SMOKELESS CANNON POWDER IN THE LIGHT OF THE MOST RECENT DISCOVERIES.

As originally made, gunpowder consisted of a loose mixture of pulverized sulphur, charcoal, and saltpetre. It then actually existed in the form of a powder, hence the name. The idea of granulation probably arose from the admixture of bituminous matter with the powder, to retard the combustion. The first methodical granulation of gunpowder recorded was in France in 1825. The pulverized ingredients were mixed thoroughly and pressed into a hard cake, which was then broken up into irregular fragments or grains.

The next important improvement in granulation was made by General T. J. Rodman, the inventor of prismatic gunpowder, who in 1854 had presses made for moulding the grains separately, giving to them a definite and uniform shape. He was also the first to make multi-perforated powder grains with a view to securing progressive combustion. (See Fig. 1.) The improvements which followed those of General Rodman related mainly to composition and density, having for their object the retarding of combustion. Brown prismatic powder was the result. There was no further improvement until the advent of smokeless powder.

Black gunpowder, being but a mechanical mixture caked together by pressure, was not well adapted to the multi-perforated form invented by Rodman, which, after much experimenting, was abandoned for the form having a single central perforation. (See Fig. 2.) Notwithstanding the obvious advantages of multi-perforations, the material did not possess sufficient tensile strength to render those advantages available.

In order to understand the action of gunpowder, we must bear in mind that there are two forms of combustion known as explosion. One is what is termed detonation, where the action takes place throughout the mass at practically the same instant. This form of combustion or explosion applies to what are known as high explosives. Gunpowder is consumed by surface combustion only. This requires time, and although the time is relatively short in the usual sense, it is long when compared with the infinitely quicker action of high explosives. From the pulling of the lanyard until the projec-

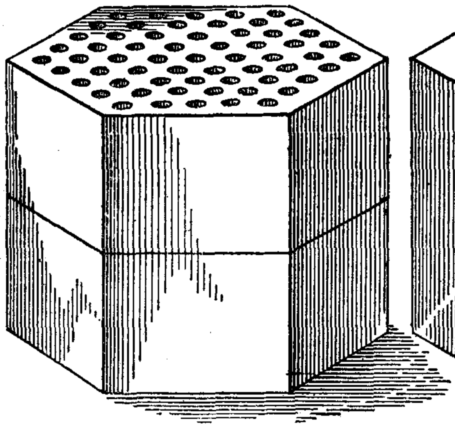

Fig. 1.

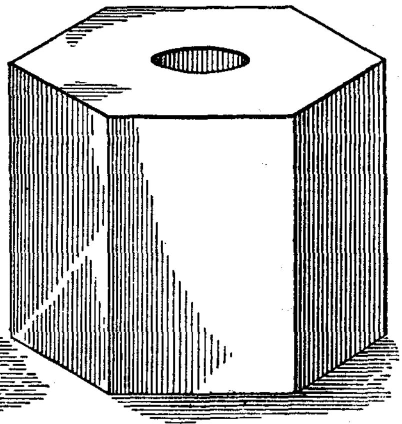

Fig. 2.

tile leaves the muzzle of a cannon only about a sixtieth of a second intervenes. Short as is this period it gives the projectile time to move forward in the bore and provide space for the reception of the powder gases as fast as they are set free; whereas, if the charge should be consumed instantly, as by detonation, the projectile would not have time for any appreciable movement, and the whole rear portion of the gun would be blown to fragments from the enormous pressure.

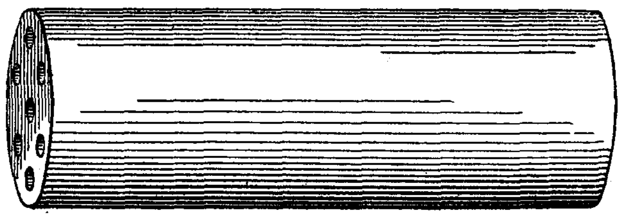

Fig. 3.

Obviously, an ideal gunpowder should produce a pressure which would be so well maintained behind the projectile in its flight through the bore of the gun that a curve representing the pressure would coincide with a curve representing the working tangential strength of the piece throughout its length. This result can be attained only by means of multi-perforations, giving the powder grains such form that they will be consumed by rapidly accelerating combustion. The powder grain which has been adopted by the United States Government for both branches of the service is the longitudinally multi-perforated cylinder shown in Fig. 3, the usual number of perforations being seven, though frequently as many as nineteen are employed. The diameter of the cylinder and the thickness of the material between the perforations is made greater or less according to the size of the gun in which the grain is to be used.

