PHILOSOPHY OF EXPLOSIVE WAVE ACTION.

BY HUDSON MAXIM.

In the SCIENTIFIC AMERICAN of April 8, immediately following the bursting of the 10-inch gun at Sandy Hook, I published an article expressing my views as to the probable cause of that disaster. In the Automobile Number of the SCIENTIFIC AMERICAN I illustrated, with diagrams, how different methods and densities of loading and of ignition may set up violent wave action in guns.

In the SCIENTIFIC AMERICAN SUPPLEMENT of May

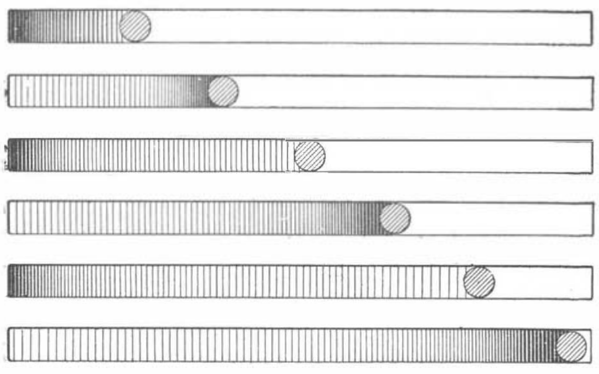

Fig. 1.

20, I took up the subject again, chiefly to reply to and correct some misleading statements made by Mr. Hiram S. Maxim, concerning the Maxim-Schüpphaus smokeless powder and other matters. Supplementing the above articles appeared an excellent contribution by Mr. Fred. H. McGahie on Wave Action in Guns, in the SCIENTIFIC AMERICAN SUPPLEMENT, May 27. Those interested in the subject will find sufficient data in the above contributions to establish the fact beyond a doubt, I think, that the cause of the explosion of the gun was due to wave action, and was not due to any inherent fault of the Maxim-Schüpphaus smokeless powder which was employed.

All of the conditions favorable to wave action were present when the gun burst, and these conditions are very clearly presented in the following paragraph, page 248, Report of the Chief of Ordnance, of 1894:

"The conditions favorable to wave action appear to be length of chamber, quickness of the powder, high density of loading, ununiform distribution of the charge, and end ignition. In our system of large guns three

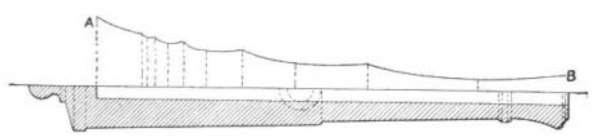

Fig. 2.

of these conditions are always present, and it is probable that more or less wave action always occurs, though it may not result in abnormal maximum pressures. And when the charge does not occupy the whole length of the chamber abnormal results seem likely to occur, the more likely as the powder is quicker."

In the present article I shall endeavor to show something of the philosophy of explosive wave action.

The subject of wave action was thoroughly investigated by M. Vieille, and his determinations were published in the Memorial des Poudres et Salpêtres, Tome III., 1890. Vieille, however, was not the first person to give this matter rational treatment. By referring to the Appendix M, to the Report of the Chief of Ordnance, United States Army, 1879, we find that Dr. W. E. Woodbridge went about as far toward a rational solution of the problem as was possible with the means at hand at that time.

Dr. Woodbridge says:

"It is evident that a difference of tension amounting to 3,800 pounds in the distance of three inches will not allow the gases to remain in quiescence, but must give rise to vibrations of great force, and alterations of tension, such as are represented in the diagrams. . . . The effect of an enlargement of the space during the vibrations such as actually occur will evidently be to

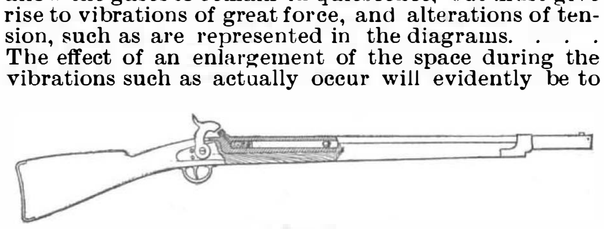

Fig. 3.

increase the amplitude of the vibrations and to diminish their frequency and force. The amount of this effect, and the number of vibrations occurring before the ball leaves the gun, will depend, other things being equal, on the weight of the ball. The figures above are designed to illustrate the character of the variations of tension occurring while the ball is leaving the bore. (See six diagrams, Fig. 1.) Adopting another mode of illustration, and representing tension by perpendicular distance from a horizontal line, the wave line, *A B* (Fig. 2), will denote the maximum pressure sustained by the different parts of the bore. The supposed limits of the cavity during the successive vibrations are given in vertical lines."

