August 12th, 1915.

"THE MANUFACTURE OF SMALL ARTILLERY SHELLS"

(By D. F. J. HARRICKS AND R. CLAYTON.)

In placing before you a brief account of some of the methods adopted in the manufacture of shells, I would first like to explain that I have no special knowledge of the subject, but merely intend to present information that it has been possible, with the assistance of Mr. R. Clayton (member), to collect from various sources during the past few months. I have no doubt that to many of you the information will not be new; to others it may be far less complete than expected, but, whilst I hope that it may to some extent prove of an interesting nature, it must be remembered that the main object of this meeting is not so much to give information as to increase interest in the matter of munitions, and to encourage that healthy interchange of ideas without which, in this national crisis, our usefulness as an Engineering Association must fail.

It is surely a very remarkable thing that we have had to turn to American technical journals for the bulk of the information available to the Australian public, and had it not been that these devoted very considerable space to the description of the remarkably quick and enthusiastic performances of our Canadian brethren, there would not have been available any useful information at all.

In referring to the work of Canada, one cannot help but reflect upon our own efforts; indeed, it is my deliberate intention to do so.

Admitting the advantageous position Canada is placed in with regard to her proximity to the American markets, and the fact that she is so much nearer the conflagration, her geographical position surely cannot be held to be the reason for her remarkably early recognition of the nation's great need, and, what is an important lesson to us, her wonderful organisation to meet it.

War was declared on the 5th August (1914). In less than one month the Canadian Committee was formed, and it lost not a day, but got to work at once, and six weeks later shells commenced to stream to Great Britain. Six months after that, no less than 150 shops in the Dominion were engaged in their manufacture. Even America, the land of huge industrial organisations, marvelled at the performance.

Although there may be found some good reasons why we have, so far, done practically nothing in this direction, there can surely be no sufficient reason for continued inactivity; so, as long as the British Minister for Munitions says that shells and munitions are the urgent need of the nation.

Since last August there has arisen a demand for shells in totally unprecedented quantities, and two months ago Mr. Lloyd-George used the following words:—

"It is the elementary duty of every citizen to place the whole of his strength and resources at the disposal of his native land in its hour of need. The State needs help —the help of each of you; the help of all of you, and all the help which each and every one of you can give. Prolonged public discussion, as a preliminary to action, is all right in times of peace; you can't afford it in war. It is a war of munitions. We are fighting against the best organised community in the world—and we have been employing too much of the haphazard, leisurely, go-as-you-please methods. We want to mobilise in such a way as to produce in the shortest space of time the greatest quantity of the best and most efficient war material.

"I ask engineering first, I ask masters, I ask men, I ask everybody, to put their strength into this task. Every shell you turn out is a lifeguard for some of those gallant fellows who are leaving our shores to risk their lives. Government work must not be sacrificed to any civil work, however important it is. The work of the country must come first, because unless it does there will be no country left worth working for. Don't let the flag be shot down for any man's profit. Let us do all in our power, sacrifice everything for the purpose of winning. Let us do each what we can."

To mark the fact that these sentiments applied to Australia no less than to any other part of the Empire, we have our own Minister for Defence stating a month later that the British Government had informed him that it could take 18lb. shells in unlimited supplies. Now, so long as words of this kind are uttered, we have no right to raise questions of expediency, but should get to work, and continue until we are told, in the plainest of plain language that no further effort is needed, or that our energies can be directed into a better channel. The responsibilities of the civilian engineer, in regard to a vigorous pursuit of our war-like intentions are great, and almost military devotion is required from us no less than from our soldiers. In this Association we have many, if not most, of the leaders of Mechanical Engineering in this State, and so much hinges upon the rapid and efficient production of shells and munitions, it is obvious that much depends upon us for the organisation of an industrial army similar to that which has already been raised in Canada, and elsewhere. We are engineering for life and death, and it is, perhaps, machinery that will mainly solve the problems of peace.

