The Europeans Face Chemicals on the Battlefield, 1915-1918

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During World War I chemists on both sides investigated over 3,000 chemical substances for potential use as weapons. Of these, only thirty agents were used in combat, and only about a dozen achieved the desired military results (Table 1). Most armies grouped war gases according to their physiological effects, that is their effects on the human body.[1]

One category, lachrymators, was composed of tear gases such as xylyl bromide, an agent that primarily affected the eyes but in large concentrations could also damage the respiratory system. Asphyxiators, such as phosgene, chloropicrin, and chlorine, were in another category. These gases caused fluid to enter the lungs, thereby preventing oxygen from reaching the blood. Toxic gases, yet another category, passed through the lungs to the blood, preventing the circulation and release of oxygen throughout the body. Hydrogen cyanide ("Vincennite" to the French) was one of the least effective toxic agents. Sternutators, such as diphenylchlorarsine, were a type of respiratory irritant composed of a very fine dust that caused sneezing, nausea, and vomiting. Some sternutators were systemic poisons that had a delayed toxic effect on the body. The final category held the greatest casualty producer—a vesicant or blister agent that, because of its peculiar odor, the British and later the Americans commonly referred to as "mustard gas."*[2]

In 1917 the Germans first used mustard against the Allies at Ypres. This was the only persistent agent used during World War I and had effects similar to those produced by a combination of lachrymatory, asphyxiator, and systemic poisons. Although called mustard *gas*, this chemical was not a gas, but rather a volatile liquid that, several hours after contact with the skin, would cause severe burns and blisters. The introduction of Yellow Cross caught the Allies completely by surprise. During the first attack, British infantry saw the gas shells explode, but were unable to "see, smell or taste any agent, nor feel any immediate effects." The soldiers concluded that the Germans were trying to trick them and did not put on their masks. After several hours, to the consternation of officers and medics, the troops began to complain of pain in their eyes, throats, and lungs. Later, blisters appeared on the exposed skin of the British soldiers. The German use of Yellow Cross

*The Germans referred to it as "Yellow Cross" because of the shell marking, and the French called it "Yperite," in recognition of the location where it was first used.

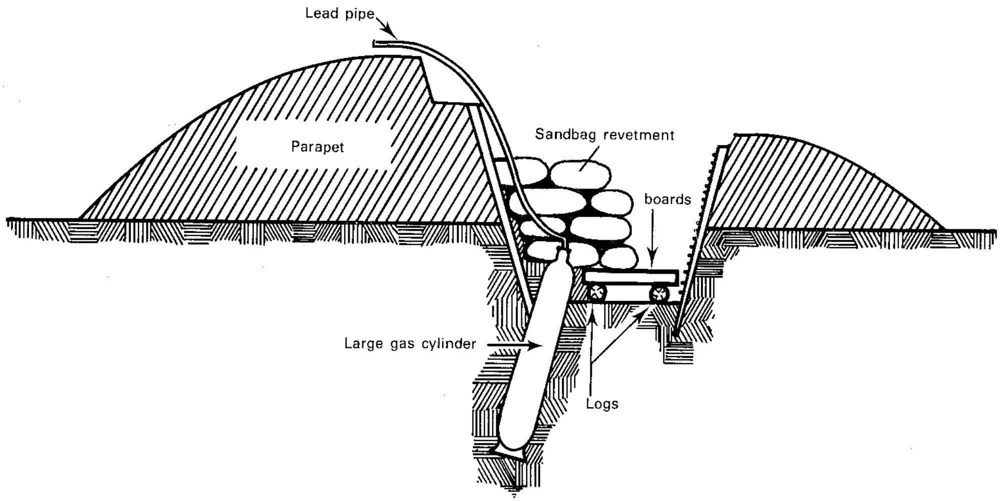


Figure 1. Side view of gas cylinder emplacement.

caused British gas casualties, which had been declining, to increase markedly. Because of its ability to produce large numbers of casualties, mustard was soon being referred to as the "King" of the war gases.[3]

The major combatants realized that the employment of gas called for specially trained troops and, accordingly, formed offensive gas units. Because of the need to emplace gas cylinders, pioneer or engineer troops usually provided the cadre of these special units. The Germans converted two pioneer regiments, the 35th and 36th, into gas units consisting of three battalions each. The regiments would deploy by companies, according to the size of the front of the attack. In addition to these units, the Germans organized a gas mortar (*Minenwerfen*) battalion. The Austro-Hungarians followed the German model and created their own special gas units.[4]

As early as July, 1915, the French and British organized gas companies called "Special" by the British and "Z" for *gaz* (gas) by the French; both employed engineer troops as cadre. By 1917 the British had expanded their original four companies to twenty-one and had organized them as a Special Brigade. The French eventually created the 31st, 32nd, and 33rd gas battalions composed of three companies each. The Russians organized gas units and called them "Gas Detachments of the Chemical Department," with one detachment assigned to each Russian Army, a total of thirteen.[5]

In addition to developing gas units and chemical agents, a constant search continued for efficient delivery systems. The cylinders used in the first gas attack at Ypres in 1915 were the major component of a cumbersome, immobile system. It usually took several days of intensive labor,* with infantry providing most of the muscle, to emplace the cylinders for a cloud attack (Figure 1). One can gain an indication of the difficulty of the task by noting that as many as 12,000 cylinders, each weighing over 100 pounds,

*The time it took to install individual cylinders varied according to the terrain, weather, available manpower, and enemy harassing fire.

