# SEMI-ATMOSPHERIC DIVING SYSTEMS

John Bevan

**Key Words**
Equipment, history, occupational diving.

**Abstract**

Semi-atmospheric diving systems are those where a part of the diver's external body is maintained at atmospheric pressure and he breathes air at atmospheric pressure, while the remainder of his body is exposed to ambient water pressure. Two principal methods were used to achieve these ends. A self-contained system, where the diver took his air supply to the sea bed with him and a surface supplied system. Since the earliest reliable report of this type of diving system being used in 1660 by a Frenchman, Chevalier de Beauve, many aspiring divers have attempted to exploit the technique with varying degrees of success, ranging from acquisition of great wealth to sudden death. This paper describes the application of this poorly understood and appreciated diving technique which spanned nearly three centuries.

## Semi-atmospheric diving equipment

I coined this term in an attempt to define more clearly a significant branch of diving technique which is generally poorly understood, misunderstood and misrepresented. I define semi-atmospheric diving systems as those where a part of the diver's body is maintained at atmospheric pressure and he breathes air at atmospheric pressure, while the remainder of his body is exposed to ambient water pressure. Thus a snorkel is not considered to be included in this definition. But if, for example, the diver's head, or head and chest, or head, chest and legs, are encapsulated in a rigid container which maintains atmospheric pressure within, then it is included.

Two principal methods were used to achieve these ends. First, a self-contained system where the diver took his air supply with him to the sea bed. These are mainly the so-called "barrel divers" whose legs were enclosed within the atmospheric compartment and therefore they had limited lateral movement capability. And second, a surface-supplied system, where the diver received his air supply from the surface. These divers had the use of their legs to varying degrees depending on the design of the suit, and were therefore able to walk about on the sea bed in a manner equivalent to the standard helmet diver.

When described in this basic manner, the inherent problems associated with the technique's exploitation quickly become apparent to anyone with a knowledge of the effects of pressure imbalances. Two main points to bear in mind are the fact that the arterial blood pressure in a fit young man is about120 mmHg and the hydrostatic head of pressure below a depth in sea water of 1.6 metres is more than 120 mmHg. Therefore it follows that when adjacent parts of a human body are exposed simultaneously to atmospheric pressure on one side and water pressure in excess of 1.6 metres depth on the other side, the tendency will exist to collapse the veins, to prevent arterial blood circulation and to force blood back up the arteries. Needless to say, at the same time there would be an increasing pressure differential between the inside and outside of the atmospheric compartment of the diving dress, which would be attended by an increasing tendency for water to leak into the diving dress. Any major structural failure of the seals would be followed by an instantaneous and complete flooding. To ensure a strong seal at such points, such as around an arm or a leg, very tight bindings were used which were, in effect, tourniquets.

Despite all these impositions, for several centuries, the inevitable pain, physical trauma and risk of a horrible death were justified by the significant opportunities (either real or imagined) to accumulate great wealth. What is surprising is that it worked at all! This is reminiscent of Johnson's controversial pronouncement on women preachers being "like a dog's walking on his hinder legs. It is not done well; but you are surprised to find it done at all".[1]

Though not the first report of a semi-atmospheric system, the following account, dated 1763, by J T Desaguliers in England is given here because it gives a useful introduction to the mode of operation of a surface-supplied arrangement.[2] *... other inventions have been contrived for diving. One is a sort of a case of armour of copper represented at Figure* 3 [Figure 1], *to preserve the diver's body against the pressure of the water. This case consists of two pieces to be joined together on the body. AGBE is the piece for the head, and upper part of the body. The head has two copper pipes PP, to which are to be screwed several lengths of leathern pipes to reach up to the top, and communicate with the air at top of the water. These pipes are kept open by small hoops of brass or copper within the leather. There is a convex glass G before the face to look through to see objects under water. The piece E slides out, and then the diver having put in his left arm, and thro' the hole opposite to B gets in his body, and raises up his right arm from E to B, and puts it thro' the hole B, then the piece E is slid up and made water-tight, and held in place by a strong ring at E. The breeches or lower piece F being put on, besides the rings at E, is made fast to the upper piece by two bars with screws Cc, Dd. The arms and hands, as well as the thighs, and legs and feet being covered with leathern hose, these leathers are fastened to the rings at B, and on the other side, as also to the breeches at F. The air pipes being fastened at PP, the diver is let down into the water, where he works at the bottom, and has a small line to*

