The Evolution of the Protective Mask for Military Purposes:

Inception to World War I

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ABSTRACT

This paper is the first of a two part series outlining the evolution of the science and technology connected to military protective masks. The information presented in this paper details the original historic design and application of protective masks developed in the civilian sector and traces the evolution of the military science of chemical and biological protection from 1500s until the end of World War I.

(Key Words: gas mask, chemical biological warfare, NBC, CBW, technology evolution, science history, military science)

INTRODUCTION

The historical development of key tools of modern warfare often has roots in civilian or scientific applications. New scientific inquiry and the extension and refinement of existing technology have been keystones in military development since the triumph of bronze swords over stone axes. The American humorist, Will Rogers once remarked, "You canï¿½t say that civilization donï¿½t advance; for in every war they kill you a new way".

While, obviously intended to be a humorous statement, this sentiment does highlight the concept of military adaptation and utilization of existing and developing technologies. As history has shown on countless occasions, the defensive implications or military necessity for a given technology often serves as the engine that drives its development.

One such tool of modern warfare, the protective mask, has undergone an interesting and vivid transformation. This paper will seek to highlight the technical evolution of the protective mask from its historic beginnings through the advent of its use in modern war fighting in World War I. This paper will also focus on the historic and socio-political factors that paved the way for the evolution of the military protective mask.

EARLY CONCEPTS OF CHEMICAL WARFARE AND PROTECTIVE MASKS

When examining the technical and scientific evolution of the protective mask, the question of original invention invariably arises. While, it is very likely that humans have used makeshift masks such as rags or kerchiefs for thousands of years, to protect their eyes, mouths, and respiratory systems from smoke and dust, the first detailed description of the protective mask concept is commonly credited to Leonardo da Vinci in the early 1500s.

Like most defensive military technologies, da Vinci's protective mask was actually proposed as a counter for an offensive technology that he had also been inspired to develop. His offensive concept is viewed as the precursor to the modern chemical shell. In his notes, he envisioned a hollowed naval cannonball loaded with arsenic and sulfur dust. Upon impact with a ship's deck, the projectile would explode into a cloud of poisonous dust that would be inhaled by the sailors on deck (McCabe et al. 1996; Smart 2000). As a defensive precaution against this technology being employed against it's originator, da Vinci cautioned that a face covering of damp cloth would help keep sailors from inhaling the toxic dust.

Like most of Leonardo da Vinci's work, however, his concepts of chemical warfare and protection were far ahead of their time. The first concrete evidence we have of protective masks being used comes from around 1656, when Dr. Schnable Von Romto constructed and employed his "plague mask".

This mask consisted of a beak-like projection, which covered the eyes, nose and mouth of the wearer. The projection was filled with cloth that had been soaked in mixture of herbs like lemon, peppermint, cloves, garlic, and cinnamon. While these did not effectively filter the air coming through the mask, they did emit an aromatic sent and served as a mild insect repellent. Thus, by lucky co-incidence, Dr. Von Romto's mask probably did, to some extent, deter plague-carrying fleas from transmitting the disease to the mask wearer. While by today's standards, the plague mask was not based on the soundest of designs; this invention clearly demonstrates an early historical attempt to design a protective device specifically for the purpose of shielding the user's respiratory system from the inhalation of harmful airborne contaminants or pathogens (NFP 2000).

Von Romto's mask and its early derivations did not immediately lend themselves to military applications, largely because there was no call for widespread respiratory protection in war fighting. Rudimentary concepts of chemical and biological warfare have been present through much of recorded history. Some of the earliest reported uses occurred in the 6th century B.C. when Assyrians began poisoning the water supplies of their enemies with rye ergot. In 1346, when plaque broke out in the Tartar Army during its siege of Kaffa in the Crimea, the attackers adopted the tactic of throwing the corpses of their dead over the city's fortified walls. The resulting plague outbreak in Kaffa ultimately forced the defenders to surrender. Various Russian soldiers and commanders also used this tactic against the Swedes in the campaigns of the early 1700s (OTSG 2000).

