

A Short History of Respiratory Protection in England

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The early history of respiratory protection in Europe is largely the history of two great companies—Siebe, Gorman & Co Ltd in England and Draeger in Germany—each responding to national emergency in time of war and competing with each other in time of peace. Both companies have been led by men of inventive genius who have left their mark on respiratory protection as we know it today, not only in Europe but all over the world.

The story in England has many interactive threads, of which a few are of particular interest; they are legislation, military, firebrigades, and mines rescue, with others profiting from advances in these four main areas.

Legislation

In the early 1800s the Industrial Revolution spawned the factory system, and whilst bringing economic prosperity to some, it brought many social evils to others. Child mortality was high and life expectancy was short, and whilst condemning slavery abroad, near-slavery was practised in our mines and factories by the employment of women and children in what we would now regard as degrading and appalling circumstances.

In 1802 the Factory Act introduced by Sir Robert Peel became the first piece of factory legislation in the United Kingdom, indeed in the whole world. It was mainly concerned to protect the health and morals of apprentices, and proposed among other things a reduction in the working day from 14 to 13 hours, and some form of education. It failed in its purpose and was almost totally ignored. Other Acts followed in the teeth of fierce and sometimes violent opposition from factory and mill owners, and the 1833 Factories Act marking the appointment of the first four Inspectors of Factories was a significant step forward.

This early legislation was mainly concerned with shortening hours and guarding machinery; respiratory protection figured in it not at all. Indeed the debilitating effects of certain trades were regarded as a natural and inevitable consequence of employment, but the seed was being sown that the factory owner had a legal responsibility for the safety of his premises and the health of his workers. The 1880 Employers Liability Act

defined these responsibilities, but it was seldom enforced and the number of inspectors was pitifully small. Even so, workers manufacturing lead paint, matches with white phosphorous heads, and certain explosives containing dinitrobenzene were required to undergo regular medical examination, and crude respirators were being used in small numbers in the developing chemical industry.

Meanwhile a succession of mining disasters resulted in the Select Committee of 1835 recommending that great benefit might arise if the outstanding scientists of the day were to examine the causes and find preventative solutions. Ironically, the introduction of the Davy Safety Lamp had made matters worse since after its introduction the need to take special precautions and exercise constant vigilance against firedamp had relaxed. Professor Michael Faraday was among those who responded, suggesting that firedamp was not the only fuel in the Haswell explosion of 1844 when 95 lives were lost and that coal dust played a very active part. It was many years before this view was accepted.

In spite of many mining disasters, legislation started in the House of Commons was thwarted in the House of Lords where the mine owners were well represented, and not until 1851 was the Royal School of Mines established in London, modelled on those in France, Belgium, and Germany. Almost simultaneously, a separate Inspectorate was formed for Mines and Quarries, although from the beginning the re-

sources were inadequate and they **concentrated** mainly on accident prevention and the mapping of mines.

The effect on **miners'** health of breathing dust has been known since **Hippocrates**, but not until 1938 and successive Royal Commissions was something done about it in the **UK**, mainly through better ventilation or, as we would now term them, "engineering controls." Apart from self-rescuers, the provision of respirators for miners has always been a controversial issue, and until recently the main role of respiratory protective equipment (RPE) in the mines was in Mines Rescue. Following deaths attributed to faulty equipment in early rescue operations, special legislation was enacted governing the approval and use of mines rescue equipment, including a compulsory water-leak test prior to wearing.

Successive Factories Acts did no more than add to the confusion, and in 1967 when the Department of Employment proposed yet another new Act, it was shelved in favour of a Committee of Inquiry with Lord Robens as Chairman, which reported in 1972 after two years of searching enquiries. The broad principles of the **Robens's** recommendations were contained in the Health & Safety at Work (HSW) Act 1974, which is a major landmark of our health and safety legislation. Robens had identified the fragmentation of the law on industrial safety as a major reason for the apathy in its application, and called for new statutory arrangements which relied less on coercion and more on self regulation by industry backed by criminal sanctions.