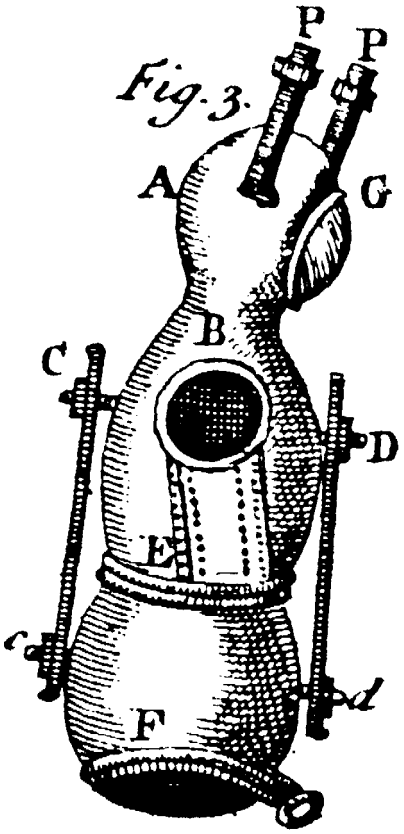


**Figure 1.** Figure 3 from Desaguliers.[2]

*pull and make signals when he would be drawn up again; or when he would have the boat above him move in any direction. See the diver with his tools Fig 4* [Figure 2] *and the air pipes going up at P, together with his line for signals.*

*This kind of diving machine has its inconveniences. 1. When the diver goes down to only a moderate depth, the lateral pressure of the water squeezes the air-pipes so strongly, that the assistants above are obliged to blow down air to the diver with bellows. But the greatest inconveniency is,*

*2. That when the depth is considerable, the diver, though his breast and the rest of his body be guarded against the pressure of the water, feels all the additional weight upon his arms and thighs, especially where his leathern hose are fastened to the armour, so as sometimes to stop the circulation of the blood, as some have experienced it to their cost. For the external air comes down to them from above being taken into the diver's lungs, has only the spring sufficient to bear the pressure of the common atmosphere, and above 1/8 more upon occasion as it is expanded about 1/8 by the heat of the human body: where-as the arms and thighs defended only by oiled leather, must bear all the pressure of the water according to its depth, besides what they used to bear above the ground. The uniformity of the pressure does indeed help a little, and these machines are much used, because the places where ships are usually cast away are but shallow. About 16 years ago I was informed that there had been granted about 14 patents for making*