French Number	Shell Filling	American and British Code Symbols	French Designation	German Designation and Shell Marking	Odor	Persistency In Open	Persistency In Woods	Physiological Effect	Remarks
						Non-Persistent Class.			
	Chlorine (Used only in cloud gas)	Red Star	Bertholite		Chloride of Lime	10 min.	3 hrs.	Lung Irritant, Deadly. Action Immediate.	These gases are very volatile; they are vaporized entirely at the moment of explosion, forming a cloud capable of giving deadly effects, but which loses more or less rapidly its effectiveness by dilution and dispersion into the atmosphere.
4	Arsenic Trichloride 30% Stannic Chloride 15% Hydrogen Cyanide 50% Chloroform 5%	Not used by A.E.F. or B.E.F.	Vincennite			10 min	3 hrs.	Lachrymator and Respiratory Irritant. Considered quite toxic, but in high concentrations only.	
4B	Cyanogen Chloride 70% Arsenic Trichloride 30%		Vitrite			10 min.	3 hrs.	A Lachrymator, Respiratory Irritant and Lethal Agent	
5	Diphenyl Chlorarsine	D.A	Sternite	Blue Cross	Slight	10 min.	3 hrs.	Sneezing Gas. Nerve Depressant. Respiratory Irritant.	These gases form non-persistant clouds of solid particles.
	Diphenyl Cyanarsine	D.C	Sternite	Blue Cross	Is interchangeable with D.A			Effects somewhat greater.	
	Phosgene	C.G	Collongite	Three White bands, White D.	Musty Hay, Green Corn	10 min.	3 hrs.	Respiratory Irritant. Very deadly. Action usually slightly delayed.	
						Semi-Persistent Class.			
	Diphosgene	Not used in S.F.	Superpalite	Green Cross	Disagreeable, suffocating. Musty Hay	3 hrs.	12 hrs.	Same as phosgene.	These gases have moderately high boiling points, are only partially vaporized at the moment of explosion. The cloud formed upon explosion is generally not deadly, but it immediately gives penetrative lacrymatory or irritant effects. The majority of the "gas" contents of the shell is pulverized and projected in the form of a spray or fog which slowly settles on the ground and continues to give off vapors which prolong the action of the initial cloud.
	Phenyl Carbylamine Chloride			Green Cross		3 hrs.	12 hrs.	Eye, Nose and Throat Irritant. Not very poisonous.	
	Phosgene, Diphosgene and Diphenyl Chlorarsine			Green Cross 2	Resembles Diphosgene a little pungent	3 hrs.	12 hrs.	Respiratory Irritant. Slightly delayed action. Very deadly. Causes vomiting and a little lachrymation.	
	Chlorpicrin 75% Phosgene 25%	P.G.			Pungent, Suffocating.	3 hrs.	12 hrs.	Causes vomiting, Respiratory Irritant, a little lachrymation.	
	Diphosgene and Chlorpicrin			Green Cross 1	Pungent, Suffocating	3 hrs.	12 hrs.	Slightly delayed action, very deadly, respiratory irritant, causes vomiting and a little lachrymation.	Phosgene in these mixtures has same effect as used above, if concentration is sufficiently high.
7	Chlorpicrin	P.S.	Aquinite		Pungent	3 hrs.	12 hrs.	Causes vomiting, respiratory irritant, tear producer.	
	Chlorpicrin 80% Stannic Chloride 20%	N.C.			Pungent	3 hrs.	12 hrs.	Respiratory irritant, causes vomiting, tear producer.	
	Ethyl Dichlorarsine and Dichlormethylether			Yellow Cross 1 or Green Cross 3	Ethereal, Pleasant	3 hrs.	12 hrs.	Nerve poison similar to diphenylchlorarsine, easily destroyed by water.	
						Persistent Class.			
9	Bromacetone	B.A.	Martonite			2 days	7 days	Lachrymator, Tear Producer.	These gases having very high boiling points are but little vaporized at the moment of explosion. A small portion of the contents of the shell is atomized and gives immediate effect, but by far the greater part is projected on the ground in the form of droplets which slowly vaporize and continue the action of the initial cloud.
	Brom Ketones			Green Cross	Pungent	3 days	7 days	Tear Producers, Slight Respiratory Irritants. Action immediate.	
21	Brombenzylcyanide	C.A.	Camite		No Odor	3 days	7 days	Not toxic but most powerful lachrymator known.	
20	Mustard Gas (Dichlorethyl Sulphide)	H.S.	Yperite	Yellow Cross	Slight Mustard or Garlic	3 days	7 days	Respiratory Irritant. Eye and Skin Irritant. Blistering Agent. Action delayed several hours.	

NOTE: The above figures on time of persistency are approximate only and for calm weather. Persistency is dependent to a large extent on temperature, wind velocity, and the amount of gas liberated, especially in woods or other more or less closed places. High temperatures and wind velocities decrease persistency, and low temperatures and wind velocities increase it.

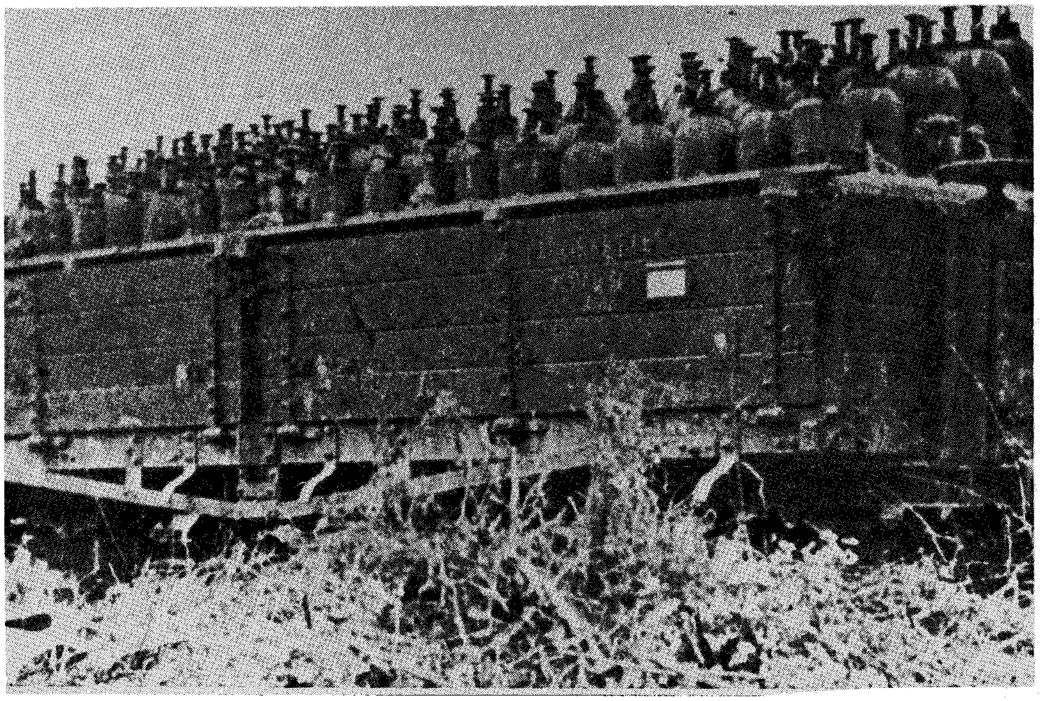
Table 1. Summary of markings for chemical shell and properties of most common gases.

were sometimes needed for a single operation. Once emplaced, the cylinders were dangerously exposed to enemy high explosive shells and easily damaged. Cylinder discharges always depended on favorable weather conditions.

Despite these problems, the British relied on cylinders as a delivery method until the end of the war. They normally used seven to eight cylinders in a section, six sections to a Special Brigade company. Sixteen companies could produce a gas wave or cloud that covered a 24,000-meter front. Several factors influenced the British decision to continue using cylinders. First, the prevailing winds favored Allied gas clouds. Second, the British suffered from a chronic shortage of shells and were reluctant to convert the production of high explosive shells to the production of gas shells. Third, British intelligence reports indicated a dense cloud attack was effective in producing mass casualties. On 26 October 1917, Brig. Gen. Charles H. Foulkes, Commander of the British Special Brigade, reviewed intelligence reports indicating that British cloud attacks created significant German casualties as far back as thirty kilometers from the front-line trenches. Foulkes proposed that the Special Brigade use what he termed "retired cylinder attacks," in which a large number of cylinders would be emplaced *behind* British lines rather than in the front lines or forward of the trenches. Because the Special Brigade companies could assemble a greater number of cylinders in a relatively small area without the interference of enemy small arms or shell fire, this method allowed for a significantly greater concentration of gas released at one point.[6]

The British improved this tactic by conducting what they called "beam attacks." These attacks called for placing numerous cylinders on narrow-gauge tram cars that troops pushed forward to positions just behind the front trenches. After the cylinders were opened, the resulting gas concentration became so dense that friendly troops had to be evacuated from the path of the gas "beam." On 24 May 1918 the British launched their first beam attack. This and similiar attacks, General Foulkes claimed, caused the Germans considerable anxiety, for they could not determine how and where the dense clouds originated. The beam attacks were especially deadly when launched from six or more separate railheads and when the individual clouds merged behind German lines. Prisoners taken from the German 9th Uhlan Regiment reported that one such attack caused 500 casualties in the neighboring 1st Landwehr Regiment, which, as a result of the attack, had to be withdrawn from the line. According to the British, the effectiveness of the improved cloud attacks, with their increased density, continued to frustrate the German Army.[7]