The dense colloid of which smokeless powder is composed, when properly made, is free from pores and wholly impervious to the hot gases with which it is enveloped in the gun. Ignited in the air, this material burns with comparative slowness, requiring several seconds for the consumption of a grain of ordinary size. When burned under

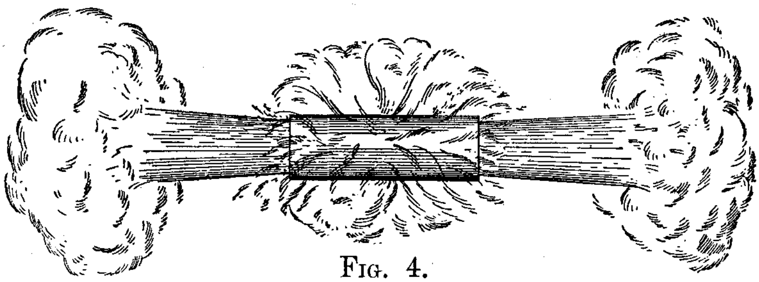

FIG. 4.

pressure, however, the action is much more rapid. Under service pressure in a gun — about 35,000 pounds to the square inch — the same grain is consumed in about the sixtieth of a second.

Fig. 4 represents a grain of smokeless cannon powder burning in the air. The expulsion of the products of combustion from the perforations generates a pressure there in excess of that upon the outer surfaces of the grain. This causes a more rapid rate of burning within the perforations, and accounts for the strong blast of flame being thrown out of the perforations at each end, as shown in the figure. As this difference between external and internal pressures is increased in proportion to the increase in the rate of combustion under service pressures, it is obvious that the tensile strength of grains becomes a very important factor in preventing their disruption or blowing up in guns. In fact, the tangential strength of a grain of multi-perforated powder is quite as important as that of the gun.

If the powder grains be made too long, or the perforations too small, they will explode even when burned under atmospheric pressure. The higher the pressure, the shorter must be the grains. The disruption of powder grains in guns might be very disastrous, because the pressure would suddenly mount to a point where a gun would burst, owing to the enormous increase of burning areas presented to the flame by the large number of small fragments.

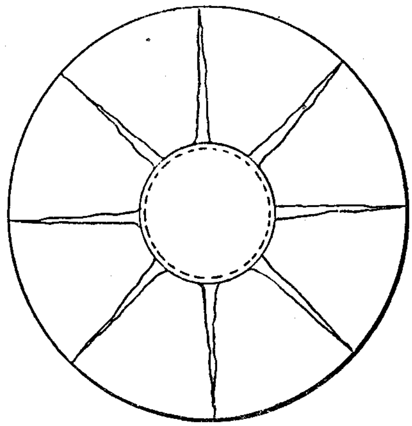

FIG. 5.

In the manufacture of smokeless powder there should be as little solvent employed as possible to effect gelatinization of the guncotton, in order to reduce shrinkage to the minimum and prevent warping and cracking in drying. The drying of cylindrical powder grains may be compared to the cooling of a piece of ordnance, the stresses set up being similar. General Rodman discovered in the manufacture of cast-iron cannon that when allowed to cool from the outside such internal stress was set up that the piece was capable of standing much less pressure than when the same was cooled from the inside. When externally cooled the outer portion of metal becomes solid and unyielding, assuming a definite and final shape, while the interior is still soft and yielding. As the inner portions of the metal also shrink in cooling, more and more stress is set up toward the bore. Although the metal may be strong and elastic enough to prevent cracking, still the stress is such that the gun is to a large extent under a strong bursting strain while in a normal state, deducting just so much from the tangential resistance of the piece to the pressure of the powder charge. Fig. 5 is a cross-sectional diagram of a gun made by General Rodman, indicating the tendency to crack from internal stress when a cannon is cooled from the outside. When cooled from the inside, the exact reverse condition is produced; the inner portion of metal becoming first solidified, the outer in cooling shrinks upon it, with the result that the stress set up materially strengthens instead of weakening the piece.

Of course, it is impossible to dry powder grains from the inside; hence the advantage of using the smallest possible quantity of solvent to secure minimum shrinkage. However, there must always be more or less internal stress; and though no actual cracks may appear, still, as in the case of an externally cooled cannon, the grains may be so nearly brought to the point of cracking as to require but little internal pressure to effect their disruption. Doubtless, many erratic pressures which have occurred from time to time in the early experiments with smokeless powders have been due to the disruption of the grains from the excess of pressure within the perforations, and were in many cases attributable to initial stress already existing in the grains, although no visible faults or cracks might have appeared.