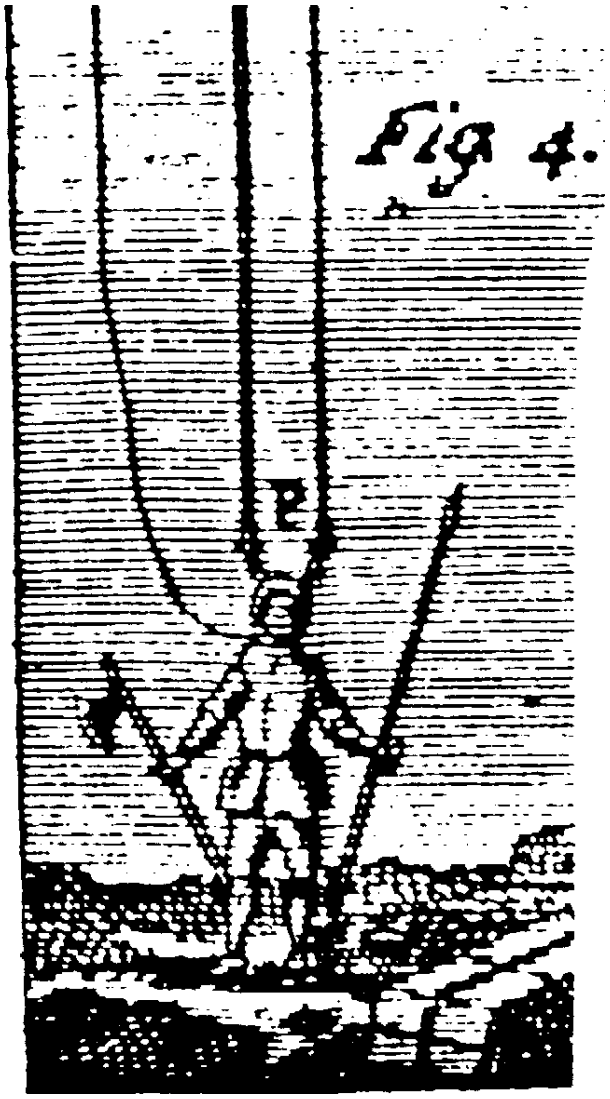


**Figure 2.** Figure 4 from Desaguliers.[2]

*these kind of instruments, several different persons having obtained those privileges, because in their improvements, which they called new inventions, they varied a little from those that had gone before them. For great depths, in which sometimes ships have been cast away, or to which they have sometimes slipped by length of time, where the shore has been steep, or in pearl and coral-fishing, these armour machines are quite useless .*

But the use of semi-atmospheric systems can be traced back much further. Chevalier de Beauve referred to the use of such a surface-supplied diving dress in 1660, in a letter to Chevalier de Borda. He also described how he himself dived in a similar suit to a depth of 8 metres at Dugay-Trorien at Rio de Janerio in 1711 and included detailed illustrations of the equipment which showed the rigid shell for the head and torso as well as the two pipes to the surface, one for supply and one for exhaust of the atmospheric air.[3] This design was to be copied many times again in the succeeding years.

**Barrel diving**

The most successful proponent of semi-atmospheric diving systems was undoubtedly John Lethbridge of Newton Abbott, Devon, England. He became the most famous of the "barrel divers", so-called because their diving suit was essentially a barrel (or some form of substitute) fitted with arrangements to allow the diver's arms to penetrate to the outside, where they were of course exposed to ambient pressure. The barrel itself was large enough to hold sufficient air for a dive lasting up to 30 minutes or more before being hauled back to the surface for flushing out or recharging with fresh air. The equipment therefore undeniably qualified as a self-contained semi-atmospheric diving system. Lethbridge had his diving engine built by a cooper in Stanhope Street, London. He described it as follows: *It* is *made of wainscot, perfectly round, about six feet in length* (1.8 m), *and about two and a half* (0.75 m) *diameter at the head, and about 18 inches* (0.45 m) *diameter at the foot, and contains about thirty gallons* (135 litres)*; it is hooped with iron hoops within and without to guard against pressure. There are two holes for the arms, and a glass about four inches diameter, and an inch and a quarter thick to look thro', which is fix'd in the bottom part, so as to be in a direct line with the eye, two air holes upon the upper part, into one of which air is conveyed by a pair of bellows, both of which are stopt with plugs immediately before going down to the bottom. At the foot part there's a hole to let out the water ... It requires 500 pounds weight* (170 kg) *to sink it, and take but 15 pound weight* (7 kg) *from it and it will buoy upon the surface of the water. I lie straight upon my breast all the time I am in the engine, which hath many times been more than six hours, being frequently refreshed upon the surface by a pair of bellows. I can move it about 12 foot* (3.6 m) *square at the bottom, where I have stayed many times 34 minutes. I have been ten fathoms deep* (60 ft, 18 m) *many a hundred times and have been 12 fathoms* (72 ft, 22 m), *but with great difficulty.*

At the deeper end of his range, Lethbridge found that he needed to wear a sort of a saddle on his back to wedge himself against the top of the barrel. This he found necessary because the differential pressure squeezing his arms and acting where they penetrated the barrel's hull, was so great that he was pushed bodily away from the bottom of the barrel. His claim for a long endurance inside the barrel is interesting because it must have meant the arrangements for sealing the leather sleeves on his arms were such that he could have recovered his blood circulation each time the barrel was brought to the surface. I have theorised that in view of the ribbon-like ends to the sleeves shown in Lethbridge's illustrations (Figure 3), he used a "Chinese finger" interlacing arrangement of these ribbons down the length of his arm. I presume the effect was, as the sleeve tended to be thrust back into the barrel by increasing ambient water pressure, the interlaced part automatically tightened over his arm. The result would have been a strong and secure attachment to the arm as well as spreading the area of differential pressure over a wider area, hopefully causing less pain than if it was restricted to a small area. That there was considerable pain involved, there can be no doubt. Perhaps this was when the term "No pain, no gain" was first coined.