The Germans, for their part, arranged their cylinders so that twenty formed a battery. Fifty such batteries were required to saturate one kilometer of front line with gas. The lack of favorable prevailing winds, however, soon forced the Germans to abandon the cloud attack. On 8 August 1916, they launched their last cylinder attack at Wieltje, near the scene of the first discharge at Ypres.[8]



Narrow gauge tram gondola with gas cylinders

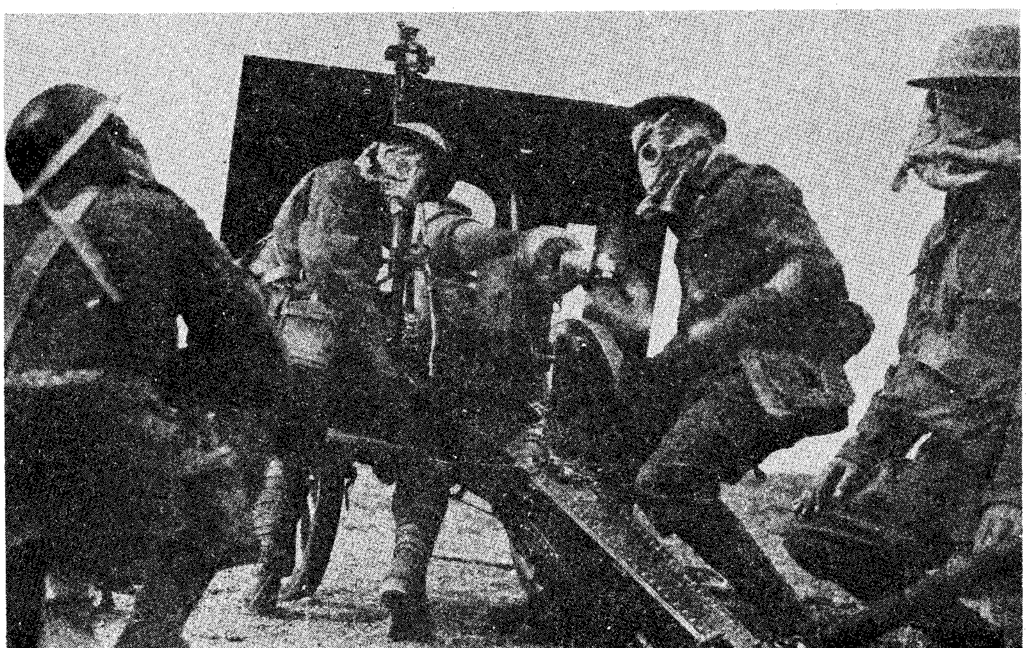
Because the prevailing winds in Western Europe blew from west to east, the German Army began to place increasing reliance on gas-filled shells that detonated beyond Allied lines and whose contents could then drift back over enemy trenches. Gas shells could be fired from standard artillery pieces with no extensive adaptation for gas employment. Although weather conditions still remained a factor, no longer did the Germans have to wait for the wind to change to a westerly direction. Now artillery could fire upward of the target, saturating it with gas and achieving the same effect as cylinders. Shells also offered an element of surprise not available with cloud attacks. Finally, gas shells proved more advantageous than high explosive rounds because the former did not have to score direct hits on a target to neutralize it. To avoid confusion and to aid artillerymen, the Germans developed a coded system of colored crosses to identify shells containing chemical agents.

The Germans were further encouraged to use gas shells by the results of an attack staged on the night of 22—23 June 1916. About 110,000 shells containing the lung irritant Green Cross fell on French forces near the fortress of Verdun. German batteries adjacent to this sector added thousands of rounds of a lachrymatory gas. The gas attack, according to French sources, had its greatest effect on French artillerymen and reserves in the rear areas, causing over 1,600 casualties. German staff officers, impressed with the results, talked of creating "special gas batteries" controlled by special gas staffs. In the interest of flexibility, however, the high command decided that all artillery units should fire gas shells. By the war's end, gas shells comprised 50 percent of a German artillery battery's basic load.[9]

The British and French also developed gas shells with unique color codes. The French Army used these shells almost as extensively as the Germans and fired the first phosgene-filled artillery shells on 22 February 1916 at Verdun. The French also experimented with an extremely small bursting charge in order to increase the gas payload. This French innovation allowed a stable, dense cloud to form. Although the French increased the chemical payload, they erred by adding comparatively harmless *funigenes* (smoke producers), such as stannic chloride, thus reducing the toxic capacity of their phosgene shells by 30 to 40 percent.[10]

The French committed another technical error in the gas war. The hydrocyanic acid (hydrogen cyanide) used in their Vincennite shell (named for the production location) was too volatile and filled only half of the shell's capacity. Unless an extremely high concentration could be built up, there were no harmful effects. All the belligerents considered the Vincennite fill practically worthless. The French, for some reason, refused to accept this conclusion and manufactured over four million shells that, when fired, caused relatively few casualties.[11]

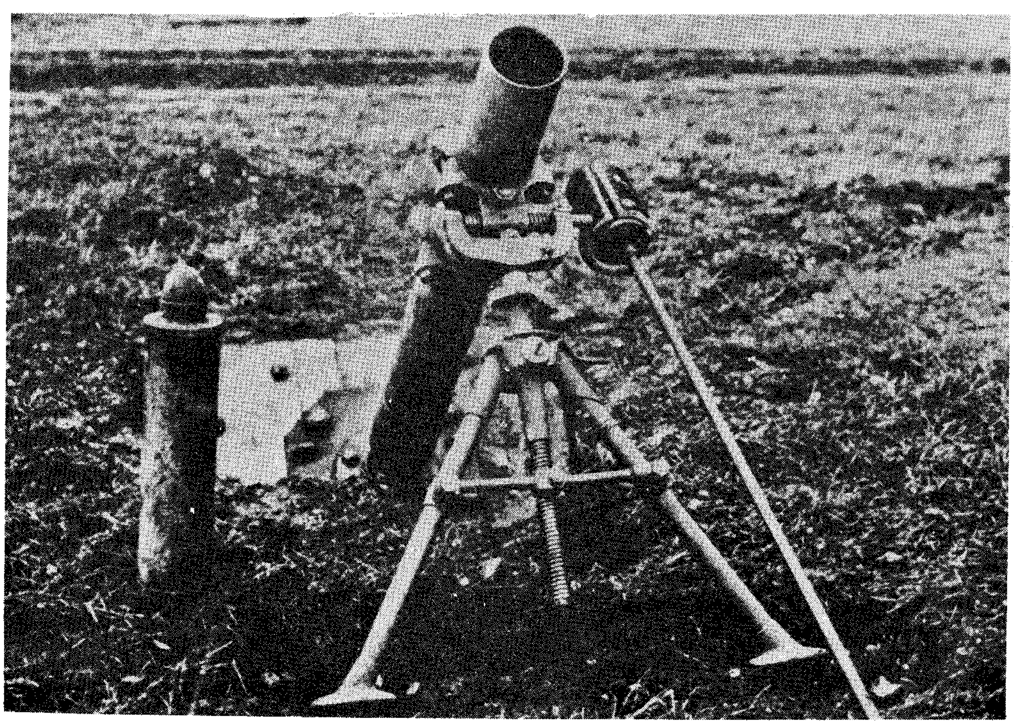
The British faced a constant artillery shell production shortage and supplemented their use of gas cylinders with the 4-inch Stokes mortar, introduced in July, 1916, at the Battle of the Somme. The weapon, designed specifically to fire gas and thermite shells, had a payload three times as large (six to nine pounds) as could be fired from the standard 3-inch mortar.



