PETER JACKSON

The Independent Diver

The story of Henry Fleuss and the Self-Contained Diving Dress

Introduction by Reg Vallintine:
Our next speaker is rather reticent about his past, but we do know that he made a pair of fins out of a pair of Wellington boots when he was ten, and manufactured oxygen sets while still at school in the 1950s. He is an engineer by training, and worked at Siebe Gorman & Co. at Chessington for a number of years. He is now is a professional designer of breathing apparatus. He is also our most avid diving book collector.

Henry Fleuss was granted a patent for his invention of an independent diving dress in 1880. We know, of course, that he wasn't the first to produce such a device. That distinction probably belongs to Monsieur de St. Simon Sicard of Paris who successfully demonstrated a very similar apparatus in the river Seine when Fleuss was barely two years old. However, there seems no reason to disbelieve Fleuss' claim that he arrived at his invention independently and with no knowledge of any prior art. Such things happen all the time in the world of design and development, often making it difficult, sometimes impossible, to establish with any certainty who really originated what and when.

There are two interwoven stories here, really, one of the diving dress and the other of the rescue apparatus. They share a common technology and, to a degree, a common purpose and Fleuss worked on both at the same time.

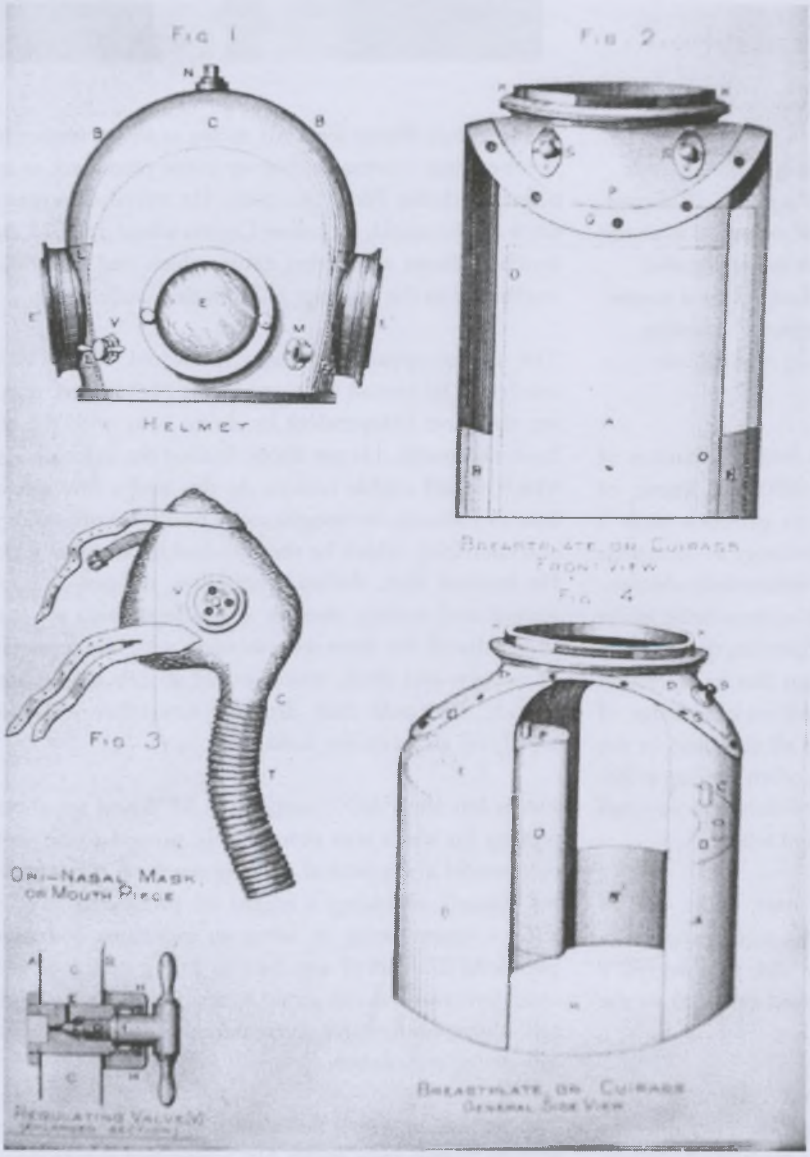
Henry Albert Fleuss was born in Wiltshire in 1851. His father, an artist from Düsseldorf, was the drawing master at Marlborough College. At the age of sixteen, young Henry Fleuss went off to sea as an apprentice in the merchant marine, ending up some years later as an officer with the P&O Company. He travelled to many parts of the world, including Ceylon where, in 1875, he watched divers recovering cargo which had been lost overboard in the harbour at Point de Gaulle.