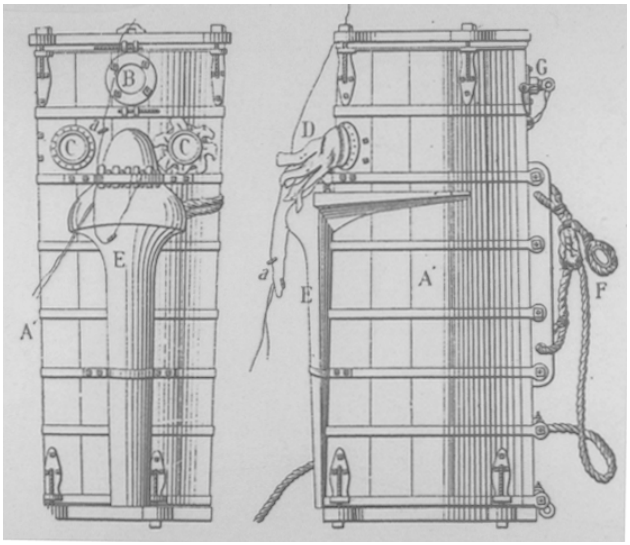


**Figure 3.** 1715 Lethbridge's diving barrel. John Lethbridge (1678-1759), of Newton Abbot, Devon, invented this self-contained diving suit in 1715. After a successful demonstration in Marseille, France, he demonstrated his "engine" to the Honourable the East India Company (HEIC) in the Thames during April 1720. He and Jacob Rowe became partners and worked all over the world including Cape Town, South Africa. He amassed great wealth.

The hole at the foot to let water out indicates that the sealing arrangements were by no means perfect. Furthermore, after six hours inside the barrel there was more than just water accumulating at the foot. Any accidental tipping forward of the barrel would have been a particularly unpleasant event bearing in mind that the diver's body was effectively clamped to the bottom of the barrel with no facility for raising it inside. Indeed, there was a good chance of drowning in a relatively small volume of water if the head end went lower than the foot end.

Lethbridge demonstrated his "engine" in Marseilles, France in 1715 and again to the East India Company in the River Thames in 1720. Other exploits included salvage of 27 chests of silver and 64 cannon from the *Vansittart*, sunk in the Firth of Forth and in 1724 work on the Dutch ship *Slot ter Hooge* sunk off Madeira. In 1726 he worked again in Madeira and recovered 349 silver bars, 9,067 guilders worth of coin and two cannon. In 1727 he worked at Cape Town, for the Dutch East India Company on the wrecks of *Zoetigheyd* and *Rotterdam*, in 1728 he worked on the *Meresteyn*, and in 1734 he recovered a valuable cargo of Spanish piastres from a wreck in Marseilles harbour.[4,5]

A Captain Jacob Rowe, also from Devon, appears to have become involved with Lethbridge at an early stage and in 1720 published "A demonstration of the Diving Engine - Its Invention and Various Uses". He described a barrel-like semi-atmospheric diving system, but this time constructed from sheet copper and designed to quite a high standard. He had various diving adventures between 1721 and 1731 but he does not appear to have achieved the level of success attributed to Lethbridge.[6,7]

**Diving suits**

The earliest example of a semi-atmospheric diving suit still surviving today is exhibited in a museum at Brahested in Finland. It is constructed from pigskin and the seams are extremely well sewn in "shoemaker fashion". The two air pipes are made of hollow wood sections, one attached at the top of the dress and one at the back of the head. Unfortunately, there does not seem to be any sign of an internal, rigid structure which must have once existed. The suit was illustrated in a letter from the Swedish Admiralty to the King of Sweden in 1727 so it is likely to be of Swedish design.[8]

Another surface-supplied system appeared a few years later around 1754. This was described by Dr Richard Pococke on a visit to the Isle of Wight, England.[9] In his own words: *I went there in order to go to the Needles to see the curious manner of diving which they lately began ... They are let down in a machine made of leather, strengthened at the knees and shoulders, and if I mistake not, at the head with brass. There are two leather tubes to it - one for the air to go down and to speak by, and the other to pump out the air. They stay down five minutes ... Sometimes as it is imagined, when they have gone too far down, they have bled at the nose and eyes.*