British artillery firing and receiving gas shells, ca. 1916.

A range of only 800 to 1,000 meters meant that effective delivery required emplacement in the front-line trenches. Members of the Special Brigade also experimented with a homemade contraption similar to a trench mortar.

Early in 1917 Capt. William H. Livens, a British officer, developed a device made from ordinary steel containers. This makeshift mortar fired oil drums packed with oil-soaked cotton waste. Captain Livens also began to experiment with firing large gas-filled shells from his homemade trench mortar. This resulted in a new delivery system known as the Livens projector. In its final form the projector consisted of a drawn steel cylinder eight inches in diameter, one and one-fourth inch thick, that came in two sizes—two feet nine inches or four feet long. Rounded at one end, the cylinders had a base plate that looked like a Mexican sombrero. The projectors were buried in a trench cut at a forty-five degree angle for maximum range. Originally buried to the muzzle, this depth was later found to be unnecessary, and the projectors were thereafter emplaced only deep enough to steady them for firing. The shells used with the projectors carried a payload of thirty to forty pounds of chemical agent and had a range, depending on the length of the barrel, of either 1,200 or 1,900 meters. The British first used this delivery system for what they called "gas shoots" at Arras on 4 April 1917. The Germans reported that the density of the gas delivered by this method equaled that of a gas cloud. Captured German documents claimed that the Livens projector was a deadly weapon because it not only developed a dense concentration of gas similiar to the one created

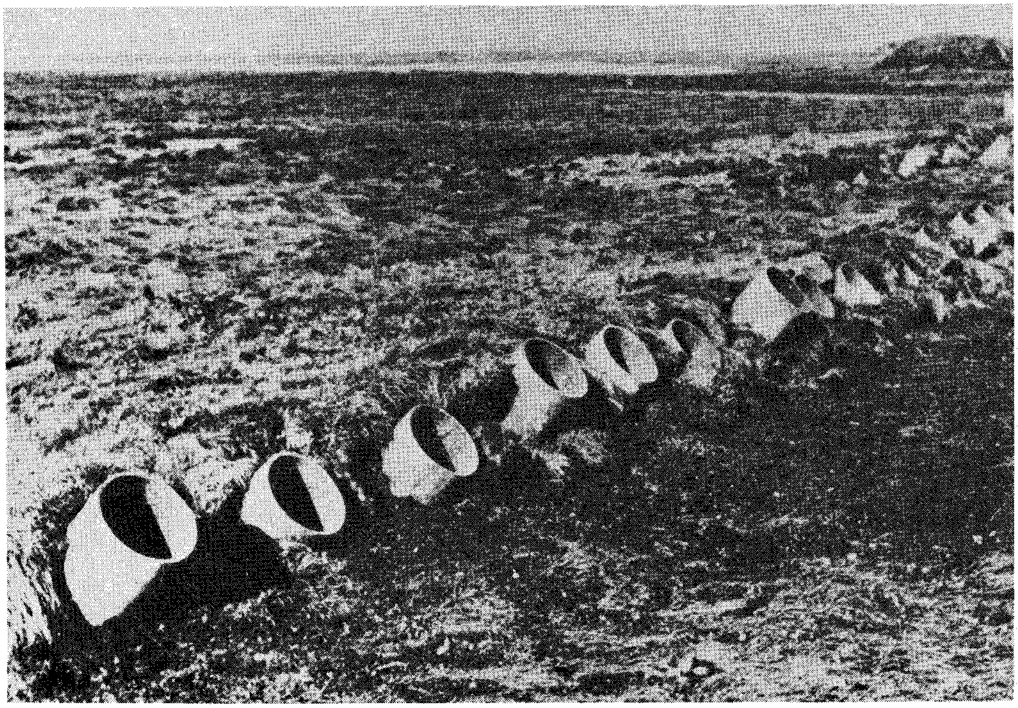


A 4-inch Stokes mortar used by British and American gas troops.

by cylinders, but like artillery, its impact came as a surprise. During the war the British fired over 300 gas projector "shoots." On 31 March 1918 the largest of these operations took place at Lens, with the firing of 3,728 of the devices.[12]

Increased casualties resulting from British gas projector attacks prompted the Germans to develop a similar weapon. Time constraints and the lack of industrial capacity for increased steel production forced them to retool their obsolete 18-cm heavy mortars. These tubes could fire a projectile containing three to four gallons of a chemical agent. In December, 1917, the Germans launched their first projector attack on the Western Front. In August, 1918, they introduced a rifled projector, 16-cm in diameter, that increased the range of the device to 3,500 meters. The shells contained thirteen pounds of chemical agent and five and one-half pounds of pumice. The pumice kept the chemical agent from being flung into the air upon explosion. It also made the agent, usually phosgene, more persistent. In one instance, the gas reportedly lingered for one and one-half hours. Yet, impressive as were these results, the Germans, despite their efforts, continued to lag behind the British in the tactical use of this delivery system.[13]

Initially, the tactical employment of chemical weapons varied to some degree between the Allies and the Central Powers; however, these variations became less noticeable during the latter stages of the war. By November, 1918, the protagonists were using similiar delivery systems and chemical agents.



Livens projector emplacement, 1918, used by British, French, and Americans.

From 1915 to 1918 the Germans held the initiative in most areas of gas warfare. They did this through the introduction of new agents that allowed them to direct more systematic thought to the question of how the employment of gas might alter a tactical situation. They were, for example, the first to use gas as an adjunct to maneuver in support of an infantry attack. The Allies struggled to keep up with such offensive doctrine, but they had to contend first with the development of effective defensive measures to counter German initiatives. Only after developing countermeasures could the Allies then plan their use of a new chemical agent or a new delivery system. This lag was evident in the case of the two most effective agents used in World War I, phosgene and mustard gas. The Germans introduced phosgene six months before the Allies were able to employ it and mustard a year ahead of their foe. The Allies had to adopt immediate defensive measures, such as effective mask filters and protective suits, before they could turn to the development of tactical doctrine. "As far as the tactical employment of gas was concerned," wrote Lt. Col. Pascal Lucas, a French officer, "it took us a long time to realize that the neutralization of personnel [by gas] could supplement the always incomplete destruction of defensive organizations" by high explosives.[14]

British gas doctrine, when circumstances did permit its development, was driven in part by a shortage of artillery shells that prohibited the British Army from mounting an artillery gas attack until the summer of 1916. In the meantime, the British, as noted, convinced themselves that chemicals released from cylinders or projectors could most effectively be used to obtain the highest possible concentration of an agent in a specific area. The consequences of this doctrine were twofold: it prevented the British from employing gas to support mobile or open warfare, and it limited the use of chemical agents primarily to the more restricted roles of attrition and harassment.