On numerous occasions, smallpox was used as an early non-conventional weapon. The conquistador Pizarro is reported to have presented the Incas with contaminated clothing and blankets around 1530 in an attempt to spread the disease through the native population. Similar tactics were later employed by Sir Jeffery Amherst and others against American Indians during the French-Indian Wars of the 1750s and 60s (Diamond 1999; OTSG 2000).

Yet, despite evidence of early chemical and biological warfare concepts and activities, the tactics for delivering a threat to an enemy's respiratory system remained largely unexplored and undeveloped. The first clear evidence of the concepts of toxic gas attacks arose during the Napoleonic Wars.

With the British Navy tied up in a costly blockade of key French ports, a renegade naval officer proposed a series of unconventional tactics to establish a beachhead on the French coast and gain victory over Bonaparte. In 1812, Captain Thomas Cochrane, the 10th Earl of Dundonald, proposed a radical plan to Prince George the IV, in an effort to free the Royal Navy from it's tedious blockade duties. Among his suggestions for exploding ships and huge floating mortars was a concept of "noxious effluvia". By covering the deck of an obsolete ship with charcoal, coal tar, coke, and sulfur powder and lining the hull with clay and gunpowder, Cochrane could detonate by fuse, a charge capable of crippling an enemy ship and generating a toxic plume of choking smoke that could be employed to secure an otherwise unattainable position and lead to the establishment of a beachhead (Lloyd 1947).

When the Prince turned the idea over to a team of nobles and admirals for evaluation, it was ultimately rejected. Not because it wouldn't work, but rather the panel was concerned with the implications of this fearsome technology being employed against them after it's initial use. Since, it was determined that the British defenses, as well as the French, would be vulnerable to such attacks, the decision was made to abandon the plans and swear all involved to a code of silence. Sir Thomas Cochrane, then Rear Admiral, died in 1860, taking the first plans for a military chemical assault to the grave with him. Only 40 years after his death, did correspondence come to light reveling the depth of his strategy (Malcomson 1995).

Since Lord Cochrane's ideas were not witnessed on the battlefield, the need for development of a military defensive mask remained on the horizon. Instead what were the early precursors to the first modern protective masks came from a series of civilian inventors at the end of the 19th and beginning of the 20th century.

The first patented idea of a protective mask arose in 1849 when Lewis Haslett, an inventor in Louisville, KY patented his "Inhaler or Lung Protector". The mask was envisioned for a wide variety of applications in any situation where dangerous substances would be inhaled. Itï¿½s design was a simple face covering and breathing tube packed with wool or other porous substances. This packing would then be moistened with water and serve as the maskï¿½s filter (Smart 2000).

The next fifty years saw some additional work in the field of civilian protective masks. Most of these designs were targeted to fire fighters or chemical industry applications. The major mask designs between 1850 and 1910 were largely of two varieties. They either employed a hood/breathing tube configuration like that of the Haslett mask, or they were a simple mouth/nose covering like that invented by John Stenhouse of Glasgow Scotland, in 1850. Stenhouseï¿½s mask was not patented, but rather given freely from the inventor for public use. While itï¿½s physical design was rather simple it did make use of an innovative filter media. The Stenhouse mask was one of the first to use wood charcoal, rather than dampened cloth as a filter. Charcoal would come to be used as an effective filter agent by numerous designers from that point on.

Civilian mask innovations were patented by numerous American and British inventors including Benjamin Land (1850 and 1865), Theodore Hoffmann (1866), John Tyndall (1871), Samuel Barton (1874), George Crofutt (1874), Huston Hurd (1879 and 1889), Alexander Henderson (1879); Arthur Moody (1896), William Moran (1904), and Samuel Danielewicx (1909). All of these masks were to one extent or another variations and refinements of the Haslett or Stenhouse masks using either fabric or charcoal filtering devices (Smart 2000). The one exception to the design similarities came from Charles Chapin (1904 and 1911) who employed two large air cylinders worn on the back to provide fresh air to the user (Smart 2000).