It would seem that this diving activity was the same as that referred to later by William Holloway, Deputy Searcher for the Customs at the Port of Cowes on the Isle of Wight when he wrote.[10] *I am to acquaint your Honor that I have in my possession the diving engine that some years since worked on the wreck of the ASSURANCE, Man of War lost at the Needles ... Our engine is not of the bell kind, but is a copper case made as fit to the body of the diver as may be, with leather boots and sleeves so that he has the use of his hands, feet and knees. A thick glass is placed opposite the eyes through which he perfectly sees and is supplied with fresh air by bellows through one pipe equal to the depth of water, the foul air passing off by another.*

This diving dress appears to be similar to the earlier dress used by Chevalier de Beauve. An interesting point to note from these descriptions is that it was relatively easy to have voice communications with the diver in a surface-supplied semi-atmospheric diving system because the air exhaust pipe would have been open at its distal, surface end and could therefore have been used as a simple voice-pipe, for two-way communications.

Denmark was the site of the next appearance of a surface-supplied semi-atmospheric diving dress. Heinrich Schultz demonstrated his diving suit in Copenhagen in 1760 and managed to reach a depth of 6 Fathoms (36 ft, 11 m) and remained underwater from 0930 to 1200 in the presence of the whole Board of Admiralty. His hands were covered with leather gloves well lacquered with bees wax and hogs lard, fastened to a copper armour at the wrists. The suit had a copper helmet and harness with iron pieces on the legs with joints. This design shows important improvements because rigid covers were now provided to other parts of the body in addition to the head and chest and the only parts exposed to ambient pressure would have been at the flexible joints of the limbs.[11] It would seem fair to say that this was one of the more successful designs for this type of suit. Thirty six feet (11 m)water depth was quite an achievement.

Meanwhile, back in England, the Royal Navy had suffered an embarrassing incident when, in 1782, HMS ROYAL GEORGE suddenly sank whilst at anchor at Spithead, near Portsmouth, taking over a thousand people down to a watery grave. Immediately a William Tracey, a wealthy ship broker at Portsmouth with 11 children, was awarded the salvage contract against stiff competition from 117 other hopeful contenders. He worked at it for the next two years. The project broke him both physically and financially and he ended up as a debtor in Fleet Prison,

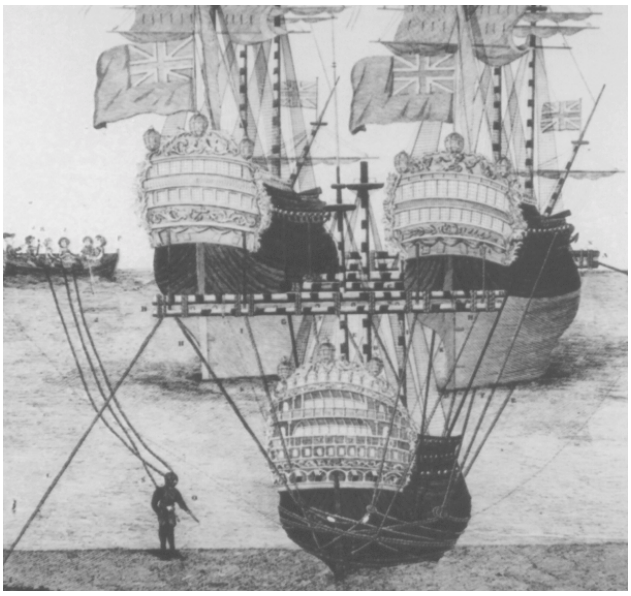

**Figure 4.** William Tracey (b 1735) was a diver and broker at Portsea, Hampshire, who attempted salvage of HMS ROYAL GEORGE in 1782-3. Unfortunately he was crippled by diving on HMS ROYAL GEORGE. By 1817 he was a "decayed ship owner" in the Fleet Prison when he was given a Trinity House pension.

London. But the interesting part for us was his use of a surface-supplied semi-atmospheric diving suit, very similar to the one described by Desaguliers back in 1763. Tracey had bought the diving equipment in London but it seems that the equipment failed on its first dive.[12] A contemporary illustration shows Tracey on the sea bed alongside the wreck of the ROYAL GEORGE (Figure 4). However it is unlikely that he made it to this depth which would have been of the order of 90 ft (27 m).