Fig. 6 is an end view of a grain of United States multi-perforated smokeless cannon powder, perfect in form. Fig. 7 is a simi-

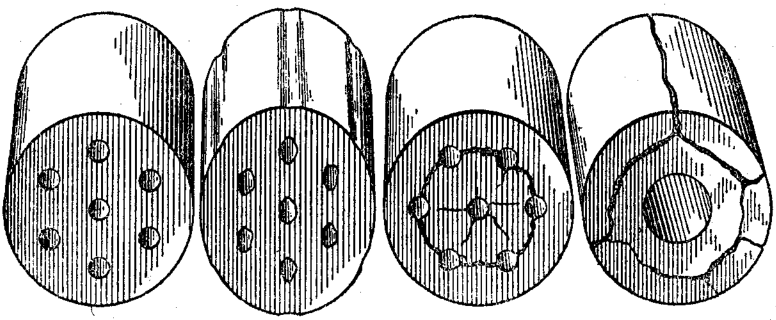

FIG. 6. FIG. 7. FIG. 8. FIG. 9.

lar grain, but made with so much solvent that it has become distorted in drying. Although no cracks may be visible, yet the tangential strength of the grain is very much lessened. When the powder composition is of a less tough material than that used in making the grain shown in Fig. 7, the cracking effect shown in Fig. 8 is the result, in which event there may be less distortion of the grain. When a powder grain is made tubular the cracks assume the form which is shown in Fig. 9.

Fig. 10 represents a grain of pyro-nitro-cellulose smokeless powder made with too much solvent, very volatile in character and dried quickly. The body of the grain, shrinking largely after the ends have become dry and solid, gives the grain the peculiar shape shown. In this grain there are strong stresses set up, which tend to separate the ends from the body of the grain, as well as tending to produce the form of cracks shown in Fig. 8.

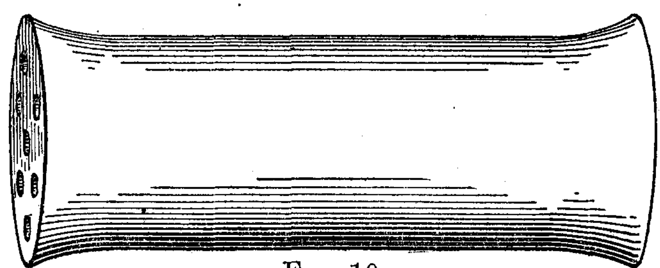

FIG. 10.

All modern smokeless powders consist either of nitro-cellulose of some special degree of nitration, or of a mixture of different grades, either with or without the addition of nitro-glycerin. Tri-nitro-cellulose, or guncotton of the highest nitration, is too difficult to work and shrinks too badly to permit of its being used alone. Mixed, however, with 10 per cent of the more soluble gelatin-guncotton, the resulting compound may be worked with but very little solvent. Upon this compound a slight rise of temperature has the peculiar effect of increasing its plasticity, which enables perfect granulation with an exceedingly small amount of solvent. When 10 per cent of nitro-glycerin is employed, there should be used at first, in the material in the incorporating machine, about twice the quantity of solvent that will be required in granulation, the excess being removed by working between steel rolls, such as those used in the manufacture of celluloid. Powder made by this formula does not warp or crack in drying, and internal stress is reduced to a minimum.

Pyro-nitro-cellulose is now used exclusively by the Government in the manufacture of smokeless powder; and while it shrinks considerably in drying, still the grains are so tough, hard, and hornlike that, in spite of any internal stress, they are capable of standing a higher pressure than when made of a more brittle compound, even though greater care be exercised to avoid shrinkage. No nitroglycerin is used in the present service powder, and the compound is so poor in oxygen that a grain burned in the air leaves a large quantity of unconsumed carbon. Burned in a gun, however, under service pressures, most of the carbon combines with the oxygen to produce carbonic oxide instead of carbonic acid. The products of combustion of this material are practically all gaseous, and therefore smokeless, and consist mainly of carbonic oxide, free nitrogen, and free hydrogen. The immense volume of the products of combustion of this powder, owing to the exceeding lightness of these gases, gives it a very high ballistic value, while at the same time the temperature is much lower and the erosive action upon the gun is less than with smokeless powders rich in nitro-glycerin, which owe their high ballistic value to the great expansive power due to high temperature.