The HSW Act is an enabling Act allowing the technical matter in about thirty Acts and several hundred Regulations to be replaced by Codes of Practice. One of the most important provisions of the HSW

Act was the setting **up** of the Health and **Safety** Commission and the Health and Safety Executive (HSE), which took over the duties and responsibilities of the old Factory Inspectorate, including the approval of RPE under Statutory Regulations. This has now been centralised under the HSE at Sheffield, formerly the Safety in Mines Research Establishment (SMRE), which is and **always** has been responsible for the approval of Breathing Apparatus.

The Consumer Protection Act of 1988 strengthened and extended the provisions of the HSW Act 1974, and we have recently had the Control of Substances Hazardous to Health (COSHH) Regulations, which are now in operation. In recent years there has been a significant shift of emphasis in the UK from approval under Statutory Regulations in a few named industries to blanket approval being required for all items of RPE by demonstrating compliance with approved standards.

At present we are in a state of transition from the old system to conformity with European Economic Community (EEC) law in 1992. By 1990 each member country must have in place a system of law and regulations which will enable it to comply with the EEC **Directive** on Personal **Protective** Equipment (PPE) when the Directive comes in force in 1992. For RPE this means conformity with standards drafted by CEN/TC 79 and published as European Norms (ENs). Under COSHH and the 100a Directive, the HSE will adopt a more detached role, requiring compliance with approved standards rather than becoming involved with the testing themselves. It is envisaged that testing will be carried out at one of a number of European test houses and that products carrying the EC mark **will** be deemed to have been tested and passed to the appropriate standard.

Military Developments

An unfortunate catalyst in the development of respirators has twice been war on the continent of **Europe**, to which both sides responded by accelerated development of gas measures and countermeasures. Prior to 1914, respirators existed in those industries where they were essential, such as the chemical industry and in the packing of bleaching powder. Also, rescue services in coal mines and fire-fighting had created the need for dependable breathing sets, supplied in the UK by **Siebe**, Gorman & Co Ltd. The flexible corrugated rubber tube and the non-return expiratory valve, which were important components in the British respirator from 1916 onwards, had been intro-

duced by Siebe, Gorman in the 1880s. But in April 1915, the use of gas by the Germans caught the Allies entirely **unprepared**. The simplest defence against the acid gas used, chlorine, was a neutralising agent; the choice fell on sodium **thiosulphate**, a soluble alkali widely used in photography.

The British forces decided to copy and elaborate on the German **pad**, and used cotton waste impregnated with thiosulphate held in place by black cotton netting—the Black Veil respirator (Figure 1). It would protect against 100 ppm chlorine for up to five minutes. By 20th May, nearly everyone in BEF had one.



Figure 1. Soldiers of the 2nd Battalion of the Argyll and Sutherland Highlanders wearing mouth pads, May 1915. (courtesy Imperial War Museum)

Prior to that, Professor J S Haldane, who was to play such an important role with Robert H Davis in the Siebe, Gorman story, had visited the battlefield and recommended as an immediate interim measure a bottle filled with moistened earth with the bottom knocked off. Alternatively socks soaked in urine could be used. To replace the pads the British developed woollen helmets dipped in a solution of thiosulphate (Hypo), bicarbonate of soda, and glycerine, with a mica (or later celluloid) window that allowed the wearer to see but not to shoot straight.

The Hypo helmet was soon replaced by the 'T' or 'Tube' helmet which remained in use until replaced by the PH helmet in 1916. The latter was dipped in a solution of sodium phenate-hexamine to improve its efficiency against phosgene, and soon thereafter the PHG helmet (i.e., with goggles) made its appearance. All gas masks produced in Great Britain at this time were made by Siebe, Gorman to the designs of H A Fleuss and R H Davis. The intensive preoccupation with impregnated helmets slowed down the development of the British respirator later to be called the Large Box Respirator. It had a half-face mask, a mouthpiece and flexible tube with non-return valve connected to a large filter or box of 1000 cm³ capacity. To provide additional protection against prussic acid, the British eventually introduced the small box respirator (SBR), in which the mask was connected by a flexible rubber tube to a filter containing charcoal and sodium permanganate-lime granules. The SBR was the military ancestor of the Puretha range of commercial respirators

approved by the Home Office for use under Chemical Works Regulations and made and marketed by Siebe, Gorman between the wars, even to this day (Figure 2).