Perhaps the most successful version of the civilian protective mask that came out of this period was the invention of Garrett Morgan. Even though Morgan, the son of former slaves, had only a 5th grade education to his name, he became a successful businessman and inventor. In addition to his work with protective masks, he is credited with the invention of the three-position traffic signal. Around 1906, Morgan had designed a gas mask for use by firefighters, which consisted of a canvas hood with a double breathing tube extending from the hood. The double tube merged into a single filter tube around the user's back and contained a water-soaked sponge, which served to filter the smoke particles.

The Morgan mask was thrust into the national (and historical) spotlight on July 25, 1916. In a daring test of his new invention, Morgan, his brother, and two volunteers used the mask to rescue several workers (and the three rescue teams that failed to save them) from a gas filled underground tunnel that resulted from an explosion beneath Lake Erie. Following the rescue, Morgan's company started receiving requests from fire departments around the country. In 1921, Morgan was awarded a patent for his "Safety Hood and Smoke Protector". Two years later, Morgan won gold medals from the International Exposition of Sanitation and Safety, and the International Association of Fire Chiefs with a refined version of his protective mask (Jackson 1992).

FRITZ HABER, FATER OF MODERN CHEMICAL WARFARE

To gain an accurate perspective of what served as the catalyst for the rapid evolution and development of the protective mask into a tool of modern warfare, one needs to take a step back an examine the pre-World War I situation in Germany. As already mentioned in this paper, defensive military technologies like the protective mask usually follow the development of offensive war-fighting technologies and strategies. And while we have seen that the precursors of biological and chemical warfare were long ago established, their effective use as tactical weapons in a modern military sense were not yet witnessed on the Pre-World War I battlefield).

When one looks at the developmental conditions for the introduction of modern chemical warfare that existed in Germany prior to the outbreak of war, itï¿½s clear from the lens of hindsight, that conditions were perfect to favor the introduction of such offensive technologies by the Germans.

The industrial and economic markets of Pre-War German were dominated by the chemical and dyestuff industries. Perhaps one of the most successful firms in Pre-War Germany was Farbenfabriken Friedrick Bayer & Co. of Elberfeld. The product lines of Bayer and its German competitors were largely related to the lucrative dyestuff industries, however, at the turn of the century, the major German chemical corporations began to develop other lines related to pharmaceuticals and photographic chemicals.

The German chemical corporations had a tradition of intense and well-developed research and development programs and were arranged in similar manners to research universities. Beginning chemists were actively recruited and well compensated. Once they proved themselves to the company, they were usually rewarded with generous long-term contracts for employment, thus ensuring that the corporations were able to retain a well-trained and talented pool of researchers. By the early 1900s the eight largest German chemical companies had merged into a single unified cartel called the Interessen Gemeinschaft. Into this industrial system entered Fritz Haber.

Haber was born on December 9, 1868 in Prussia, the son of a prosperous German chemical merchant. At the age of 25, Haber began teaching physical chemistry at the university-level quickly earning notoriety for his work in electrochemistry and thermodynamics.

During the early part of the twentieth century, the global demand for nitrogen based fertilizers far exceeded the existing supply, most of which originated from a huge guano deposit located along the coast of Chile. This situation put industrial nations like Germany at the mercy of the Chilean monopoly of this limited and valuable natural resource. Haber, along with Carl Bosch, began the first serious work on the problem of generating ammonia and nitrogen compounds from elemental components. Haber invented the first large-scale catalytic synthesis of ammonia and thus furnished the essential processes and precursor reagents for many important substances, particularly fertilizers and explosives.

In 1911, Haber was appointed director of the Kaiser Wilhelm Institute for Physical Chemistry in Berlin. At the beginning of World War I in 1914, Haber was put in charge of research to aid the German war effort. His work with explosives and anti-freeze substitutes were critical to the German Army, however the work that will forever be associated with his name was his development of compounds for chemical warfare. In 1915, he directed the first large-scale production of chlorine for use in military weapons. He firmly held the belief that the use of such technology would tip the scales in favor of Germany, terminate trench warfare, and quickly bring the war to a conclusion (McCoy and Phillps 1992).

As the war continued Haber and Richard Willstädter worked on the development of respiratory filters to protect German troops. Due to his military research, the Allies ultimately labeled Fritz Haber a war criminal. However, despite this stigma from the western scientific community, the Swedish Academy of Sciences awarded him the 1918 Nobel Prize for his contributions to the solution of world hunger by the development of synthetic ammonia (Goran 1947).