Persons familiar with the old style muzzle-loading musket are aware of the necessity of getting the ball well down upon the powder charge. If, from the gun being foul, or from other cause, the ball should stick in the bore, say a foot above the powder charge, and the gun be fired, it is likely to burst. To illustrate this, let us refer to Fig. 3, showing a side elevation of an old-fashioned musket with the powder charge, and a portion of the barrel in section, and showing the bullet stuck in the bore some distance forward of the powder charge. Here we have a similar condition to that presented in a modern cannon, charged with a single bag of powder placed near the breech plug and ignited at the rear.

Upon ignition, the powder charge will rocket along the bore, while the rapidly burning grains strew the chamber, the main portion of the charge being thrown with great violence with the dense products of combustion upon the ball, tamping themselves by their inertia into the space immediately behind the ball. Before the projectile is displaced to any considerable extent, the pressure directly behind it will mount very high, which will cause the grains to burn with greatly accelerated rapidity. The enormous pressure resulting will be greatly in excess of the pressure at the rear of the powder chamber. This will cause a wave of explosion to rebound from the ball and rush backward through the powder chamber to the breech of the gun. This wave, meeting the outward-rushing gases laden with burning powder, will throw them back upon themselves, and impinging upon the immovable breech block, cause a repetition in much exaggerated form of that condition just described as taking place behind the ball. The explosive wave, if it does not blow out the breech block or burst the gun, will again rebound to rush forward through the bore to overtake and impinge again upon the projectile before it has had time to leave the gun, again mounting the pressure very high immediately behind it.

Fig. 4.

There are two ways in which explosive compounds are consumed, namely, surface combustion and detonation. Gunpowder is burnt in the first way, and dyna-

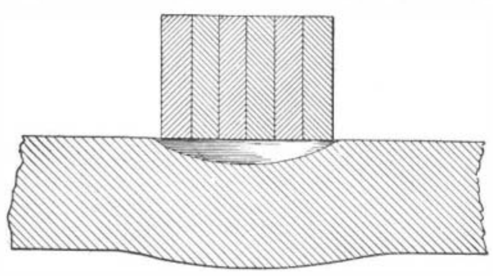

Fig. 5.

mite in the second. Detonation means the breaking up of the chemical arrangement of the molecules composing the compound, by a wave action transmitted with great velocity through the body of the compound. With gunpowder under service conditions, in guns, detonation is practically impossible. To cause the detonation of a grain of any standard smokeless powder, such as are employed in large guns, would probably require a pressure, instantly applied, of more than 100 tons to the square inch, while the pressure to which it is usually subjected in guns is from 15 to 17 tons.

It is probable that no gun is strong enough to allow the pressure to mount to a sufficient height within the

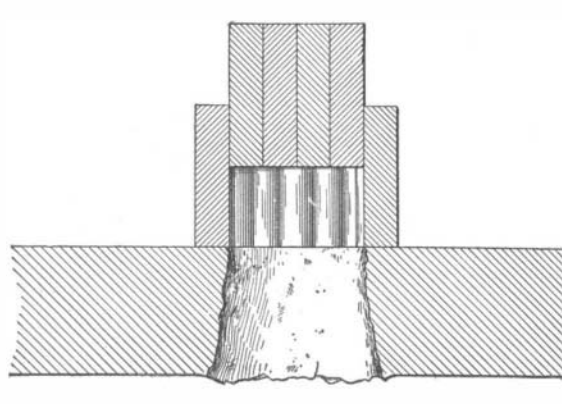

Fig. 6.

bore to detonate a service powder charge before the bursting of the gun; and it is probable that if the granulation be coarse enough, the strongest piece of modern ordnance could be burst in this way without the complete consumption of the grains; and some of them would be blown out in a partially consumed condition, with the pieces of the walls of the gun. Although dynamite is exploded in an entirely different manner from gunpowder, yet we may draw valuable conclusions from the action of the gases set free by the detonation of dynamite, as to what high velocity means with dense gases.