In the case of harassment, the British High Command, relying on intelligence reports, would indicate for one reason or another what German units it wished the Special Brigade to weaken or demoralize. German divisions recently transferred from the Eastern Front were prime targets because of their ignorance of defensive measures for gas warfare. The British sought out units that they expected to be transferred to the main battle fronts, i.e., Somme or Ypres, and tried to weaken them physically and psychologically before they deployed. On at least one occasion, a gas operation was postponed to await the arrival of a particular division. Once a German unit became a target for a gas attack, the Special Brigade made a point of following that unit around the front. The 1st Bavarian Regiment, for instance, was gassed fifteen times; the 1st Guards Regiment twelve times in six months; the 10th Bavarian Regiment ten times in five months, and the 9th Bavarian Regiment fourteen times from 28 June 1916 to 1 August 1917. The effects could be devastating to the morale of the gassed units and those units around them. A captured German diary recorded, "We have again had many casualties through gas poisoning. I can't think of anything worse; wherever one goes, one must take one's gas mask with one, and it will soon be more necessary than a rifle. Things are dreadful here."[15]

The British ultimately developed tactical doctrine for the use of gas shells. This doctrine set three methods for inflicting enemy gas casualties. The first and most favored method was by a surprise gas attack, in which British gunners attempted to establish the greatest concentration of gas in a target area by firing a "lavish expenditure of ammunition" at an extremely rapid rate. After one or two minutes of shelling, enemy soldiers who had not put on protective masks would be incapacitated by the dense gas; the remainder would be masked, rendering further bombardment uneconomical and unnecessary. The second method for using gas shells tried to exhaust the enemy by desultory fire over a period of many hours. In most instances, the British believed this attrition method not worth the effort, because few casualties were produced. The third method was an attempt to penetrate the enemy's gas masks with new agents such as chloropicrin, which when fired in a high concentration in a specific area, seeped into the masks and created intolerable eye irritation, coughing, vomiting, and inflammation of the respiratory tract. Enemy soldiers forced to remove their fouled masks were then subjected to a shelling with lethal phosgene.[16]

The Germans attempted to make the enemy trenches no less dreadful than their own. Having the technological advantage that gave them the ability to introduce new gases before the Allies, the Germans devoted much thought to the tactical employment of chemical weapons, and in this respect, they reached a high degree of sophistication. After abandoning cloud attacks, the Germans increased their use of gas shells. They discovered on the Eastern Front that tear gas was extremely effective in neutralizing Russian artillery. Even a few rounds would incapacitate a gun crew or, having forced it to mask, prevent it from delivering accurate fire. On the Western Front in 1916, the Germans fired some 2,000 tear gas shells at an extensive French trench system near Verdun. This massive surprise bombardment resulted in the capture of 2,400 Frenchmen who, after being temporarily blinded by the tear gas, were surrounded by German troops wearing goggles, but no masks.[17]

The Germans introduced other agents to the battlefield for specific tactical purposes. In May, 1916, they fired their Green Cross shell filled with diphosgene, a lung irritant. Later, as an indication of the increased sophistication of gas shells, they subdivided the Green Cross shell fill, first by a mix of 75 percent phosgene and 25 percent diphosgene, which was labled Green Cross 1. Then, in July, 1917, four different percentages of phosgene, diphosgene, and diphenylchlorosine called Green Cross 2, A, B, and C, respectively, were introduced. These were followed shortly by Blue Cross and Yellow Cross shells. The former shell was filled with an arsenic compound of finely separated dust. In field trials, this agent proved extremely effective in the penetration of all mask filters in existence. The need to encase the compound in a glass-lined shell, however, reduced its effectiveness, as the heat of the explosion failed to cause vaporization, and the force of the explosion caused only mechanical pulverization. The recipients, the French and British, considered Blue Cross a "failure and not worth the effort." The introduction of Yellow Cross (mustard gas), however, again gave the Germans the initiative in chemical warfare, which they held to the end of the war. By increasing the explosive charge in the shell, the Germans further extended the area contaminated by this blister producing agent. This shell was marked by a double (Lorraine) cross.[18]

The Germans found gas persisted even longer when an agent and a small amount of high explosives were placed in one shell. The effect of the high explosive, when used in the proper amount, was to spread the agent over a wider area and keep it airborne longer. With this knowledge, the Germans changed their gas doctrine from attacking a particular target to gassing large areas for extended periods of time. German staff officers began to plan operations that called for "gas barriers" and "gas pockets."

German tactical doctrine for the use of artillery gas shells offered a variety of possibilities. For the offense, it called for surprise and the concentration of as much gas as possible through the sudden and rapid placement of shells on a target area. "Cloud concentration" tactics imitated surprise tactics, but with an increase in the number of shells and an expansion of the size of a target area. Another offensive tactic was the use of gas shells that contained a high explosive charge and shrapnel. These shells, used exclusively by the Germans, had an effect "so devastating that the efficacy of a high explosive shrapnel[-gas] shell bombardment was always increased."* Once introduced, the Germans always added a percentage of these shells to any high explosive or shrapnel bombardment. The high explosive-gas shell was used extensively in German rolling barrages to support advancing infantry during the spring offenses of 1918. These shells were also used to neutralize known enemy artillery batteries and machine gun nests, thus allowing German infantry to bypass Allied strong points.[19]

The key figure in the expansion of German gas shell tactical doctrine was Lt. Col. Georg Bruchmüller, known as "*Durchbruck*" (Breakthrough) and considered an artillery genius because of his success on the battlefield. While on the Eastern Front, Bruchmüller, a great believer in the efficiency of gas shells, developed a highly sophisticated system of gas artillery fire. His tactical ideas were incorporated in the December, 1917, edition of the German manual for employment of gas shells.[20] Bruchmüller's system created "Gas Squares," which were areas known to hold enemy batteries or concentrations of enemy troops. These locations would be saturated by surprise gas shell fire, and the lethal concentration would be renewed by subsequent periodic fire. Bruchmüller's artillery tactics achieved surprise through a predicted-fire method that eliminated the usual ranging of the target by one gun of a battery. Bruchmüller formulated advanced firing