When Hitler became German Chancellor, Haber realized that his contributions to the country would not overcome his Jewish heritage (even though he had renounced his fate at the turn of the century). He left Germany in 1933 to take a teaching post at Cambridge and he died two years later at the age of 65 (McCoy and Phillips 1992).

GENESIS OF THE MODERN MILITARY PROTECTIVE MASK

The work of Fritz Haber in the early 1900s set the stage for Germany's initial use of chemical weapons on the battlefield. His search for a toxin that could be appropriately used in battle lead him to experimentations with diatomic chlorine gas, which was readily available as an unwanted by-product of the dyestuff industry.

Fritz Haber, who was by all accounts, a supremely patriotic German, undertook his research at his own initiative. His wife Clara, who was also a chemist, was strongly opposed to the use of science for the manufacture of weapons of mass destruction. When he could no longer hide the goals of his research from his wife, their marriage rapidly deteriorated and ended in her suicide in 1915.

As the German offensive bogged down in the trench warfare of 1914 and 1915, the German military could no longer be certain of its victory on the Western Front. The Kaiser decided that a decisive victory against France was necessary to break the stalemate. It was in this atmosphere that Haber approached the leadership with his chemical warfare ideas (Addington 1994).

While, the German military had no great respect for the scientific community and the concept of "poison gas" seemed without honor to many seasoned officers, Haber nonetheless convinced them in late 1914, with a demonstration conducted at a proving ground outside Cologne, Germany. With the acceptance of his plan, Haber was commissioned with an officer's rank (later promoted to Captain) and given the responsibility to help organize Germany's chemical corps (Goebel 2000).

Under Haber's guidance, plans were drawn up for the world's first chemical assault. On April 22, 1915, German troops set up 5,730 cylinders of chlorine gas, opened the valves, and sent approximately 180,000 kg of gas blowing towards French and Algerian troops entrenched along Ypres, Belgium. The Allies were totally unprepared for such an attack, and the effects were devastating. Allied soldiers choked and died with burning sensations in their lungs. Those who could escape the green tinged clouds broke ranks and fled. The attack opened an 8-9 km gap in the Allied line. (Goebel 2000; MTS 1998).

The initial attack was followed by a similar one on Canadian lines on the morning of April 24th, with similar results. After two days of chemical attacks, there were an estimated 5,000 dead and 10,000 wounded at Ypres (Addington 1994; Goebel 2000). Despite reports that a German solider was apprehended with a crude gas mask, and that he reviled the planned attack under interrogation, several days before the battle of Ypres, the Allies were still unprepared for it and soldiers had no protective equipment available to them.

Following the attack at Ypres, a call went out among the Allies for protective masks of any kind. British troops in immediate response were provided 30,000 cotton mouth-pads within 3 days (Smart 2000).

Despite the initial success of the German gas attacks, the German military was largely unprepared to exploit this tactic while they still held the advantage. Due to shifts in the prevailing winds along the Western Front, German gas attacks stopped on May 24th and did not resume until December. This delay allowed the Allied forces to prepare both defensive and offensive chemical technologies of their own (Goebel 2000).

While, immediate precautions for the gas attacks were cotton masks dipped in soda solutions, or the more colorful and field expedient precaution to "piss on your hankerchiefs [sic] and tie them over your faces", more sophisticated protective devices were rapidly being developed (Smart 2000).

After a Canadian soldier observed a German trooper pulling a bag over his head during a gas attack, the British developed the Hypo Helmet in mid-1915. This mask (developed under the direction of MAJ Charles Foulkes of the Royal Engineers) consisted of a flannel bag soaked in sodium thiosulfate. A mica window in the front of the mask, allowed the soldier to see and conduct operations while wearing the mask (Smart 2000). By June of that year, approximately 2.5 million of the Hypo Helmets were issued to Allied troops (Goebel 2000). While, moderately effective protection against chlorine attack, the Hypo Helmet had a number of inadequacies that were addressed in subsequent mask designs.