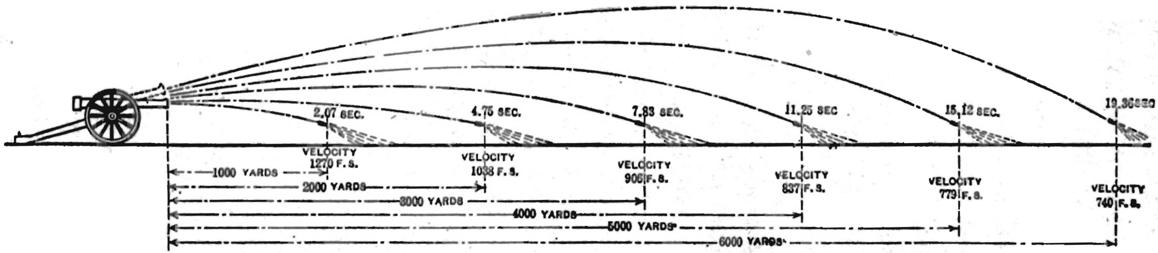
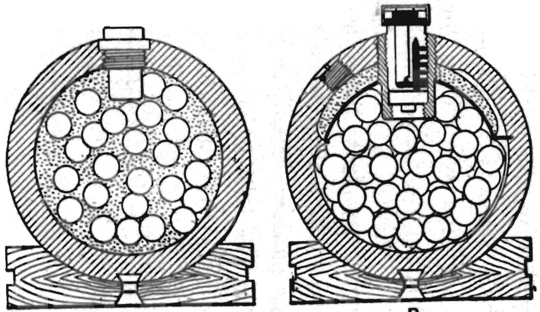


Diagram illustrating Path of a Shrapnel and the Time of Explosion at the Various Distances.



Original Shell designed by Lieut. Henry Shrapnel and Col. Boxer's Improvement.

Fig. 1.

As shrapnel shell was, at the beginning of the war, mostly in demand, the information available to us deals more with this class of shell than the high explosive. It would, perhaps, therefore, interest you if, before dealing with the actual processes of manufacture, a brief reference is made to the historical side of the shrapnel shell, and Fig. 1 shews a section of the original shell designed by Lieutenant Hy. Shrapnel, about 130 years ago, and which was adopted by the British Government 24 years later. This shell was spherical in shape, and the powder, or explosive charge, was mixed with the bullets. They were, at first, fired out of plain-bored guns, but upon the advent of rifling, a circular wooden base was added, and this was covered with sheet iron, or steel, to take the rifling grooves.

Alongside, is Colonel Boxer's improvement, and from which you will notice that the bursting charge has been separated from the shrapnel, by a diaphram. The same figure also illustrates the path of ordinary 3in. shells, fired from light field guns, and the time of explosion at various distances.

As you are aware, the ordinary shrapnel shell is fired from the quick-firing light field guns of the various nations, and which are all, approximately, of 3in. bore.

Table 1 gives an outline of the type and size of these guns.

In referring to field artillery it has recently been pointed out that these words are now too limited, for we know that our enemies, particularly, have been using in the field guns of all the calibres of land artillery and, in fact, Germany has been using naval ordnance of the greatest power. One of the most largely used guns during the present war has been the field howitzer, of approximately 4in. bore, and firing a projectile weighing 31lbs., and with a range of 6 to 7 miles. Germany has also largely used a 6in. heavy howitzer, with a projectile weighing approximately 60lbs., for a similar range, and this gun has its more efficient counterpart in the French quick-firing

TABLE I.

THE FIELD-GUN ARMAMENT OF EUROPEAN NATIONS.