If a dynamite cartridge, set on end upon the ground, be exploded from the bottom, the wave of detonation moving upward will detract from the downward effect of the explosive upon the earth. If, however, the cartridge be exploded from the upper end, a much larger hole will be blown in the earth. When dynamite is detonated adjacent to a body offering great resistance, the body of the explosive, being instantly converted into incandescent gases, will rebound from the resisting body with great velocity, and the destructive effect upon the latter body will be less if the detonative wave moves from the body, than if it moves toward it. If two bodies of dynamite be placed adjacent to each other and detonated simultaneously, the gases of the explosion will meet in the space which separates them to be thrown out with greatly increased velocity in a lateral direction.

Under the advice of Prof. Charles E. Monroe, the

Fig. 7.

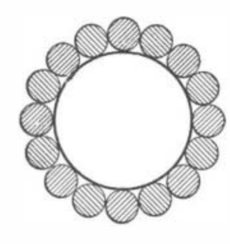

Fig. 8.

celebrated high explosives expert, and the inventor of jovite, some experiments were conducted in the destruction of safes and safe deposit vaults some years ago. The following data is obtained concerning these experiments, from a letter of the Secretary of the Treasury, 1894.

It was found that a package of dynamite cartridges, tied together, as shown in Fig. 4, and placed upon the steel wall of the safe, would, when exploded from the bottom, only serve to slightly indent the wall of the safe (Fig. 5).

When, however, the same quantity of dynamite was tied about a tin can, as shown in Fig. 7, and in section, Fig. 6, and plan, Fig. 8, the effect of the explosion detonated from the top was to blow a 3-inch hole through the wall of the safe, Fig. 6. This greatly increased effect was due to the fact that the gases of the explosion (Fig. 6) met in the space formed by the tin can, which imparted to them greatly accelerated velocity under great density. The direction of the movement of the united gases being toward the safe, instead of simply indenting it, blew a hole completely through.

When the products of combustion in a gun are thrown violently backward and forward by wave action, the velocity and inertia factors serve to run the pressure up very high at different points along the bore.

How Large Fossils are Preserved.

Each summer the field expeditions sent by the American Museum of Natural History go to the great fossil beds of Wyoming and Kansas, where in past geological ages were the great fresh water lakes, in and about which lived the extinct animals whose skeletons they are seeking. Here, says The Evening Post, they begin by prospecting along the bluffs or over the beds of hard clay in which the bones are found. When one is found protruding above the surface the clay is carefully cut away, but sufficient is left to cause the fossil bones to be firmly embedded in it. They are usually broken into many fragments, and if they were laid completely bare, as was formerly the custom, there would be great danger of losing some of the pieces, and there would be considerable difficulty in determining the relative positions of the rest. The new method of handling them is to leave them embedded in enough of the original clay to hold them together and to cover the whole with a plaster cast. This is boarded up and shipped with wet rawhide around it, which shrinks as it dries and binds the whole firmly together. These blocks weigh from 100 to 1,500 pounds. They are then crated and shipped to the museum, where the matrix is removed, and the bones are put together at once as they are removed, thus avoiding the difficulty of solving a dissected puzzle. A complete photographic record is kept of every stage of the proceedings, so that an adequate idea of the location of the bones in situ is obtained. One of the many specimens thus unearthed and preserved is part of a skeleton of a huge herbivorous reptile, called a camarasaur (Cope) or brontosaur (Marsh). Of this skeleton the museum has two of the dorsal and nineteen of the cordal vertebræ and parts of the pelvis and leg bones.

To most people the interesting thing about this skeleton is the fact that the bones show unmistakable evidences of having been broken and gnawed by the teeth of some other animal, presumably one of the flesh-eating reptiles whose bones are found in the same clay beds. It is hard to picture such a scene of conflict. It might be likened to a fight between an elephant and a tiger, if the elephant was 80 feet long and 16 feet high and the tiger in proportion.