The year after Tracey's disastrous attempt to raise the ROYAL GEORGE, John Braithwaite arrived in Portsmouth to recover cannon etc. from the wreck, by arrangement with the Admiralty. Though Braithwaite was very secretive about his diving technique and equipment, sufficient information leaked out to establish that he was using a similar technique to Tracey. On 9 July 1784 the following report appeared.[13] *An artist lately arrived in London in his own sloop ... has four assistants and by means of leather tubes often spends 5 hours on board the unfortunate ship ... by this means he is supplied with fresh air and communicates with his people.*

And two years later, a Dutch Consul in Lisbon sent an intelligence note to his government in the Hague, Holland dated 21 February 1786 describing what he had spied going on in Gibraltar. *Meanwhile a Savoyard in the pay of the Spanish Ambassador reports that he was present in Gibraltar (at the time of salvaging the guns) and he saw the clothes and pipes that the English used with so much success and with which they can stay under water for almost 2 hours.*

The French Consul in Cadiz, about the same time, sent his intelligence to HQ in Paris on 14 March 1786. He made a detailed examination of their machine. *One of his* (Braithwaite's) *servants and a boy had dived down to more than 15 feet* (4.5 m) *of water from on board the ship "Bellandre". He had conversed with them through two leather conduits or pipes that could be paid off as the machine went down. ... The machine was hoisted by a swing boom, using two warps and two blocks with tackles.*

The references to diving clothes, two pipes, the ability to talk down the pipe, all point to a surface-supplied semi-atmospheric diving dress. Braithwaite became very successful with the diving "machine" and ranks close to Lethbridge in the financial success league.

The next contender appeared in the small town of Breslau, Germany. Here M Klingert developed another similar diving dress in 1798. This was when he demonstrated the system by sending Frederick Joachim, a huntsman, down to the bottom of the River Oder where he allegedly sawed through a tree trunk. The excellent and detailed illustrations of the diving dress (Figure 5) have been published very widely but nothing further is known of its success or otherwise. The sealing arrangements for the suit