Figure 2. The modern S10 military respirator. (courtesy Avon Industrial Polymers)

With **hindsight**, it is easy to see how materials availability in 1916 dictated national design preferences which persist to the present. The Germans had no problems with charcoal, but fabric shortages **forced** them to adopt tanned leather. The reverse was true of the British and they compensated for inferior charcoal by larger volumes, leading to respirators that had to be carried in haversacks. The Germans were able to opt for the screw-in **filter**, which gave greater flexibility in use, the screw thread being the same as those used for Osram street **lamps**. This meant that the machines for making lamp bases and sockets could be turned **at once** to the manufacture of these components. The German and continental preference for screw-in canisters based on this thread, which became the DIN 3182, has been evident in the way their filter industry has developed ever since. Conversely, the UK approach has led to more cumbersome equipment joined to the mask with tubes. The philosophical difference between rapidly interchangeable components on the one hand and dedicated complete equipment on the other is still being fought out in CEN/TC 79, although in a decidedly more friendly spirit than in 1916.

In January 1916 the War Office bought 1200 hectares at Porton near Salisbury, which expanded to 2600 hectares (about 10 square miles) by 1918. Porton was to become the centre of British chemical warfare research and development for the next half century, but more importantly for our purposes many of the inventions, test methods, even respirator design and performance standards were to find their way into commercial use once the exigencies of war were over. Dr Leonard Hill, later Sir Leonard, the inventor of the

sodium chloride filter test method; Henry Walton the inventor of the methylene blue test; Dr Norman Maurice the inventor of the charcoal cloth batch process, were all members of CDE Porton in the early days. The evolution of the military respirator between the wars has been entirely done by CDE Porton in collaboration with partners in industry, and successive Directors **have generously allowed staff to sit on** British Standards committees that chose the sodium chloride method as the **reference method for measuring** filter penetration in all CEN filter standards.

By a strange quirk of fate it was an observation by Professor John **Tyndall** that very fine smokes were difficult to filter out that prompted the Germans to develop the **so-called** arsenical smoke in 1916. It was whilst investigating **countermeasures** that the electrostatic Hansen filter was discovered and developed by CDE Porton. Hansen **found that a** small amount of rosin powder added to a wool **fibre filter** greatly enhanced its efficiency without increasing the resistance. Hansen was later Director of the Danish Army Research Laboratory from 1927-1935. The early fundamental work on the resin wool **filter** carried out at Porton by **W H Walton** was continued by **R G Dorman**, and more recently by John Feltham in industry under the trade name of **Capofilter**, by researching and developing new and improved rosins to coat the wool mixture. The Hansen filter was to become the workhorse of sub-micronic particulate filtration in the UK for many years to come, and is still going strong. It exists in symbiotic relationship with the sodium chloride test method, and it is unlikely that either would **have** developed to the degree they have without the other.

Fire Brigades

It is more **difficult** to pinpoint the introduction of RPE into **the** fire brigades, due to the haphazard way in which **the** fire brigades themselves **evolved**, and weird and wonderful are **some** of the early designs. It needed someone of the stature and force of personality of Eyre Massey Shaw, the **first** Chief of London Fire Brigade, to put matters on a sound footing. Early attempts were directed towards smoke hoods and smoke hoses; then Shaw collaborated with Professor John Tyndall in the design and testing of a smoke respirator, the same Tyndall whose observation regarding fine smoke filters led indirectly to the Hansen filter. Both Shaw and Tyndall were largely self-taught since they were working in uncharted waters, and both achieved great eminence in their respective professions, Tyndall becoming Superintendent of the Royal Institution. At this point **the** needs of the fire brigades coincided with

those of the mines rescue services, and both were using the versatile "Proto" and the shorter duration "**Salvus**" closed-circuit oxygen sets which continued for many years through various Marks until the mid 1970s, by which time they had largely been replaced in the fire brigades by compressed air (Figure 3). Considering the Proto Mk I was **used** by the British and American forces in 1914-18, this was a remarkable lifespan for any product and a tribute to its designers, H A **Fleuss** and Robert H Davis of **Siebe**, Gorman. Even today it is possible to find senior firefighters who speak of the Proto with affection and respect, based on its **reliability**, ease of maintenance, and body-hugging profile.