The high explosive quality of picric acid, which contains too little oxygen for its complete combustion, is another example where the larger volume of lighter gases compensates for the greater expansive value of heavier gases at a higher temperature produced with explosives rich in oxygen, which yield carbonic acid in place of carbonic oxide. If all of the carbon present in pyro-nitro-cellulose smokeless powder were to combine to form carbonic oxide with a minimum production of carbonic acid and aqueous vapor, to satisfy an ideal equation, still higher ballistic results would be attained. But the pressure in guns is not sufficiently high to effect this; whereas in the detonation of picric acid a pressure from fifteen to twenty times as high is instantly produced, under which the density and temperature of the gases are such as to cause practically all of the carbon to combine with the oxygen, forming the lowest oxide of carbon at the expense of the hydrogen present. Consequently, we get as the products of combustion the maximum of carbonic oxide, with free nitrogen and free hydrogen, and with a minimum of carbonic acid and aqueous vapor. Under high pressures and temperatures the chemical affinity of carbon is especially intensified.

If a charge of pyro-nitro-cellulose smokeless powder were to be reduced to a very fine state of division, loaded into a strong, steel shell, and then detonated by a powerful exploder, the reaction would differ from that produced by burning the same material in guns with infinitely greater slowness and under very much lower pressures and temperatures, and the total energy developed would also be much greater. To develop the same energy behind the projectile and to impart to it an equal velocity there is required about 20 per cent more in weight of pyro-nitro-cellulose smokeless powder than of a smokeless powder compound consisting of 68 per cent tri-nitro-cellulose, 7 per cent gelatin guncotton, and 25 per cent nitro-glycerin.

The pyro-nitro-cellulose composition, being much harder than the nitro-glycerin compound, has a correspondingly slower rate of combustion. The thickness through which it burns being much less, it would at first appear that it would counteract to a large extent the advantages of multi-perforations, because there is not so much enlargement of the perforations with resultant acceleration of combustion. We must bear in mind, however, that for the very reason that the combustion is slower the perforations may be made smaller; and, owing to the toughness of the material, the size and length of the perforations may be so small as to give practically the same accelerating rate of combustion as can be secured with a more rapidly burning compound, but one not possessing such great tensile strength.

This is true, however, only with high pressures. Pyro-nitro-cellulose is essentially a high-pressure powder compound. The present tendency continually to increase the weight and strength of guns of all calibres in order to withstand the enormous pressures necessary to impart ever increasing velocities to projectiles, to keep pace with improvements in the resisting power of armor plate, renders pyro-nitro-cellulose powder especially valuable.

British cordite is the smokeless powder containing the greatest percentage of nitro-glycerin, and consequently the one which develops the highest temperature and greatest amount of energy of all, while pyro-nitro-cellulose develops the lowest temperature, but without a corresponding diminution of ballistic value. It would probably require about a third more pyro-nitro-cellulose compound to develop the same energy behind a projectile as that developed by the British cordite composition, containing 58 per cent of nitro-glycerin. Notwithstanding this and the fact that pyro-nitro-cellulose is a more expensive compound, the greater erosive action of cordite at high pressures is so destructive to ordnance as more than to balance the additional expense of using greater charges of the more expensive material. For the foregoing reasons it is believed that the United States Government has in its pyro-nitro-cellulose composition and its form of grain a really ideal smokeless powder for high-power guns.

The multi-perforated grain and the composition necessarily go together, because it would be impossible to use such a hard and dense material, and one which burns through such a small thickness, without its being multi-perforated. This is owing to the enormous initial areas presented to the flame with the resultant high pressures developed by full charges if granulated sufficiently fine or made thin enough to be burned in the gun without perforations.

While pyro-nitro-cellulose admittedly possesses superior advantages for high-power guns, when the pressures are great enough to make the material burn through a sufficient thickness to produce high ballistic results, it would still not be so well suited to guns with very large bores and comparatively thin walls, adapted to throwing aerial

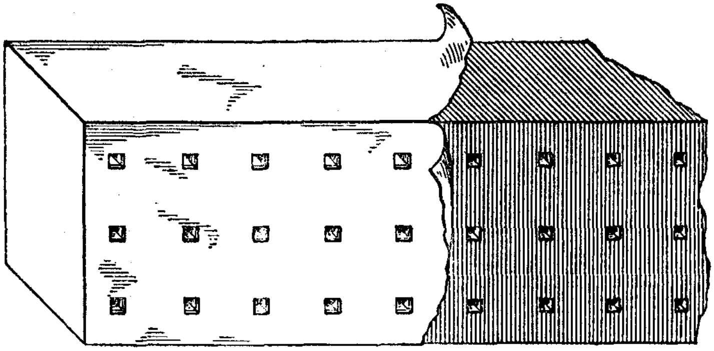

FIG. 11.