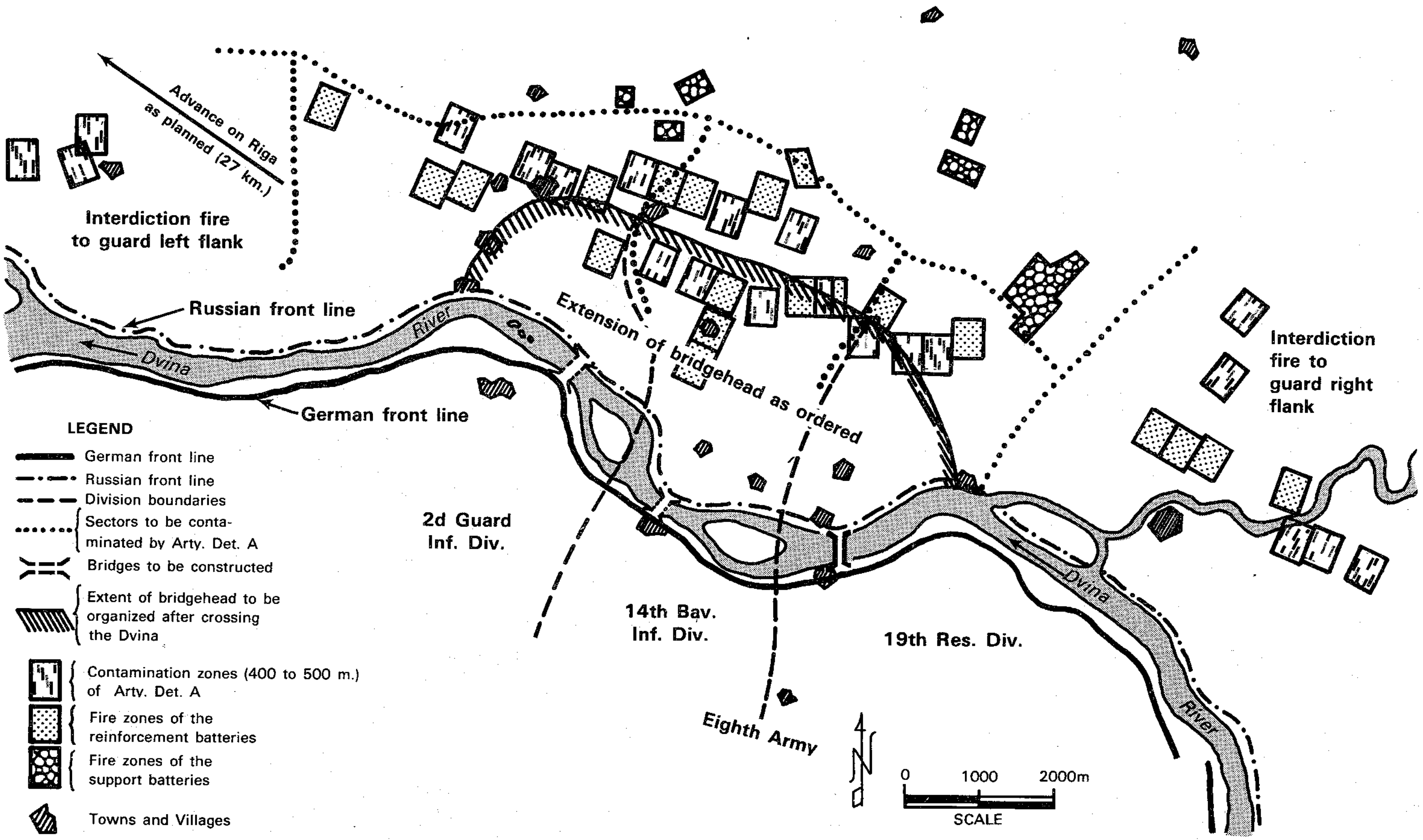
*Infantry troops seeking shelter from the high explosive bombardment were often forced into locations such as shell holes, where the gas settled. Furthermore, the concussion often stripped a mask off a soldier's face, exposing him to gas poisoning. More important, this tactic made Allied soldiers mask everytime they were subjected to artillery fire.

British soldiers blinded by mustard gas at an advance aid station near Béthune during the German Lys spring offensives, 9—29 April 1918.

data and tables based on meteorological variables such as wind, air temperature, and barometric pressure.[21]

When Blue Cross and Yellow Cross shells became available, Bruchmüller devised *Buntkreuz* (colored cross) tactics. One of the most successful uses of this new doctrine came on the Eastern Front, in the German crossing of the Dvina River before Riga (Map 3). On 1 September 1917 a two-hour preliminary bombardment of the Russian batteries created "varicolored zones,"* as combinations of Blue Cross and Green Cross were used both during bombardment and then during three hours of firing for effect. For the preliminary gas fire, each German battery had a set of firing sequences every twelve minutes to counter Russian batteries, which first maintained a desultory fire and then fell silent. According to German estimates, more than 116,400 gas shells were fired, which caused at least a thousand Russian casualties, mainly because of the ineffectual respirators issued to Russian troops. The figure might have been higher had not the Russians fled. German infantry reached the opposite bank to find that the Russian artillery crews had abandoned their guns in "great haste, resembling flight." The Russian infantry, which lacked effective personal protection against chemical agents, had followed suit.[22]

*Zones containing either Blue, Green, or Yellow Cross gas shells or combinations of all three.

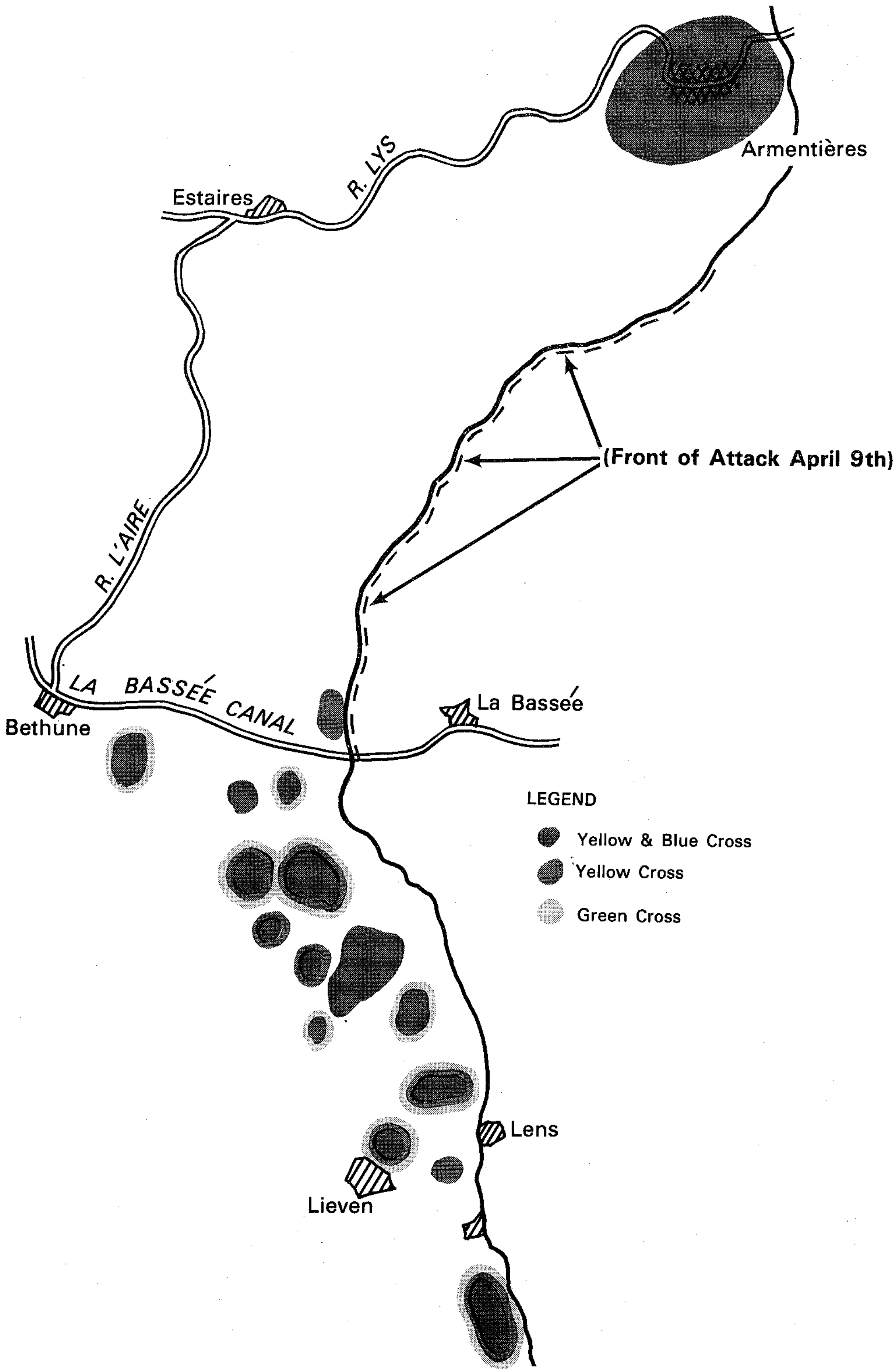


Map 3. Varicolored zones of German gas fired in support of a crossing of the Dvina River before Riga, Eastern Front, 1 September 1917.