The diving apparatus clearly interested Fleuss very much and he turned his mind to the problem of making the diver independent by doing away with the air hose and pump. He set about finding the information which would enable him to do this and a few weeks later in Calcutta, he bought some books on physiology and chemistry, which he then studied in his spare time. He learned that, during respiration, oxygen is consumed and carbon dioxide is produced and so reasoned that if the diver were to carry with him a supply of oxygen and alkali, which would absorb the carbon dioxide, he could then dispense altogether with the supply of air from the surface.

Fleuss left the P&O Company in 1878 and set about putting his ideas into practice. He proved to be very resourceful and practical, making much of the apparatus himself, including a means of producing oxygen and of compressing it, using an ingenious hydraulic pump. At 27 years of age, he was young, energetic and confident and was not afraid to test his apparatus himself, alone, underwater, even though he had no previous diving experience.

The apparatus was a bulky and, apparently, not very elegant contrivance, much like a standard diving dress with helmet, weights and lead-soled boots. The helmet, made from tinned copper, had a double wall, the space between forming a reservoir with a volume of about a quarter of a cubic foot. This was charged with oxygen, by means of a hand pump, to a maximum pressure of sixteen atmospheres and could thus hold four cubic feet of oxygen. A screw valve, to one side of the front window, allowed the wearer to admit oxygen into the helmet and also facilitated charging the reservoir. A screw plug in the crown allowed the reservoir to be purged of air. The double helmet was large and complicated and must have been very difficult to construct. The Jacket, as Fleuss called it, was also a complicated assembly. It comprised a standard corselet, to the inside of which were fixed two metal chambers, one at the front and one at the back. These were joined around the sides by metal plates, one of which could be removed to allow the diver to get into it. Each chamber was fitted internally with a vertical division and a perforated false bottom and had a removable lid with two short pipes attached. The chambers were filled with small pieces of sponge rubber soaked in a strong solution of caustic soda.

The diver wore a leather ori-nasal mask which had non-return valves in the sides and a flexible tube at the front, leading to one of the pipes on the lid of the front chamber. He inhaled from the helmet through



Fleuss's first diving apparatus.

the non-return valves and exhaled through the flexible tube into the front chamber, where his breath passed down one side of the division, through the false bottom and up the other side. A flexible tube, leading over the shoulder, connected the outlet of the front chamber to the inlet of the back one, so that the exhaled breath passed through this also, finally returning to the helmet via a non-return valve. The dress, being flexible, acted as a counter-lung.

There were clearly some deficiencies in Fleuss's apparatus, principally the lack of any control over the partial pressure of oxygen in the system. It was intended that the oxygen valve should be adjusted to give the correct flow and would then require little attention, so there was, at least, a continuous flow of oxygen into the helmet. However, the method of determining the correct flow was, to say the least, a bit vague. Fleuss stated that too little oxygen was indicated by "an uneasy breathing" and too much by "feeling a pressure on the eardrums". This was most likely just an indication of pressure in the diving dress relative to ambient pressure but, crude as it was, this evidently sufficed, as the apparatus was used many times under water.