Engineering—23/10/08

Nation.	Calibre in Inches.	When Adopted	Where Built and Type.	After Competition With	Weight of Projectile in Lbs.	Muzzle Velocity in Feet per sec.	Weight of Gun and Limber in Lbs.	Weight of Limber and Ammunition Waggon in Lbs.
Great Britain ...	3·3 3	1904 1904	Govt (British Works) after étude of Vickers, Armstrong and Ehrhardt types		18·5 12·5	1611 1657	4320 3372	4232 3350
France	2·95	1897	Government Factories ...		15·96	1735	3967	4297
Russia	3	1903	Governm't (Poutilow) after étude of Krupp, Schnider, and Ehrhardt types		14·42	1929	4364	4276
Germany	3·03	1905	Government, with the collaboration of Krupp and Ehrhardt.		15·09	1526	3835	3923
Austria-Hungary	3	1905	Government, with the collaboration of Skoda and Ehrhardt.		14·76	1640	3857	3967
Turkey	2·95	1904	Krupp		13·2	1650	3967	
Roumania ...	2·95	1904	Krupp		14·32	1640	3900	3835
Italy...	2·95	1906	Krupp		14·32	1673	3746	3857
Sweden	2·95	1903	Krupp	Cockerill ...	14·32	1640	3967	
Belgium	2·95	1904	Krupp	St. Chamond	14·32	1640	4110	3945
Denmark	2·95	1902	Krupp	Schneider, Cockerill & Ehrhardt	14·87	1640	4264	4518
Holland	2·95	1902	Krupp	Schnider and Ehrhardt	13·2	1640	3900	3989
Switzerland ...	2·95	1903	Krupp	Schnider, Ehrhardt, Cockerill & Skoda	14	1591	3857	4011
Bulgaria	2·95	1904	Schneider	Krupp	14·32	1640	3857	3790
Portugal	2·95	1904	Schneider	Krupp	14·32	1640	3857	4011
Spain	2·95	1905	Schneider	Krupp, St. Chamond and Vickers	14·32	1640	3857	3702
Servia	2·95	1906	Schneider	Krupp, Ehrhardt & Skoda	14·32	1640	3923	3790
Greece	2·95	1907	Schneider	Krupp, Ehrhardt & Armstrong	14·32	1640	3967	3945
Norway	2·95 Reserve	1899	Schneider ... ... After trials at Creusot and Essen.	Krupp	14·32	1804	4077	
Norway	2·95 Standing Army.	1901	Ehrhardt	Schneider and St. Chamond	14·32	1640	3857	

gun of about the same size. Of the large guns, Germany and Austria have used very extensively in the demolishing of fortresses, howitzers and mortars, 11in. and 12in.

in calibre, firing projectiles of 750 and 880 lbs. respectively. The range of these guns is approximately 6 miles, and they are capable of 10 rounds per minute. Perhaps the greatest surprise of the war, i.e., in artillery, was the 16½in. diameter mortar of the German army, which fired a projectile, very nearly one ton in weight, to a distance of 8 miles, whilst we also know that Germany must have used naval ordnance of 15in. calibre for what is popularly known as the "Dunkirk" gun, and which fired a projectile weighing 1675lbs. a distance of 23/24 miles. Too much use cannot be made of these guns, for they are unwieldy, and are not capable of more than 100 rounds without having to be returned to workshops capable of re-boring or re-fitting. France has, apparently, not thought it necessary to use such large calibre guns as Germany, but perhaps this may be due to the fact that she has not had the same work of demolishing fortresses as her enemies.

It has been frequently asserted, and with apparently very good reason, that the French 75mm. quick-firing field gun is the best of its kind, so that I have shown in Fig. 2 an illustration of this particular piece of artillery.

This is typical of the quick-firing light field gun now used by practically every important nation. It may not be generally known that the quick-firing gun made its appearance less than 20 years ago, and it is the result of the field artillery as modified to meet the tactics now prevailing. An enemy's guns are no longer visible; they are hidden and disguised in the most ingenious ways. Infantry form practically disappearing targets. When outside the trenches they are usually in a laying-down position, rising but for a few seconds to advance, before they lie down again. On a modern battlefield there is, at most times, practically nothing to be seen, and in order