Persistent agent fire was used tactically by the Germans on both the offense and the defense. Surprise, though desirable, was not necessary for persistent agents. Yellow Cross allowed an area to be "cleared of, or rendered inaccessible to," the enemy. Fire continued for several hours, and the contamination could be renewed each day thereafter, if so desired. The areas gassed were called "Yellow Zones of Defense." In April, 1918, the Germans shelled the city of Armentières with mustard gas (Map 4). The bombardment was so heavy that witnesses claimed liquid mustard gas ran in the streets. Naturally, the British evacuated the locale; the contamination, however, prevented the Germans from entering the city for two weeks. In the spring offensives of 1918 (Map 5), the Germans created mustard gas zones to protect the flanks of advancing infantry, to neutralize enemy strong points, to deny the enemy key terrain, to block supply routes, and to render enemy artillery batteries ineffective. "Even in open warfare," a German officer wrote, "the troops soon were asking for gas supporting fire."[23]

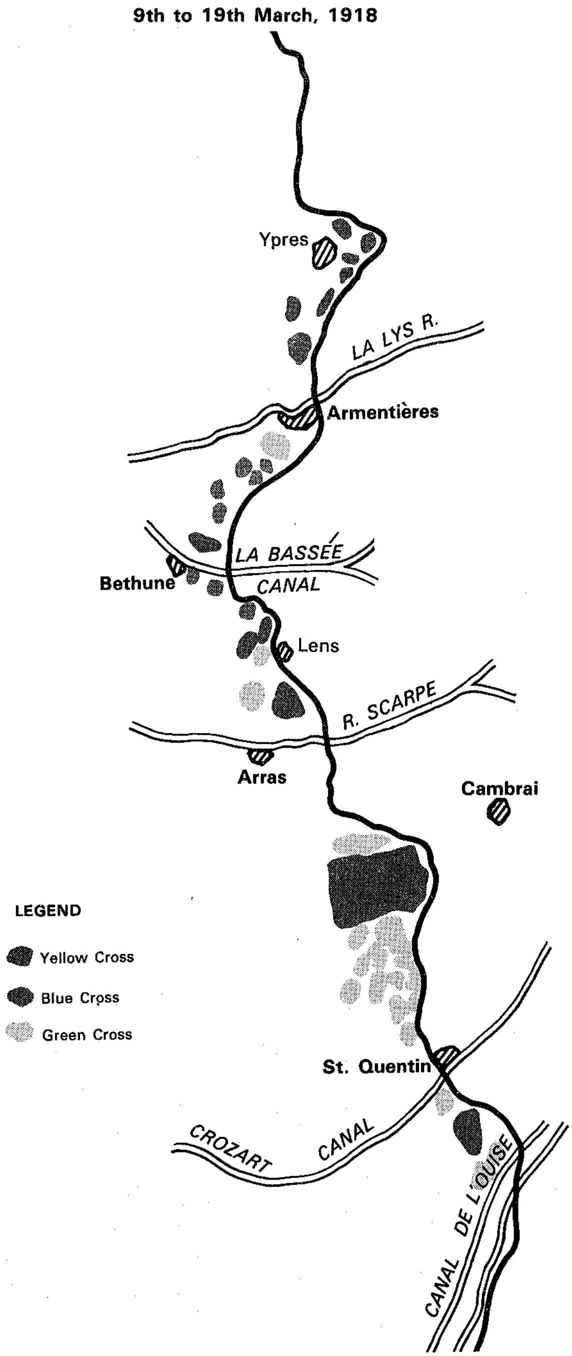
Mustard gas caused considerable consternation among the Allies. "We were outdistanced . . . ," a French officer noted, "the German lead on us in this respect . . . was a source of real inquietude," for the units that were exposed suffered considerably and the struggle against Yperite "seemed most deceptive of solution." The Allies eventually responded in kind, but not until June, 1918, a full year after the Germans introduced the ultimate agent of World War I, did the French use Yperite, and it took the British until 26

Various types of gas masks used in World War I.



Map 4. German gas shell bombardment of Armentières on 9 April 1918.

September 1918 to retaliate with mustard. So desperate were the French to obtain the agent that British officers reported teams of French soldiers draining unexploded German Yellow Cross shells in order to reuse the gas.[24]

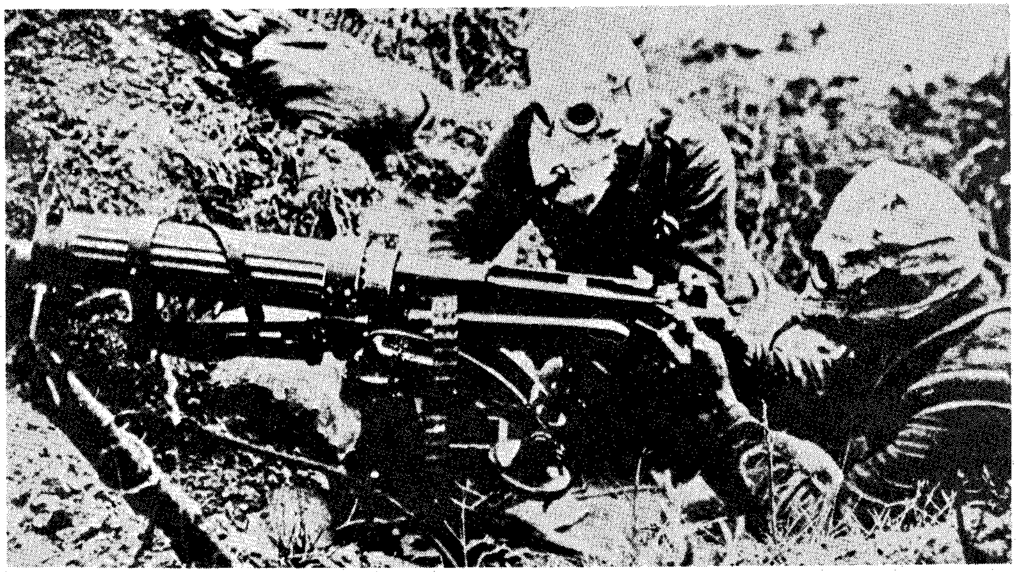


Map 5. The German spring offensives of 1918 were heavily supported by a variety of gases.

Personal protection was always a problem, one neither side ever really solved in World War I. The German High Command, prior to the first attack at Ypres, made no effort to develop an efficient gas mask. Attacking German soldiers had small protective bags of mull or hemp that were soaked in a sodium bicarbonate (baking soda) solution and then tied over the mouth and nose. Not until the closing months of 1915 did the German army begin to issue a self-contained respirator. The mask had a treated leather facepiece (because of the shortage of rubber, only officer facepieces were constructed of this material, which was more efficient than leather and easier to maintain) and eyepieces of an outer glass lens and a celluloid inner lens. The first German mask had a significant drawback: the filter had to be screwed on to the facepiece each time the mask was used, which meant that more time was required to mask during a gas attack. Later, this problem was remedied by a single construction model with a replaceable filter element.[25]

The French, British, and Russians did not coordinate their research and development of gas defenses. Although they passed information and some equipment to each other, they worked independently for the most part on

German artillerymen wearing the single-piece gas mask, early 1917.