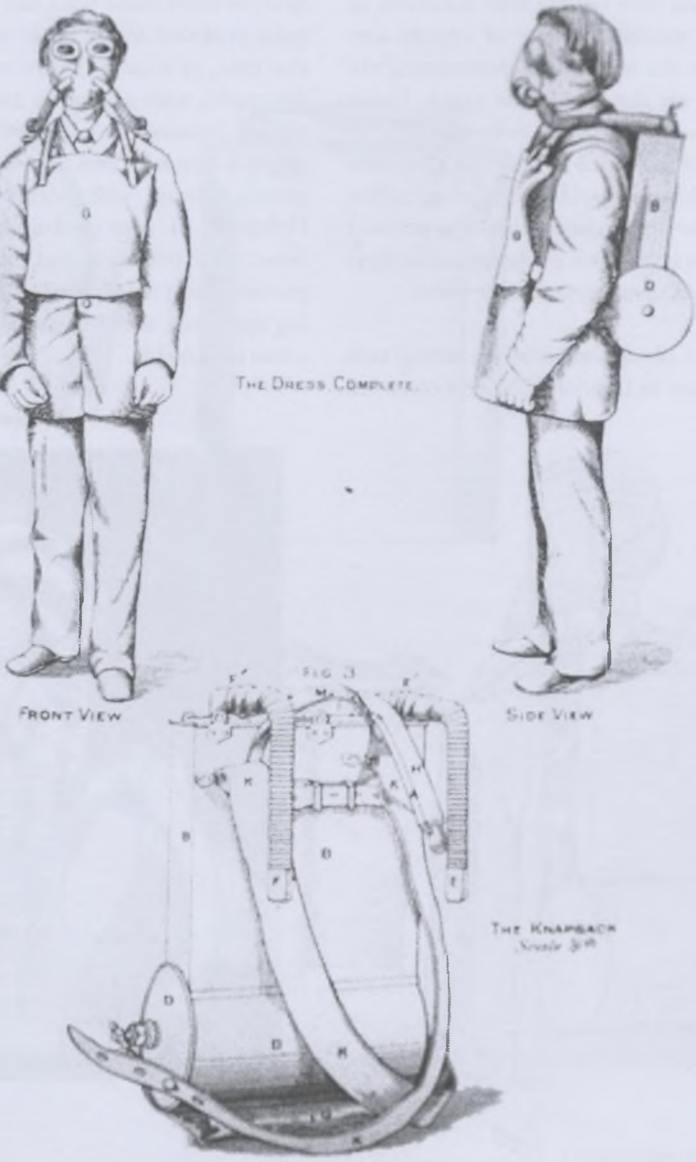
In 1879, Fleuss tested his apparatus in the diving tank at the Royal Polytechnic in London. This was observed by the eminent physiologist, Benjamin Ward Richardson, who showed a great interest in the invention and, together, they conducted numerous experiments to prove its effectiveness, both under water and in poisonous atmospheres. Richardson was clearly impressed by Fleuss and his invention and saw great potential in it, particularly as a means of enabling rescuers to enter gas-filled mines. He wrote several papers on the subject for scientific journals and, in May 1880, presented a paper to the Society of Arts, at which Fleuss was present to demonstrate his invention in a glass chamber filled with carbon dioxide.

Fleuss's invention attracted considerable interest, particularly from those who, like Richardson, could see its great potential as an aid to rescue work in mines. At that time, of course, Britain was the industrial centre of the world, with a massive consumption of coal. The mining industry was huge, with an annual output of nearly a hundred and fifty million tons. It was a dangerous industry, with more than its share of accidents. Hundreds of men died underground through explosions, roof falls, fires and floods and there was a very pressing need for a portable and self-contained breathing apparatus, without which any attempt at rescue was often impossible.

Fleuss's first rescue apparatus

Encouraged by so much professional interest and enthusiasm, Fleuss set about making a new apparatus, of a simpler and more practical design than the diving dress and more suited to use in the mines. It was carried on the back like a knapsack and comprised a tinplate box, twelve inches square and four inches deep, which housed the alkali chamber made from Vulcanite with a perforated false bottom and three vertical divisions. A Vulcanite lid, sealed with a sheet rubber gasket, was clamped in place by metal rods which passed through holes in the outer box. The lid had connections for the breathing tubes and for the breathing bag which, in the first model, was mounted on the back of the metal box.

Two formed tubes led over the shoulders to a junction piece, containing the non-return valves, from which two short corrugated hoses led to a full face mask. Attached to the bottom of the box, at waist level, was a copper cylinder, twelve inches long and six inches diameter, which contained four cubic feet of oxygen at a pressure of sixteen atmospheres. A valve in one end of the cylinder allowed the wearer to control the flow of oxygen and was connected, via a copper pipe, to the inhalation tube.