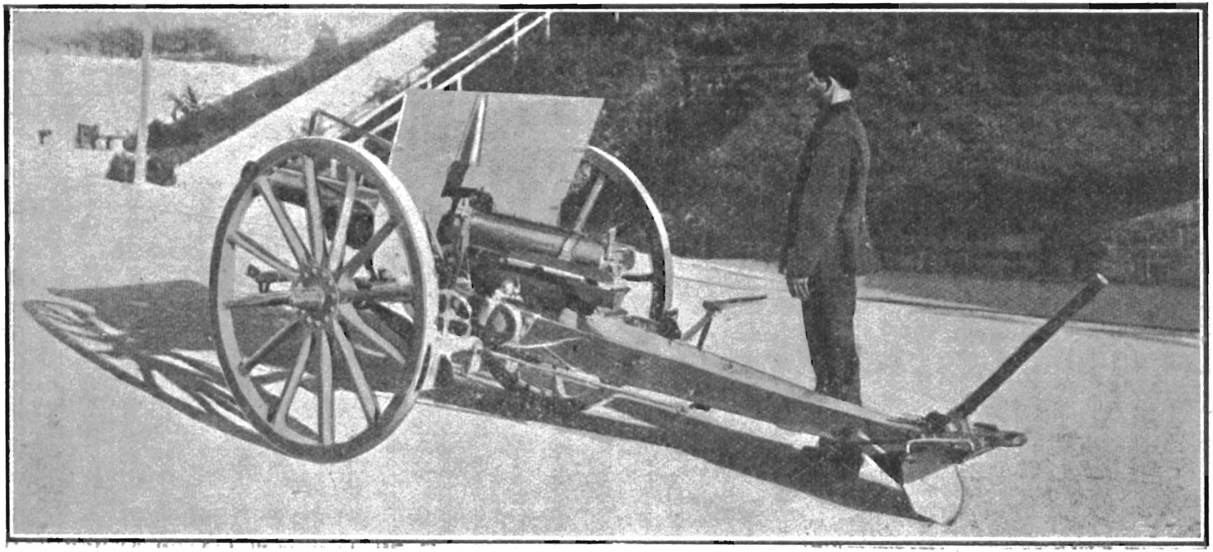
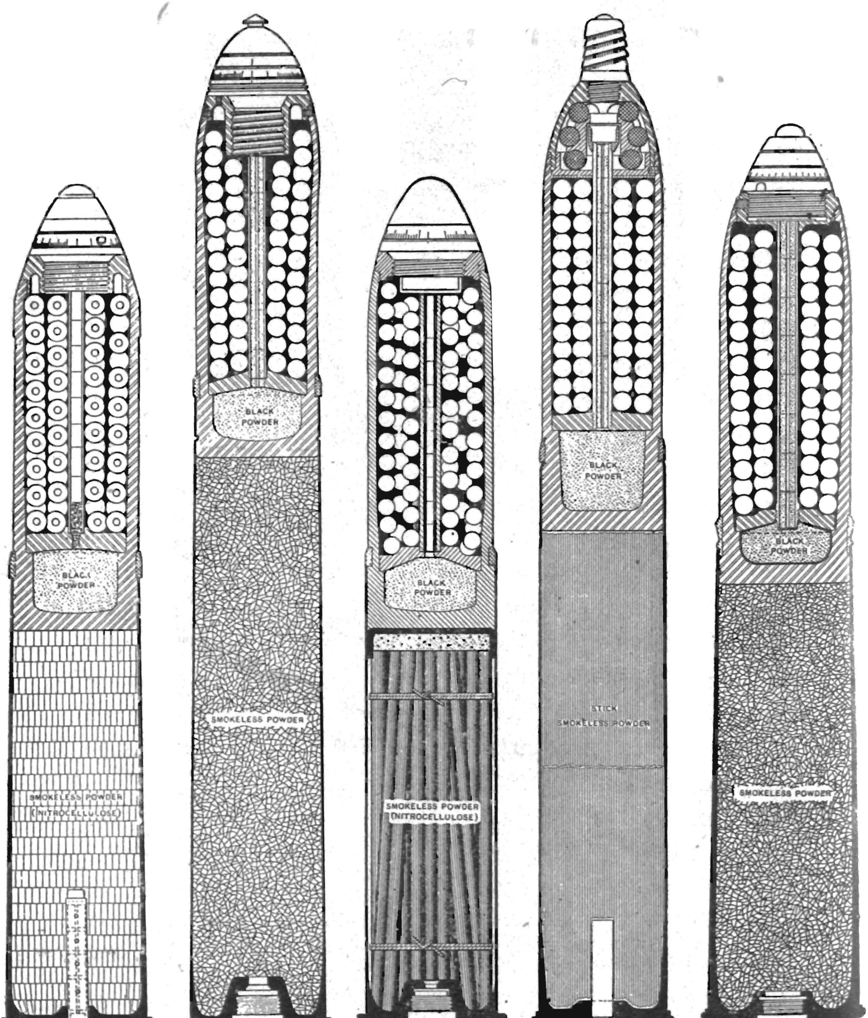