By fall of 1915, Foulks had developed "Special Companies" for gas warfare and the British were prepared to offer chemical counter-attacks to the Germans. The first Allied chemical attack was conducted on September 25, 1915 at Loos, Belgium. While the British gas attack partially backfired (resulting in thousands of Allied casualties) it was devastating on the German front-line trenches (Goebel 2000).

Around December 1915, the Germans had developed another tool in their chemical arsenal. On December 9th, the Germans launched another chemical attack on Allied forces at Ypres, this time in addition to chlorine, they used the gas phosgene. Phosgene was another industrial by-product available to Haber. It was substantially more toxic than chlorine with death occurring about two to three days after exposure. Fortunately during the summer of 1915, the British undertook a careful analysis of the industrial processes and compounds available to the Germans and they were well prepared for the possibility of phosgene being used as a weapon (Goebel 2000). To protect troops against the use of phosgene, the British developed the P.P.H and P.H.G Helmets, collectively termed "P-Helmets".

The P-Helmets were a modification of the Hypo Helmet. In this version of the mask, a two-layered flannel hood was treated with a mixture of sodium phenolate and glycerin. The mask was also equipped with a rubber outlet valve. Hexamethylentramine was later added to the mixture to increase the effectiveness, and goggles were added to the hood to help protect the wearer against lachrymators like ethyl bromoacateate (Smart 2000). Approximately 9 million P-Helmets were manufactured and issued by December 1915 (Goebel 2000).

The French also developed a mask similar to the British Helmets. By February 1916, they had developed the M2 Mask that was constructed of layers of treated fabric. It is estimated that the French manufactured and deployed about 29 million of the M2s by 1918 (Smart 2000).

Throughout the rest of World War I there were additional advances in the offensive use of chemical weapons. The most notable of these was the Livens Projector developed by the British. Since conventional artillery shells did not achieve the high gas concentrations necessary for relatively low-toxicity compounds like Chlorine, an alternative was developed by Captain F. H. Livens. The Livens Projector was a small crude mortar type system that could be used to project drums of gas about a mile. The drums would then explode on impact by means of a bursting charge and deliver their contents in a concentrated plum (Goebel 2000).

The Germans continued to experiment with chemical artillery shells containing a variety of compounds including bromine, trichloromethyl chloroformate, hydrogen cyanide, hydrogen sulfide, cyanogen bromide, cyanogen chloride, and methyl cyanoformate, among others (MTS 1998). On July 12, 1917, however, the Germans introduced a new weapon to the line-up. Once again, on an attack of the British line around Ypres, Belgium, German shells erupted in the trenches. This time, however, instead of chemical gas, they released a brown oily fluid that smelled like rotten garlic or mustard. As the battle wore on, the British began to suffer swelling, throat irritation, and huge painful blisters wherever their skin had come in contact with the liquid. The compound was dichlorethyl sulfide. The Germans called it Yellow Cross for its shell markings. The British called it HS for "Hun Stuff". The common name that followed it, however, was "Mustard" for it's putrid smell (Goebel 2000).

As a result of the constant experimentation by the Germans, the British moved from the "helmet" design in protective masks to a more modular design. In 1916, they developed the Large Box Respirator. To avoid the need to change the face piece and filtering system each time a new chemical weapon was encountered or during prolonged gas attack, the system consisted of a face piece attached by a hose to a canister filtering system. The filter typically contained a mixture of soda-lime, charcoal, brimstone, sodium sulfite and potassium permanganate. Separate canisters could be attached quickly without removing the face piece (Smart 2000).

While the Large Box Respirator was bulky and uncomfortable, it quickly gave rise to new and improved designs. The most common was the Small Box Respirator (SBR), which used a nose clip and required breathing through a rubber mouthpiece.

When the United States entered WWI in 1917, the Army was largely unprepared for the chemical warfare going on in the trenches of Europe. There were no protective masks of U.S. design for troops deploying in Europe, so the Army borrowed foreign equipment. Soldiers were typically issued SBRs for highest protection levels and French M2s for extended wear. This dual equipment apparently lead to numerous casualties as soldiers attempted to switch from the SBRs to the more comfortable M2s while gas still lingered in the trenches. The U.S. attempted to design it's own version of the protective mask based on the British SBR design. The initial attempt completed in 1917 by the Bureau of Mines and Department of Interior was largely unsuccessful and resulted in over 600,000 masks that could only be used for training purposes in the U.S. (Smart 2000).