British machine gun crew with PH-Helmets (note exhaust valve) firing during a German gas attack, Oise Sector, Marne, France, 1916.

their own protective masks.* In England, shortly after the first gas attack in April, 1915, housewives were asked by the high command to produce what became popularly known as the Black Veil Respirator—black veiling held a pad of cotton waste soaked in a chemical solution over the nose and mouth. These makeshift masks reached the British trenches in early May. When, in the latter part of 1915, the Germans began to use tear gas, the British countered with a flour sack type mask made of flannel, called the "Hypo" or "H-Helmet" after the chemical in which it was soaked, calcium hypochlorite. This mask offered protection to the eyes as well as to the respiratory system. One British officer described it as "a smoke helmet, a greasy grey-felt bag with a talc window . . . certainly ineffective against gas." This H-Helmet contained two celluloid eyepieces, but no apparatus to expel the carbon dioxide that built up in the mask.[26]

In the fall of 1915 British intelligence learned of Germany's intention to use a new gas, phosgene, a delayed-action choking agent. The Russians had also learned that the Germans intended to employ phosgene and advised the British that a solution of phenate-hexamine was effective in blocking the agent. As a result, the British soaked their H-Helmet in the Russian solution and added an outlet valve to reduce the carbon dioxide buildup inside the mask. The British Army called the new device the "PH-Helmet." The troops called it a "goggle-eyed booger with a tit."[27]

*This "go-it-alone" attitude, created perhaps by national pride, prevailed for most of the war in many areas besides chemical warfare. In fact, it was not until the German spring 1918 offensives that a Supreme Command came into existence to direct and coordinate the operations of the Allied armies.

French soldiers with M-2 masks advance through a gas cloud.

Although the PH-Helmet successfully blocked phosgene, it had serious drawbacks: it was hot, stuffy, and emitted an unpleasant odor; it also offered little protection against dense concentrations of lachrymatory agents. To counteract both phosgene and the lachrymating agents, the British in early 1916 took an entirely different approach to protective masks by developing a two-piece device called the "Large Box" or "Tar Box Respirator." A canister worn on the back contained neutralizing chemicals and attached by a rubber hose to a facepiece covering the chin, mouth, and nose. The wearer endured an uncomfortable noseclip and a mouthpiece similar to an athlete's rubber tooth protector. Goggles protected the eyes. The advantage of the mask rested in the use of a large filter. However, this also caused difficulties because the canister was too large and clumsy to be carried for extended distances over prolonged periods. This kind of mask reached its final stage of development with the introduction of the "Small Box Respirator" (SBR), which employed a smaller filter worn on the chest and a single construction facepiece. The details of the SBR became very familiar to men of the American Expeditionary Forces.[28]

The French wrote a different chapter to the development of the gas mask. After using the same primitive masks as the British, they set out to develop a mask that was both effective and comfortable to wear—two criteria that were, and still are, essential for the successful design of protective devices. The first significant French protective device, the M-2 mask, was similar in design to the British H-Helmet, except it did not cover the entire head, but took the form of a "snout" similar to a feedbag for a horse. Its filtration ability was limited, so French doctrine called for troops to be rotated after several hours of exposure to any gas.[29] In 1917 the French introduced the ARS (*Appareil Respiratoire Spécial*) mask. In appearance it resembled German protective equipment. The rubber facepiece had a waxed or oiled linen lining. Inhaled air passed in front of the eyepieces to prevent clouding. A canister attached to the facepiece could not be removed.

In September, 1917, these French masks were followed by another, the *Tissot*, which became one of the most effective masks of the war. As one postwar American observer noted, "the French deserve great credit" for the introduction of this defensive piece of equipment. In design, the *Tissot* was similar to the British Small Box Respirator except that the former's filter canister was carried on the soldier's back, not chest. This meant that infantrymen could carry only the *Tissot* and no other equipment. It covered the entire face, but without the uncomfortable nose clip and mouthpiece. The design allowed air to enter the mouth across the eyepieces, thus removing the normal phenomenon of condensation. The circulation of fresh air also diluted any lachrymatory gases that might enter the mask. Finally, the entire facepiece was of thin rubber. The French thought the filter location, the same as for the Large Tar Box Respirator, clumsy and difficult to adjust and, therefore, judged it unsuitable for infantry. Troops, such as artillery gun crews and stretcher bearers, who were not loaded with personal equipment and who had to continue to fight or function during a gas attack, did receive the mask. These soldiers found, in addition to comfort, that one could breathe easier and that the filtration system was superior to the ARS and M-2 mask.[30]

Unlike the British and French, the Russians devoted few resources to the development of chemical protective equipment. Consequently, they suffered the greatest number of chemically inflicted casualties in World War I. On 2 May 1915, not quite a month after the second Battle of Ypres during which French Colonial and Territorial troops collapsed under the first German gas attack, the Russians were subjected to a similar experience. German pioneer troops directed by Fritz Haber released 263 tons of chlorine gas from 12,000 cylinders against Russian troops at Bolimov. The first cylinder attack on the Eastern Front killed 6,000 Russian soldiers. Two more gas cloud attacks were made on the same position, and upward of 25,000 Russian casualties resulted. According to German sources, in June, 1915, at Bzura, two Russian regiments, the 55th and 56th Siberian, suffered approximately 9,000 gas casualties, or about 90 percent of their total strength. On 7 September 1916 a German cloud attack killed 600 Russian officers and men. The following month Transbaikal Cossacks suffered 4,000 casualties. A gas attack in 1917 cost the Russians 12 officers, 1,089 men killed, and 53 officers, 7,738 men incapacitated. Despite these casualties, the Tzarist Army developed only one mask in addition to the basic chemical-soaked gauze respirator. The fabric facepiece of this mask covered the head and attached directly to a canister containing a charcoal filter. It looked similar to the bill on a duck. Although the mask had no noseclip or mouthpiece, soldiers still found it extremely uncomfortable because the weight of the filter placed a great strain on the muscles of the neck. To make matters worse, the filter of this mask was of questionable effectiveness. By 1917 different types of British and French masks were being sent to Russia and used, to some limited extent, by Russian troops.[31]

By the summer of 1917, when U. S. troops began to arrive at French ports, chemical warfare had become commonplace and, in practice, had reached a high degree of sophistication compared to the first significant gas attack at Ypres a little over two years earlier. By July the most effective chemical agent of the war, mustard or Yellow Cross, had made its appearance. Gas shells now might contain two or even three different agents. All of the delivery systems for chemical war were in operation and efforts were being made by the combatants to improve on these weapons. The British had, for example, devised electronically detonated cylinders on tram cars for beam attacks. Also, the British had finally begun to overcome their shell production problems and had used gas shells in large quantities at the Battle of Arras in April, 1917.

Tactical doctrine for chemical warfare had reached a high level of sophistication, especially in artillery employment. In this area, the Germans, thanks to Lt. Col. Georg Bruchmüller, led the way. German artillery firing instructions became increasingly complex in regard to the selection of the gas or combination of gases to be used in a variety of tactical situations.

Given the advantage of viewing the development of chemical warfare from afar, the United States Army, upon entering the war, should have been in a position to operate in a chemical environment without repeating the costly experiences of the French, British, and Germans. Unfortunately, this was not to be the case.