Fig. 2

to strike targets which appear but momentarily, there arose the necessity for a gun which could fire instantaneously. To meet this necessity, the quick-firing gun was the result. In order to fire quickly, it has been necessary to eliminate all loss of time, and this formerly was considerable, and obtained in running out the gun, aiming, and loading. The loading was accelerated by breach blocks operating a single quick action on the breach mechanism, which simultaneously ejected the empty cartridge. To overcome delay in running out the gun and in aiming, the gun tube now recoils and returns to its position on the carriage, which is strongly anchored to the ground. An elastic connection, coupled both to the carriage and to the gun, practically allows the gun to recoil without exerting on the carriage sufficient pressure to cause this to rise or to drive the trail spade further into the ground. The recoil is combined with what is called a recuperator, which runs the gun out to its original position. This action practically dispenses with all necessity for re-aiming. Then, furthermore, the adoption of complete cartridges for each shell, has rendered it possible to fire 20/25 rounds per minute. France adopted the solution of this problem as far back as 1897, and from the table given above, the adoption by other nations followed fairly closely. Germany, however, seems to have been one of the last of the important nations to adopt the quick-firer, and it was not until 1905, after the most costly and unsuccessful trials of "accelerated firing" guns, that they finally came into line with the other nations.

Coming now to the shells themselves, it will no doubt be of interest to everyone to see, side by side, sectional views of the shrapnel shells used by the five leading nations. These, as will be seen from Fig. 3, vary slightly in construction and general contour as well as in the constituents entering into their different members.

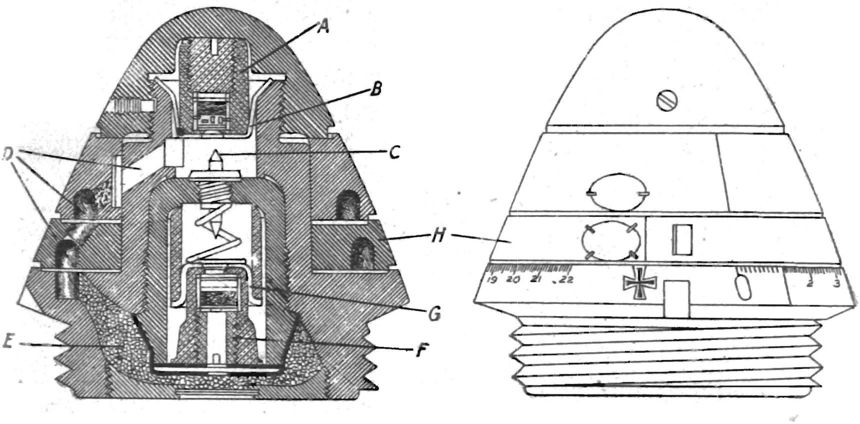


Types of Shrapnel Shells used by the British, French, Russian, German and American Governments.

Fig. 3

The complete shrapnel comprises a brass case carrying a detonating primer, and the explosive charge for propelling the projectile out of the gun. The projectile itself comprises a forged shell, which carries the lead bullets, the bursting charge, and the fuse. The latter is screwed into the front end of the shell, and consists of a timing and percussion fuse, which can be set so as to explode the shell at any desired point, or upon percussion only. If by any chance the timing device should fail to act, then the shell would be exploded by percussion upon the shell striking an object. After the magazine in the base of the fuse is ignited, the flame is conveyed through a tube filled with powder pellets, down through the diaphragm to the powder pocket containing the main charge for exploding the shell.