The U.S. ultimately moved forward with its Corrected English Model (CEM) gas mask. This was an upgrade to the SBR, which utilized a rubberized face piece, nose clip, and snorkel like mouthpiece. The faceplate of the CEM was effective against agents like chloropicrin and the angled tube of the American mask lessened breathing resistance and wearer fatigue.

The CEM was further refined as the Richardson, Flory and Kops (RFK) mask design, produced in early 1918. The RFK incorporated a new face piece with an improved shape for fitting and comfort but was in most other respects similar to the CEM (NFP 2000; Smart 2000). Several other variations were developed by the U.S. including the Akron Tissot Mask, the Kops Tissot Mask, and the Kops Tissot Monro Masks. All of these masks proved to be more comfortable than the RFK, but also more difficult to manufacture. All were designed in 1918 and were produced in numbers of around 300,000 or less before the armistice was signed on November 11, 1918 (Smart 2000).

The one face canister design employed by the U.S. was the Navy Mouth Canister gas mask. This design crossed the CEM faceplate with the canister design of the most common German Masks.

The masks of Imperial Germany largely fell into two groups during World War I. The Gummimaske was produced from 1915 to 1917 as the first mass issued design of the German Army. The mask was made of fabric with a thin rubber layer with a snout-type arrangement connecting the filter directly to the face piece. The mask was considerably lighter than the box-type filter systems of the allies and the German filter screwed into a metal plate, which made it easily replicable.

In 1917, the Gummimaske was replaced by the Lederschutzmaske. Rubber shortages in Germany meant that alternative materials had to be located for the face piece. The Lederschutzmaske used sheepskin leather in its primary construction and used mounting rings to seal the eyepieces. Both major German designs suffered from the lack of an outlet valve. This deficiency resulted in the wearer having to force the air back through the filter, causing unnecessary exertion.

It is estimated that approximately 100,000 soldiers were killed and over 1 million injured as a direct result of chemical warfare from 1915-1918. Chemical attacks proceeded right to the end of WWI. In one of the final Allied chemical assaults of the war, the British fired their own mustard shells into German positions at Wervick, Belgium. One of the injured was a corporal by the name of Adolf Hitler, who was evacuated back to Germany burned and blinded (Goebel 2000). As a result of that experience, Hitler developed distaste for the use of poison gas on the battlefield. The experience of this German corporal would in turn, shape the events in another World War sixteen years later.

As the gas poured over the battlefields of WWI, defensive technologies continued to improved. By the end of the World War I protective mask technologies had advanced to the point were troops who were equipped and trained to deal with chemical attacks could effectively deal with them and minimize associated casualties. Against the un-protected, however, the German poison gas attacks continued to have devastating effects, particularly against the Russians on the Eastern Front and the Italians in Northern Italy.

CONCLUSIONS

As we have seen in this historical outline of the evolution of the protective mask, the defensive technology of respiratory protection, while pioneered in the civilian sector for use in fire-fighting and industrial application, was catalyzed through the events of World War I, namely the advent of offensive chemical weapons technologies by Germany. As with the development of other military technologies, offensive developments precede the mass development and refinement of defensive technologies, even on the side of the antagonist.

While German troops were the first to initiate chemical gas attacks, the earliest deployments of Germany's chemical corps still relied on relatively un-sophisticated protective measures. It was not until the Allies were on the brink of chemical retaliation, did German troops receive effective gas masks of their own as standard-issue equipment.

The military application of protective mask technology evolved the state of design from simple cloth coverings or sponge filled filter tubes to technologically superior canister filter systems, which could be used under field conditions to counter a variety of chemical hazards. The rapid series of developments in mask design and utilization reflect the situational pressure of chemical attacks on the battlefield of WWI and the catalytic effects of that pressure on the evolution of existing technology.

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