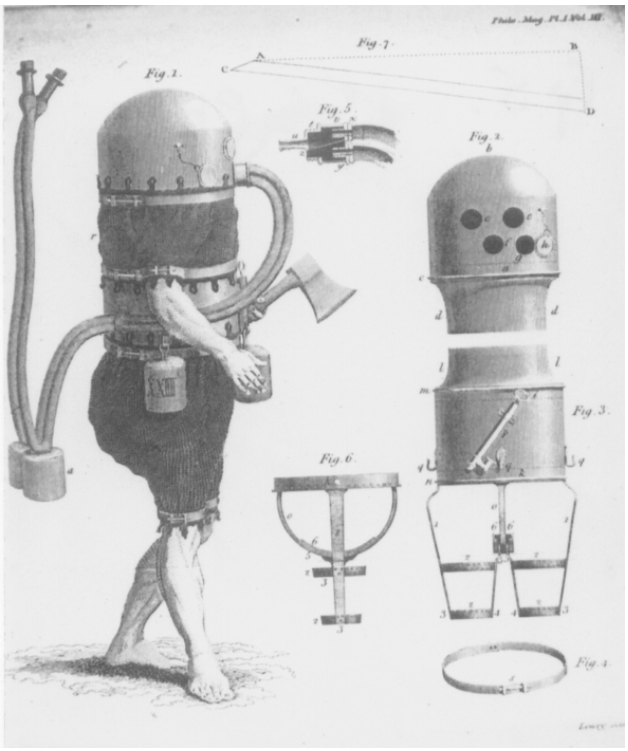


**Figure 5.** In 1798 M Klingert, of Breslau, Germany, used a semi-atmospheric diving machine to dive in the Oder River.

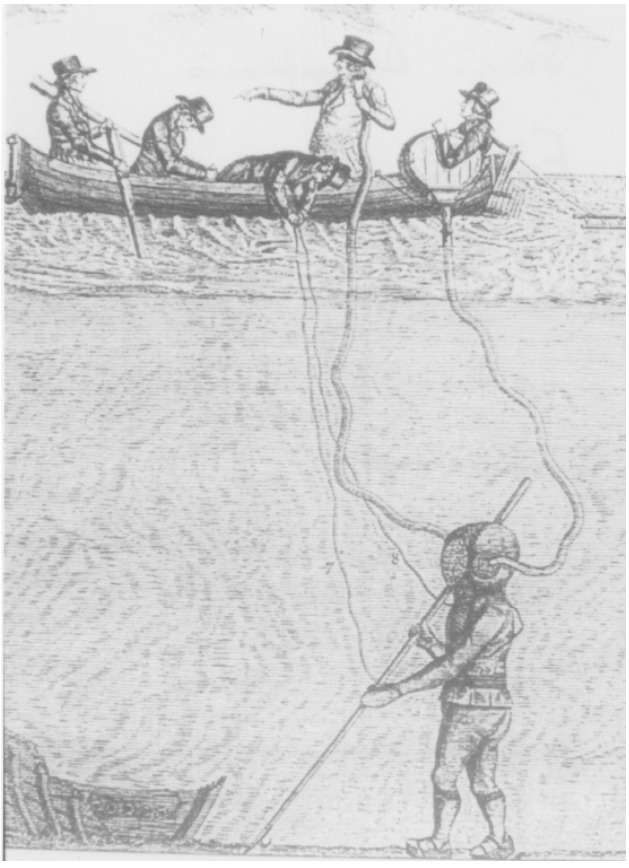

**Figure 6.** Peter Kreeft on the sea bed. Between 1800 and 1805 Kreeft, a German, produced the "Busseruhn" diving dress at Barth in Pommerania.

at the arms and legs show that a metal clamp was bolted tightly to achieve the seal. The pain must have been excruciating. The legs were clamped into a frame just above the knees, so designed to protect the crotch from the inevitable suit squeeze.[14] Walking with immobilised knees would have been an interesting spectacle to behold.

Not far away at Barth, Pommerania, another German diver by the name of Peter Kreeft produced a successful surface-supplied semi-atmospheric diving suit around the year 1800 and worked it for about five years. He called his suit the "Busseruhn" and the rigidity was provided by a frame inside a flexible, waterproof suit. An excellent illustration of the suit being dived (Figure 6) shows clearly how atmospheric air was flushed down one pipe to the diver and a second pipe returned the exhaust air to the surface. The latter pipe can be seen being used as a voice pipe by an attendant on the surface.[15]

The wreck of the ROYAL GEORGE at Portsmouth continued to attract ambitious divers throughout this period. In 1801 Enoch Tonkin began hounding the Admiralty for permission to work on the wreck. Later with Ralph Tonkin and the Braithwaites, he eventually succeeded in salvaging the valuable cargo, consisting of some 27 treasure chests and miscellaneous material worth a total of £30,000, from the wrecked East Indiaman *Earl of Abergavenny*, sunk in 60 ft (18 m) of water near Weymouth in Dorset, England. A drawing of the suit, which included a description of its construction, has survived (Figure 7). It had a body of copper and iron boots with *Joints as of mail covered with strong leather and canvas over it to prevent the leather being cut*. The suit had strong leather for the arms and a *glass eye, size of a dessert plate, an inch thick* and the whole suit was painted white.[16]

This represents the last known successful application of this type of diving system. The familiar diving helmet and dress was introduced in 1829 and the problems associated with differential pressures on a diver's body was solved once and for all.

But surprisingly there were a few later designs. In France for example, Jules le Batteux re-invented the barrel diver in 1853 which had been so successfully exploited by John Lethbridge. His barrel was fitted with fully enclosing sleeves and gloves for the diver.[16]

The last example came as recently as 1894 when an Australian engineer named Alexander Gordon, together with his colleague J Buchanan, designed, patented and built a very strange dress which provided for the divers hands only to be exposed to ambient pressure.[17,18] This elaborate and extremely heavy diving suit does not appear to have got much further than its first sea trial.