Let us now take the shrapnel shell in parts, commencing with, as it were, the brain of the device, viz., the fuse at the top of the shell. At first sight of Fig. 4 this

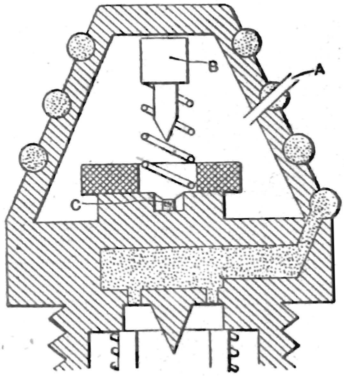


WEIGHT 10·229 OZS.

Fig. 4

would perhaps appear a complicated contrivance, especially when it is realised that the whole thing can be held in the palm of the hand. However, it is not so complicated as it appears, although the device is a delicate one, and requires careful design and construction. When the shell is fired, the inertia of the time pellet A shears the spring stirrup B, and the time needle C strikes and fires the time detonator, contained in pellet A. The flame from the explosion passes through the powder train to the powder magazine E. If the time pellet fails to act, then on striking an object the momentum of the percussion pellet F carries it forward, breaking the spring stirrup C, and firing the percussion detonator, contained in pellet F. If desired, of course, the time pellet can be prevented from action by turning the timing ring H to a position which blanks the connection between the powder channels and the magazine. The detonators are of fulminate of mercury.

It will, no doubt, be of interest to notice the fuse of the French 75mm. gun, and Fig. 5 shows this. The fuses of most of the nations are of much the same type as the



French Type of Combination Time and Percussion Fuse.

Fig. 5

British, but the French type of combination timing and percussion cap is a different design, and remarkably simple. In this fuse, the firing for the timing train is contained in a sealed tube of pure tin, and this is wound spirally around the head of the fuse. To set the time part of this fuse, it is placed in a tube-setting machine attached to the field gun and by pressing down the handle of this device, a piercing point is thrust through the sealed tube and the outer cap of the fuse penetrated to the interior space of the head as shown. Upon the discharge of the shell, the inertia and gas pressure forces the firing-pin "B" back, striking the percussion detonator "C". This causes a flame to pass out of the opening previously punched, and ignite the rope powder fuse; the flame then traverses this latter until it reaches the magazine in the base of the fuse. The accuracy with with shrapnel can be exploded in the air at any desired point is remarkable.

On the base ring of the British fuse will be noticed graduations up to 22; these correspond to the 22 seconds in the duration of the flight of the projectile. There is a space "from safety to zero," which is ungrooved on the face of the timing ring and prevents connection between the tunnels of the powder train when the shell is not set, and until the movable timing ring is swung round far enough to bring zero opposite the first time mark on the fixed ring the shell can be handled with safety. The graduations, of course, accord with the trajectory of the flying missile.

Referring to the main body of the shell, and this is the part which is most likely to concern us here, for the present at all events, it has already been explained that this is now made almost invariably of forged steel. Many of the original shells were made of cast iron, which had necessarily to be much thicker, they were more liable to premature explosion, and reduced the effectiveness, because the weight of the shrapnel balls was reduced to 20 to 30 per cent. of the total weight of the shell; whereas, with the thinner forged steel casing, the weight of the bullets represents from 40-50 per cent. of the total weight.

It has been a difficult matter to obtain accurate information as to the steel used in these forgings, but the general specification, as published by the Commonwealth Government, is as follows:—

SPECIFICATION OF STEEL.

Carbon, not over		0.55 per cent.
Nickel, not over		0.5
Silicon		0.3
Sulphur		0.05
Phosphorus		0.05
Copper, not over		0.1
Manganese	minimum	0.4
	maximum	1.0

Tensile strength not under 35, nor over 49 tons per square inch.

Yield point, not under 19 tons.

Ingots and bars to be stamped with the name of manufacturer.

4 per cent. top end each ingot intended for shell bodies to be discarded.

Any shell shewing tracing of piping will be rejected.

Small modifications in the specifications will be considered.

To enable you to carry in your minds the object to which some of the operations, to be further described, are applied, it might be as well to show in the next, Fig. 6, a detailed section of the shrapnel and high explosive shell bodies. Our information, as already explained, is not so complete with regard to the latter, but many of the operations referred to as applicable to the shrapnel shell will certainly apply to the high explosive.