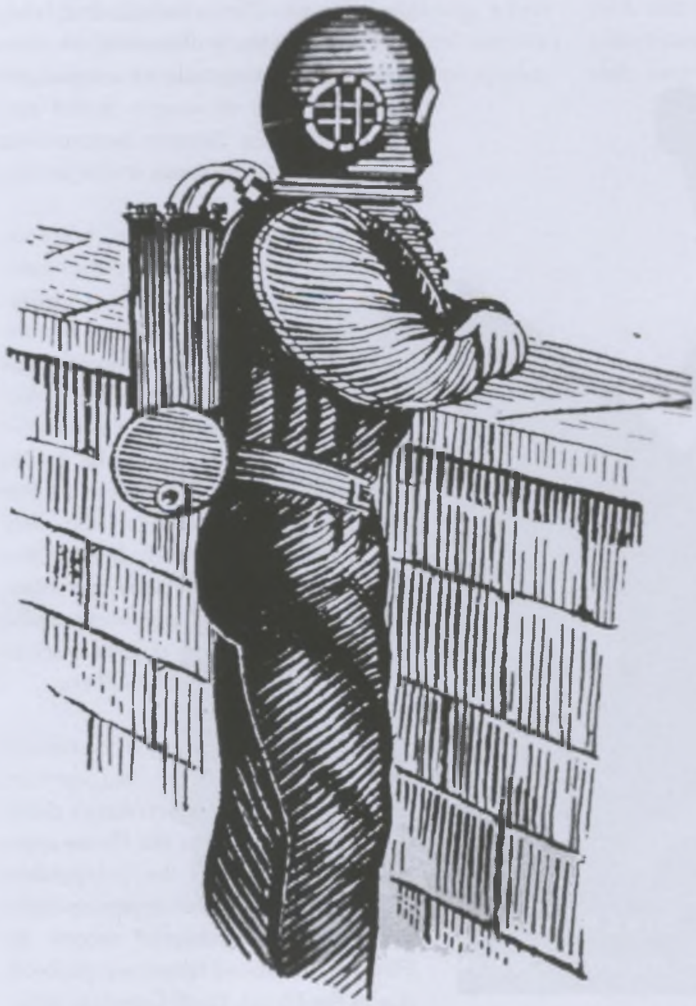


Second rescue apparatus

Fleuss soon improved the design by moving the breathing bag to the wearer's chest, where it was much less vulnerable to damage. He also placed the non-return valves at the connections to the lid of the chamber and fitted two long corrugated hoses over the shoulders and into the sides of the facepiece, giving the wearer much greater freedom of movement. A heavy copper cowling was added to protect the valves and hose connections at the top of the alkali chamber.

Meanwhile, Fleuss was still actively promoting his original diving dress and had arranged to demonstrate it to the Admiralty at Spithead in June of 1880. He was to be put down to a depth of seventeen fathoms (102 feet) which might well have cost him his life. However, fate intervened in the form of a small accident which, more than likely, prevented a far greater one. The apparatus was being towed in a small boat which was capsized by the wash from the Ryde steamer and it was lost overboard. Fleuss had to build a new diving dress.

The new model used a knapsack arrangement, similar to the rescue apparatus, adapted to a standard diving dress and was altogether much simpler and more practical than the double helmet and metal jacket of the original. The alkali chamber was housed in a metal case with a heavy lid secured by screws and wing nuts. Two copper pipes with brass unions attached the case to connections on the corselet. The copper cylinder, with its screw valve, was fixed to the bottom of the box and had loops attached, through which passed a leather belt. The diver wore a leather ori-nasal mask as before, with the exhalation tube connected to a short pipe extending into the helmet from one of the corselet connections. The helmet was a standard pattern but had no air connections and, as far as is known, no exhaust valve.



This was the diving dress used in the famous Severn Tunnel incident, when, during the construction of a railway tunnel under the river Severn, a spring was struck and the tunnel began to flood. In their enthusiasm to escape, the workmen failed to close a watertight door and the tunnel eventually filled with water to a depth of about thirty-five feet. The watertight door was one thousand and twenty feet along the tunnel and attempts to reach it by divers in standard dress had failed due to the impossibility of dragging the necessary length of air hose behind them.

Fleuss was called to the scene with his diving dress in November of 1880 and made a number of attempts, in total darkness, to reach the door and close it. He had never been underground before and was not familiar with his surroundings or with the obstacles he encountered, and he failed to go much further than about three hundred feet into the tunnel. The diver at the scene, none other than the famous Alexander Lambert, made a further attempt, this time using the Fleuss apparatus, and succeeded in reaching the door and uprooting a rail which passed over the sill. He was under water for an hour and a half. On a second excursion, he was able to close the door and the tunnel was eventually pumped out and construction resumed.