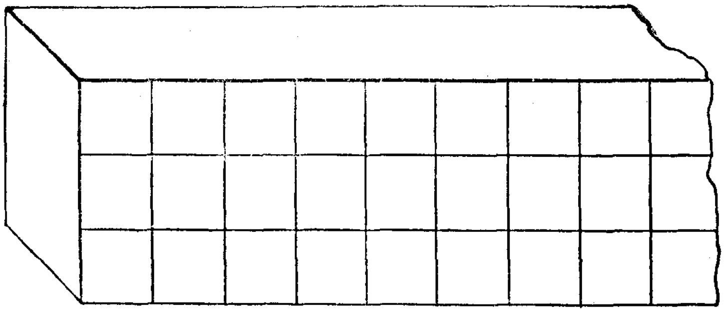

FIG. 12.

torpedoes, where a powder should be employed capable of burning through a necessary thickness under low pressures, to effect the accelerating combustion required for highest ballistic results. It is the belief of the writer that torpedo guns of this description will be soon largely used in this country, and it will be necessary to employ a smokeless powder made especially for the purpose. Such a powder must present a very small initial surface to the flame of ignition, with maximum surface at the instant before complete consumption.

The powder grain shown in Fig. 11 has been recommended by the writer for this purpose. It is a long, rectangular bar, about twice as wide as thick, and having a length of from eighteen inches to two feet. This bar is pierced with a large number of rectangular perforations, small in size, and so arranged that the grain shall burn out to the diagram shown in Fig. 12. In order to secure the maximum acceleration of combustion, the grain is given a suitable exterior covering or varnish coating, which is intended to be only of such thickness and character as will effectually delay the ignition of the outer surfaces of the grain, but will not prevent the grain being wholly consumed before the projectile leaves the gun.

The composition which the writer recommends for this grain would contain nitro-glycerin, tri-nitro-cellulose, gelatin guncotton, and about 10 per cent of a compound at present held as a secret, which latter effects the combination of the nitro-glycerin with the other ingredients in a much more intimate relation than has ever been heretofore secured. This compound would be very tough and elastic, and would permit of the perforations being made comparatively small. Furthermore, although the compound would contain nitro-glycerin and burn rapidly, nevertheless, its products of combustion would be so low in temperature and of such a non-oxidizing character as to have no more erosive effect upon the gun than is produced with the pyro-nitro-cellulose compound already described. Even were the pyro-nitro-cellulose compound to be employed in torpedo guns, the transversely perforated grain shown in Fig. 11 would still possess the same advantages above the longitudinally perforated cylinder, because, owing to the shortness of the perforations, they could be made very small in size. By making them very small a sufficient number of them could be used to reduce the thickness of the material between them to such an extent as to cause the grains to be entirely consumed under the necessarily low pressures, while presenting so small an initial area to the flame of ignition as to enable full charges to be employed.

HUDSON MAXIM.

A NEW INDUSTRY BROUGHT BY AN INSECT.

An article by the present writer, entitled, "International Relations Disturbed by an Insect," was published in The Forum for July, 1898. In that article it was shown how the San José scale had caused the adoption of quarantine measures against United States fruit by many foreign countries, and that it had been the subject of much discussion in diplomatic circles. It is a pleasure, therefore, to record a recent industrial occurrence of an entirely different character, and to show how the United States has gained a new insect inhabitant which promises to add greatly to our wealth.

During all past time the dried fig trade of the world has been controlled by the countries bordering on the Mediterranean Sea, and principally by Turkey and Algeria. Figs grow in nearly all warm countries, and superior table figs are found in many localities, including our Southern States and California; but none, when dried, has been found to compare with the so-called Smyrna fig, which has heretofore been grown successfully in Mediterranean regions only. California figs have been dried, and have sold at from 7½ cents to 10 cents per pound; but, in the autumn, as soon as the crop of Smyrna figs for the year begins to appear in the market, the price of the California product drops, and it has practically no sale.

Now, it is certainly not the habit of the United States to allow herself to drop behind any other part of the world; and this characteristic is particularly in evidence in California. That State would not rest under the imputation that she could not supply the world's markets with dried figs equal or superior to those exported from Smyrna and Algiers; so, in 1881, there began a series of experiments which, at last, during the present year, has been crowned with success.

The first step was to secure the Smyrna fig trees. This was begun in 1881 by Mr. G. P. Rixford, of the San Francisco "Bulletin," who imported 14,000 cuttings, and distributed them to prominent fruit-growers. When these trees came into bearing, however, the fruit failed to mature, dropping to the ground after reaching the