion was provided by a large, spring-driven paddle wheel in the middle of the vessel, half submerged in the water. During tests while the submarine, which was in fact a ship, was moored at the quay, the wheel worked well and provided 'propulsion' for eight hours before it had to be rewound. Once the ship was launched, it turned out that the clockwork mechanism was not strong enough to set the paddle wheel in motion. The fact that water has a greater density and weight than air, had escaped the builder's attention. The invention was a failure. To recoup some of the costs incurred, De Son turned the boat into an exhibition for which curious visitors had to pay an entrance fee. De Son's fiasco probably discouraged future inventors, because there followed a long period of silence surrounding submarines.



ABOVE L-R: French physicist and priest, Edme Mariotte; Nathaniel Henshaw's hyperbaric chamber; Blaise Pascal's experiments on pressure.

KNOWLEDGE ON THE RELATIONSHIP BETWEEN TEMPERATURE & VOLUME

Robert Boyle (1627-1691) was an Anglo-Irish natural philosopher, chemist, physicist, and inventor. He is now regarded as the first modern chemist and one of the pioneers of the modern, experimental, scientific method. We know him from Boyle's Law. The peculiar thing is that this law was never explicitly formulated in the works of this scholar.

In 1660, Boyle published the first edition of 'New Experiments Physico-Mechanical: Touching the Spring of the Air and their Effects', which described experiments that Boyle and his assistant Robert Hooke carried out to reduce air pressure. Boyle gave much more detail than modern scientists about the 43 different experiments with air and an air pump, among other things, and listed all the tedious measurements he had carried out. For example, he described the problems with glass shattering and the struggles with glass tubes that were so long that they had to be placed in a stairwell. Boyle and Hooke discovered that in a space with reduced pressure, sound travelled less well, liquids evaporated more quickly and animals died. Boyle, it turned out, could create a vacuum, or something close to it. The book proved controversial because it challenged the contemporary scientific knowledge. At that time, scientists believed that air was one of the four elements (air, earth, fire, and water), and a vacuum was therefore considered impossible.

What we know as Boyle's Law was originally published in 1662 in the appendix to the second edition of the book. This edition contained arguments intended to silence his scientific opponents, as well as a modest table of numbers showing the inverse relationship between the pressure and volume of air. Although it was never explicitly stated, Boyle's Law could be found by following Boyle's invitation to compare two columns in his table. The numbers were the result of an experiment in which Boyle and Hooke poured mercury into a glass J-shaped tube. This J-tube was closed at the short end and open at the long end. As they poured mercury, the air in the short end became more compressed. By measuring the height of the mercury, Boyle was in fact measuring the pressure of the enclosed air.

Hooke's role in the experiments is sometimes forgotten. Hooke built the version of the air pump used by his employer Boyle for the experiments. Fortunately, he is better known for his own law, Hooke's Law, based on his work with springs. There is a direct link between Hooke's work with the 'elasticity' of air and the relationship he found between force and the compression of a spring.

The dissemination of scientific knowledge was much slower then than in our digital world. In 1676, the French physicist and priest, Edme Mariotte (1620-1684), independently of Boyle's research, published his results demonstrating the inverse relationship between pressure and volume. Mariotte went a step further by stating that this relationship was only valid at a constant temperature. Thanks to his independent discovery, we know the law governing the relationship between pressure and volume as Boyle-Mariotte's Law. Mariotte is also known for designing the first 'Newton's cradle.' You may have seen this arrangement of colliding metal balls suspended on wires somewhere.

FIRST HYPERBARIC CHAMBER

The English priest and doctor Nathaniel Henshaw (1628-1673) claimed, without any scientific evidence, that higher pressure would alleviate emergency situations, while lower pressure would help with chronic conditions. A system of bellows with unidirectional valves was designed to increase or decrease the ambient pressure in an airtight chamber called the 'Domicilium.' Due to the use of bellows, the pressure difference probably did not exceed one metre of water (+/- 0.1 bar). Nevertheless, he believed that a therapy session in his 'Domicilium' would improve digestion and prevent lung diseases. Nothing was written about the increased oxygen concentration, as this gas had not yet been discovered. As far as is known, this hyperbaric chamber was never used in the treatment of a diving accident.

KNOWLEDGE ABOUT PRESSURE

Blaise Pascal (1623-1662) was a French mathematician, physicist, inventor, philosopher, and Catholic writer. He was a child prodigy raised by his father. Pascal's first mathematical work was on conic sections, and at the age of 16, he wrote an important treatise on projective geometry. Later, he corresponded with Pierre de Fermat on probability theory, which greatly influenced the development of modern economics and social science. In 1642, motivated to help his father in his profession as a tax collector in Rouen, he began pioneering work on calculating machines, which led to the development of the 'Pascaline' in 1645, the first real calculating machine. He used dials to enter whole numbers and could only add and subtract.

He then returned to his scientific interests and tested the theories of Galileo and Evangelista Torricelli (the Italian physicist who discovered the principle of the barometer). In doing so, he reproduced and expanded experiments with atmospheric pressure by building mercury barometers and measuring air pressure. These tests paved the way for further studies in hydrostatics and dynamics. His work in this field led later scientists to name the unit of pressure, 'the Pascal.' While experimenting, Pascal invented the syringe and created the hydraulic press, an instrument based on the principle that became known as Pascal's principle (sometimes also called Pascal's law): pressure exerted on an enclosed fluid is transmitted undiminished by the fluid in all directions, regardless of the surface on which the pressure is exerted. His publications on the problem of the vacuum (1647-1648) contributed to his reputation.

Some also know Pascal for his religious 'wager': if God does not exist, the sceptic loses nothing by believing in him; but if he does exist, the sceptic gains eternal life by believing in him.