In spite of all the good publicity that Fleuss gained from this successful application of his invention, little more progress was made with his independent diving dress, although he did develop another design, for a shallow-water version, which was demonstrated in April of 1882 at the Naval and Submarine Exhibition in Islington. This apparatus used the familiar knapsack arrangement in conjunction with a lightweight dress which had a built-in mask in place of the usual helmet. The diver entered the dress through the top, which was subsequently sealed by two curved metal clamping straps secured with screws and wing nuts. There is evidence that this shallow-water dress was demonstrated to the Navy but, seemingly, nothing further came of it.

Shallow water diving apparatus

The eventual lack of success for the Fleuss diving dress was doubtless due to several factors, not the least of which being that there would be few occasions where the advantages of such a device would outweigh the disadvantages of having a diver on the bottom whose duration was limited and whose whereabouts and well being were uncertain. Also, tests carried out by Fleuss himself and, later, by Damant, clearly illustrated the dangers of not being able to control the partial pressure of oxygen in the system. Both men became unconscious when using the apparatus under water.

The new rescue apparatus, however, was still being successfully demonstrated to mining and engineering institutions throughout the land and continued to gain widespread enthusiasm and support. In June of 1881, it was successfully used to enable men to re-enter the Seaham Colliery, where an explosion in September of the previous year had killed one hundred and sixty-four men and caused so much damage that the pit had remained closed ever since. In April of 1882, the apparatus enabled the rescue of ten men trapped after an explosion at Killingworth Colliery.

Early in 1883, a Home Office circular was sent out to the coal owners, expressing the Home Secretary's desire that they should adopt the Fleuss apparatus. However, like the independent diving dress, the rescue apparatus failed to become a commercial success for Fleuss. This second failure was probably due to the Fleuss, Duff Company refusing to actually sell any of the apparatus.

They wanted, instead, to set up and equip rescue stations at the collieries and to train selected men in the use of the apparatus, their reimbursement being a percentage of the value of the coal produced. This evidently didn't find favour with the coal owners, who eventually turned their backs on Fleuss.

The Fleuss, Duff Company had been founded in 1880, but it seems doubtful that any of the apparatus was actually made by them. They seem to have been more of a marketing organisation, although, looking back, not a very successful one. It is clear that Siebe, Gorman made much, if not all, of the hardware for Fleuss, who stated that they were the agents for working the patent. He demonstrated his first diving dress daily in their tank at lunch times.

After the commercial failure of his rescue apparatus, Fleuss moved into other fields of interest. He went to work for the Pulsometer Company in Reading, where he applied himself to developing efficient vacuum pumps and ice-making machinery. The rescue apparatus wasn't completely dead, however. Someone, perhaps Fleuss himself, was still working on improving the design, as evidenced by a photograph which appeared, with no related text, in the Strand Magazine in 1895, showing what was destined, eventually, to become a very successful product indeed.

The need for rescue apparatus in the mines hadn't gone away, of course, and by the turn of the century other people were actively working to produce such apparatus, both here and abroad. In 1902, Robert Davis, of Siebe, Gorman, invited Fleuss to co-operate with him to develop his apparatus commercially. The Fleuss-Davis apparatus had a chest-mounted breathing bag, divided internally into front and rear sections by a vertical partition reaching to within an inch or so of the bottom, which was filled with sticks of caustic soda to about five inches deep. Two non-return valves, at the top corners of the bag, led one to each compartment such that the wearer's exhaled breath passed into one compartment and filtered through the bed of caustic soda into the other compartment, from which it was

The Proto apparatus

inhaled. A steel cylinder, containing six cubic feet of oxygen at a pressure of a hundred and twenty atmospheres, was slung across the wearer's back.

The whole apparatus was strong, simple and reliable and was well suited to use in the mines. Further improvements were made, including the addition of a pressure gauge and a regulator which supplied a constant flow of oxygen to the breathing bag and later, when soda lime took the place of caustic soda, a chemical cooler was added. Davis named the apparatus Proto and it was a successful and enduring product, adopted by mining and tunnelling companies and fire brigades all over the world. It was in widespread use before the First World War and is still in use in some mines today. Only a few years ago, not long before Siebe, Gorman closed their factory in Wales, I saw a batch of newly-made Proto sets, destined for a mine in India.