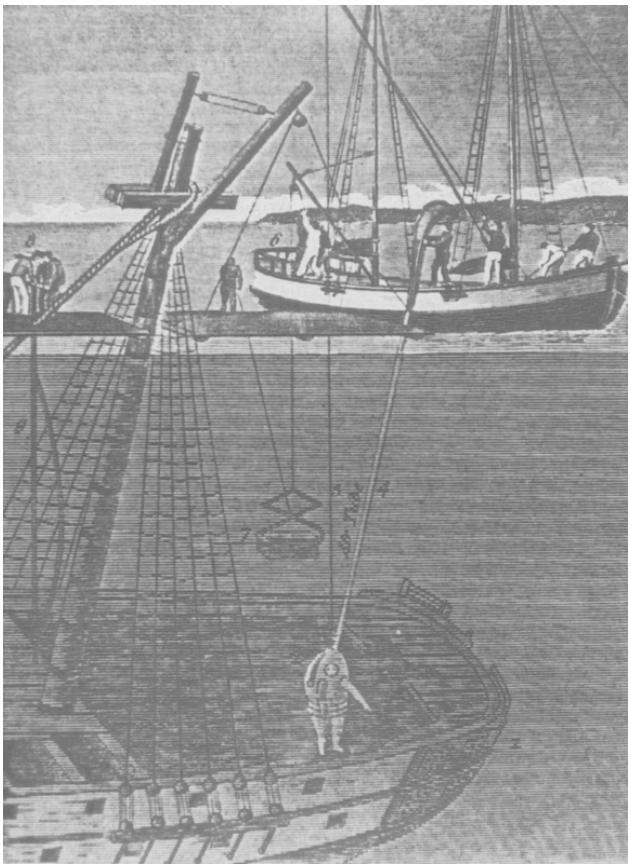

**Figure 7.** John Braithwaite (1760-1818) working on the *Earl of Abergavenny* on September 29 1805, wearing Tonkin's diving machine which he had hired. He later teamed up with Ralph and Enoch Tonkin for further salvage on this ship. The original illustration is captioned "CURIOUS DIVING-BELL".

**Improvements to the design**

For completeness, it should be mentioned that a variation on the system did emerge, which tended to increase slightly its limited depth capability. This was to add a spring-loaded exhaust valve to the outlet of the exhaust pipe. This meant that the air supply had to be provided at a pressure higher than atmospheric, depending on the strength of the spring loading on the exit valve. The higher air pressure was, however, not equivalent to the depth of the diver so the exhaust air had to be released at or near the sea surface, again necessitating the two pipe air supply system. The technique did have the effect of reducing the pressure differential between the inside and outside of the rigid part of the dress and allowed the dress to be used slightly deeper than without the modification.

**Conclusion**

This paper has dealt with a unique form of diving system which deserves to be better known and understood.

Whilst a semi-atmospheric diving system is plagued with major inherent disadvantages, it cannot be denied that it was successfully applied in several significant salvage operations spread over three centuries.

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## A BRIEF HISTORY OF SCUBA DIVING IN THE UNITED STATES

Drew Richardson


**Key Words**

History, recreational diving.


**Summary**

This presentation provides a brief overview, with dates, of how recreational scuba diving developed and is developing in the United States of America.

**Introduction**

Recreational compressed air diving, except for occasional experimenters using home made surface supplied equipment, came into being with the invention of the Aqualung by Cousteau and Gagnan. Self contained underwater breathing apparatus (scuba) had been envisaged, and even used long before the 1940s, but it was the simplicity of Cousteau's Aqualung (twin hose scuba equipment) and the manufacturing and technical support available which enabled recreational diving to move from "macho" breath holding to spear fish to scuba diving and photography.

This paper shows how much the development of recreational diving in the USA has been influenced by publicity, both books and films.

**Early ideas**

We start in antiquity, for in 1680 Borelli, an Italian, wrote of a closed circuit rebreather and swim fins. If the equipment had been made and used it would have been the first "frogman" outfit.

**Nineteenth century**

In 1831 an American machinist, Charles Condert, designed a self-contained diving dress. This was the only US predecessor to Cousteau's concept of scuba.

Recreational diving supports the recreational diver training industry, which supplies its trainees with travel, equipment and instruction. The first "how-to" diving manual appeared in 1836 when John Deane published, in London, his *Method of using Deane's Patent Diving Apparatus*.

In 1864 two Frenchmen, Rouquayrol and Denayrouze, developed the first tank based, demand valve