The move to compressed air was dictated by rising costs, the simpler logistics of the open circuit set, and revised operational procedures which reduced the



Figure 3. The Proto compressed-air breathing apparatus. (courtesy London Fire Brigade Museum)

need for one- and two-hour sets. The set which replaced the Proto in the majority of fire brigades, including the London Fire Brigade, was the Siebe, Gorman Airmaster, a two-stage set with piston-type first-stage reducer, having a nominal working duration of 21 or 46 minutes, depending on the cylinder used and its charging pressure (Figure 4). In the 1970s it underwent two rejuvenations: an ori-nasal mask was fitted inside the face mask to reduce CO_2 , and the demand valve was converted to positive-pressure operation in response to changing standards and market expectations.

In 1974 British Standards for breathing apparatus started to emerge, and the BS 4667 series was the first in Europe to deal comprehensively with closed-circuit, open-circuit, compressed-air line and escape sets. From this point onwards, the fire brigades were to become important users of open-circuit sets, others benefiting from their influence on the design and performance of the new sets.

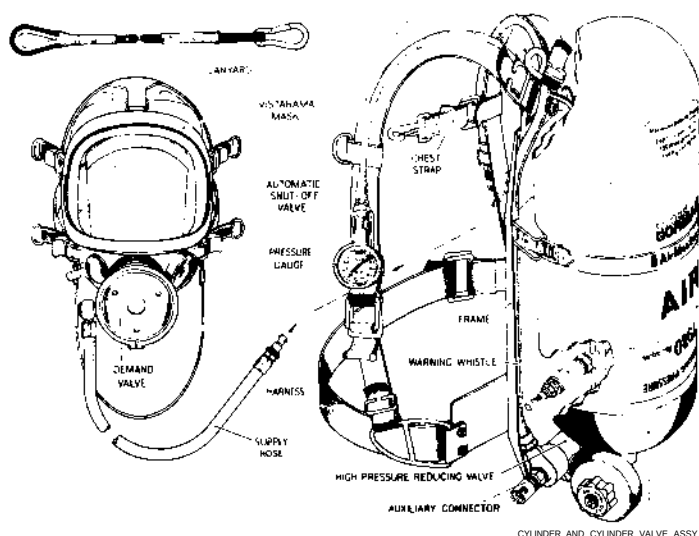


Figure 4. The Airmaster SCBA. (courtesy Siebe, Gorman & Co. Ltd)

Mines Rescue

But let us put the clock **back** and look at the early history of **closed-circuit** oxygen sets and their use in mines rescue. To many of us this represents the most challenging, **arduous**, and yet the most rewarding of all applications of **RPE**.

While some attribute the design of the first closed-circuit breathing apparatus to Dr Theodore Schwann, a Belgian physiologist, it has been determined that his apparatus designed in 1852 employed barium peroxide and not compressed oxygen and CO₂ absorption. Some twenty-five years later he did exhibit an apparatus in which oxygen and CO₂ absorbent were used, but there is no evidence it ever went into production. On the other hand, a number of sets of the Fleuss-Siebe, Gorman apparatus were manufactured by Siebe, Gorman & Co as early as 1879 and were used with success at the Killingworth Colliery after the disaster there in 1880, at the Seaham Colliery in 1880, and the flooded Severn Tunnel in 1882 (Figure 5). Fleuss's first apparatus made by Siebe, Gorman in 1878 consisted of a mask of rubber-proofed fabric, a breathing bag, and a copper cylinder charged with oxygen compressed to 30 atmospheres with a chamber of CO₂ absorbent carried on the back behind the breathing bag (Figure 6). Interest waned in this type of apparatus prior to 1902 but was revived by R H Davis, who persuaded Fleuss to resume work in this field, and together they produced the original Proto and Salvus sets some years before the outbreak of the first World War. These



Figure 5. Henry A. Fleuss (**centre**), Seaham Colliery, 1880. (courtesy Siebe, Gorman & Co. Ltd.)