In 1905, Fleuss and Davis applied for a patent for a new shallow-water diving dress which, in place of the full suit, had just a jacket, open at the bottom, with a flexible hood attached. The familiar knapsack and hoses were also attached and lead weights, in pockets around the ankles and hung around the bottom of the jacket, could be jettisoned rapidly if the diver needed to rise to the surface and float.

The full diving dress, with helmet and boots, reappeared in 1908, modified by Davis and Hill to a semi-closed circuit, with a mixture of air and oxygen stored in two cylinders below the alkali chamber and supplied at a constant rate to the helmet by a regulator. The surplus gas escaped by way of a conventional exhaust valve, which also gave the diver some control over his buoyancy. The old ori-nasal mask had given way to a mouthpiece and nose-clip and the diver inhaled from the helmet and exhaled through a flexible tube into the alkali chamber, as before. A second version of this apparatus incorporated an injector to induce a continuous circulation of air around the breathing circuit, thus freeing the diver from the mouthpiece and nose-clip, but it is not known if either pattern was ever produced in any quantity.

In the early 1900s, the increasing use of submarine boats and the number of accidents which befell them led to a very pressing need for a means of escape in the form of a simple apparatus which would enable a man, wearing ordinary clothes, to breathe under water. One of the first of these was the Hall-Rees apparatus of 1906, which was still very much a diving suit, complete with metal helmet and, with the addition of lead weights and boots, was used for shallow-water diving. The Williamson Brothers equipped the divers of the Nautilus with this apparatus in their 1916 film of Jules Verne's "Twenty Thousand Leagues Under The Sea".

The Hall-Rees apparatus was very simple and used a canister containing Oxylithe, a compound of sodium and potassium peroxides, which liberates oxygen on contact with the moisture in the wearer's exhaled breath. Conveniently, the by-product of this reaction is alkaline and thus absorbs carbon dioxide. This ingeniously simple arrangement worked well and is still used today in escape apparatus for miners. The use of peroxide under water, however, wasn't without its problems, as it had an unfortunate tendency to catch fire if too much water got into the canister. It would also burn your fingers if you touched it and this was not too easy to avoid as the canister had to be emptied and refilled every time it was used.

Whilst the Hall-Rees apparatus was enjoying its brief but much publicised adoption by the British submarine service, Draeger were working on a more compact apparatus, the Tauchretter, which was in service in the German submarines by 1913. It was not unlike the Fleuss rescue apparatus, but reversed, with the breathing bag on the back and the cylinder and alkali canister at the front. It was also very complicated in its construction.

The Davis Submarine Escape Apparatus, introduced in the 1920s, was altogether a much simpler and more practical apparatus than anything that had gone before. It was a neat and compact development of the Fleuss apparatus, with a breathing bag on the chest and a cylinder of oxygen slung below it. A small soda lime canister, inside the bag, was connected by a single breathing tube to a mouthpiece, which was fitted with a tap to close off the tube and preserve the soda lime. The apparatus allowed the wearer to move about freely, not only inside the submarine but also under water, and this new freedom was to bring about an unexpected turn of events. The apparatus for saving life was about to become the means of waging a new form of underwater warfare.

The military potential of the Davis apparatus was first demonstrated in 1941 by the Italians, who adapted it for use with their manned torpedoes. The British, smarting from the success of the enemy's new

weapon, soon followed with an intensive programme of design and development work on self-contained diving apparatus. Somewhere, amongst all the ensuing activity, the free swimming diver was born and the art of diving changed forever. Underwater man no longer had to struggle clumsily on the bottom. He was weightless. He was, at last, the independent diver.

QUESTIONS

Q. (Mike Fardell) When did Fleuss die?

A. In 1933. He was retired by then, of course, but he had worked until then for the Pulsometer Company in Reading, and although he went back to work with Davis at Siebe Gorman, it seems that he was still working for the Pulsometer Company at the same time. He worked on vacuum pumps, but he also had a patent for a tubeless tyre for cars quite early on in about 1895 or '96, and he also patented a steam car, but that was in the early 1900s, and steam had given way to the petrol engine by then so it never really got anywhere. He was quite an ingenious guy.

Q. (John Towse) Did Fleuss ever put any depth limit on oxygen breathing or was he just confined to the shallows by the equipment? Was he physiologically constrained by the depths, to his knowledge?