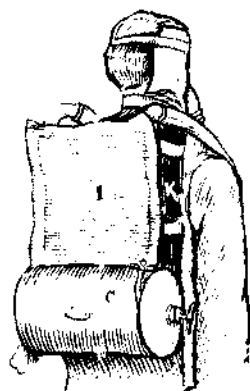


Fig. 6.
A. Breathing bag. B. Oxygen cylinder. C. CO₂ absorbent chamber.



Figure 6. **Fleuss's** first oxygen apparatus (1878). (courtesy Siebe, Gorman & Co. Ltd.)

were adopted by the **British, American, and other allied** armies for mining, tunnelling, and other military operations in poisonous air during the **1914–18 war**. Subsequently, with **alternativemouthpiece valves, the Proto Mark I** was adopted by the US Bureau of Mines and received the **Government's** Certificate of Approval, this British apparatus being then the only apparatus of **the kind** to be approved by both the British and American **Governments'** Testing Departments. At the same time R H Davis was engaged in the design and manufacture of a wide range of diving equipment, including the **"Oxylithe"** in **collaboration** with Captain S S Hall, RN, and Dr O Rees, RN, and many variants of compressed-oxygen apparatus. His collaboration with Professor John Scott Haldane, **FRS**, must surely be one of the most productive on record. Together they conducted experiments in the UK's first high-altitude chamber in Siebe, Gorman's works in 1912 and developed the world's first saturation diving tables in the diving tank and deep-diving simulator (in which I myself have spent many anxious hours) at Chessington. This became the Admiralty Experimental Diving Unit during the **1939–45 war**, and there have always been strong links between Siebe, Gorman and the Royal Navy. They were active across the whole range of respiratory protection, and there is scarcely any idea that appeared then or subsequently which does not appear in Sir Robert Davis's notebooks of that period.

Safety in mines has always been the prime concern of the Safety in Mines Research Establishment in Sheffield, and the 'Aerorlox' liquid oxygen set was the result of collaboration between SMRE and Siebe, Gorman. For some years, mines rescue strategy was based on compressed oxygen quick-entry sets in a state of instant readiness, supplemented by Aerorlox liquid-oxygen sets, which needed more time to charge and get ready, for deep penetration underground. Not only was the Aerorlox cool, and having few moving parts very reliable, but was capable of phenomenal duration on a 6.5 lb charge of LOX—up to three hours. The main disadvantage was, and is, the logistics and cost of maintaining a supply of liquid oxygen constantly available at mines rescue stations, or nearby. These problems were overcome however and at very short notice in the Sunshine Mine disaster in Wallace, Idaho, USA in 1972 when a number of Aerorlox-equipped mines rescue teams from Vancouver were supplemented by 24 sets flown out from Siebe, Gorman, Chessington (Figure 7). It is sad to recall that 93 miners lost their lives in that disaster.

The Proto Mark IV set was a hard act to follow, but the modern mines rescue set, the SEFA, is the result of collaboration between the NCB and two very special companies in the UK, Life Support Engineering Ltd of Storrington and Sabre Safety of Aldershot. Both companies are headed by "graduates" of Siebe, Gorman, carrying on the tradition of excellence in design and reliability in performance in direct descent from R H Davis, his Chief Engineer L R Philips, Professor J S Haldane, H A Fleuss, and ultimately of course Augustus Siebe himself.

I have deliberately drawn a line some twenty years ago, to which the SEFA set is an honourable exception, because recent developments in the UK have followed an international rather than a strictly national trend. The ubiquitous filtering facepiece is but one example of an alien product that has come to dominate the UK national scene in its class. But it would be a serious omission not to mention the Racal 'Airstream' helmet as a uniquely British conceived and designed product that has found a place in the international arena, and the 'Powerflow' powered respirator. Both are in the tradition of innovative engineering for which the UK has been famous in the past, and will become even more so in the future.



Figure 7. The Aerorlox LO₂ set, Sunshine Mine, Idaho, 1972. (courtesy Siebe, Gorman & Co. Ltd)

Acknowledgments

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