A. I don't know that he was, early on. I don't think they knew much about oxygen poisoning in those days, and because he had only the one gas – oxygen – the deeper he went, he would have had to keep topping the suit up with pure oxygen, so that he didn't get crushed, so the partial pressure of oxygen would be increasing as he went down, which of course is not what you want. You really want it to go the other way. He was rendered unconscious once, as far as I can discover, but that was because he deliberately, or so he says, did not turn the oxygen on, and he had air in the bag, so that was because of hypoxia really.

Q. On one of those sepia slides there are two things that look like square weights. Do you know what they are?

A. He held those in his hands to hold him down to the bottom. I think they were just handles on a pair of weights, as far as I know, or he may have just picked them up to demonstrate. I don't think they were part of the apparatus, but I'm not certain.

Q. (Gary Potter) How many versions of the diving helmet suit do you think Fleuss made? You talked about the original one that had the double skin, and then you said he made another version, which you think Lambert used in the Severn Tunnel.
A. Yes, that must definitely be the one that Lambert had used, because the first one was lost in that accident before the Severn Tunnel incident, so he must have been using a second dress. But he only made, as far as is recorded, two helmet diving dresses, and a third diving dress which had the built-in metal mask that you saw in the tinted slide.

Q. (Gary Potter) In my researches on Lambert, I found various accounts that may possibly indicate that he tried both versions, the helmet version and the bag version during that attempt to close the door. Although Fleuss made a couple of attempts himself, in one account he actually mentioned that he didn't like the thought of going down the tunnel and refused to do it. That's where Lambert stepped in. I think Lambert was actually talked into it because he wasn't very keen on the new equipment. One of the descriptions said that the engineer operating the works said that he was concerned about how delicate the copper tubes on the actual apparatus looked. That led me to think that he was possibly talking about the bag version rather than the helmet version.
A. It's possible—I don't really know. There's no real description of it, and apart from that photograph of Fleuss in his shallow water dress we don't have any photographs to back any of this up. There are only the illustrations that I have shown, unless anyone can come up with anything new.

Q. (Gary Potter) To go back to John's point, there is an account that Lambert went down in about 50ft. of water.
A. Quite possibly. There is an account somewhere that Fleuss used that apparatus in about 75ft. of water, I don't remember where it was exactly. There are several snippets of information about where he tried his apparatus but it's not clear which one for much of the time. You can't tell by the date because by those dates he had produced two or three. I think there is also some evidence that he did actually try the rescue apparatus under water before he built that lightweight suit. I don't think we will ever really know what he tried and where.

Q. (Ray Sutcliffe) Is there any reason why he didn't register it with the patent office?
A. He did, in fact. In 1880, during the time he was demonstrating his apparatus to Richardson in the London Polytechnic he had got a patent for the original diving dress with the double helmet. That was the only patent that I believe he was connected with relating to diving apparatus until later on when he was working again with Davis, and the patent was related more to a rescue apparatus.

Q. (Nick Baker) How did he get his oxygen?
A. Originally he got it by making it through a chemical process. I forget exactly what it was but it liberates oxygen. In those days gases were carried around for laboratory use in large flat rubber bags, and you generated the oxygen, from where it would flow into the bag. From that he would compress it into his copper cylinder using a hand pump, which apparently was quite ingenious. He said that he made this pump himself, but we'll never really know whether he did or not. Also it used hydraulic seals to prevent any leakage and to prevent any dead space.

Q. The self-contained diving apparatus of 1908 used the same principles as the corresponding Draeger apparatus of the same time. Do you know if there was any cross-fertilization or piracy?
A. Piracy is probably a better word to use. There's a lot of evidence that Davis had people get information from competitors. He used to have a copy of all the patents that came out sent to him directly by his patent agents in London. Draeger patented anything of interest, and they were pretty hot on that sort of thing. Draeger probably had more patents on diving equipment than everybody else in the world put together. They patented everything they could think of to stop other people doing it, and made work for a lot of lawyers as well. So he would have known about it through the patent specification, certainly. Siebe's would make any pattern of diving apparatus, as you probably know. Looking in *Deep Diving*, they have all the Continental patterns of helmets and everything. They would just copy the Denayrouze helmet or the Draeger helmet and manufacture it. They didn't seem to be too bothered about that sort of thing.