

The Author. effect of lessening the sudden shock upon the projectile, and weakening the plate at the same time. The effect when armour-plate was struck by an uncapped projectile might in some degree be illustrated by the curious result which was obtained when a slab of flint or glass was struck by a hammer with a rounded face; a cone of glass or flint, having its apex at the point of impact, was separated from the rest. Majors Barlow and Wolley-Dod had spoken of the punching action of projectiles, and of irregularly-shaped pieces of plate being punched clean out. With the cap, however, there appeared to be, as Major Wolley-Dod had said, a true boring action similar to that which occurred in attacking wrought-iron armour; and this was no doubt due to the weakening of the plate by the first blow received from the cap. Mr. Oscar Guttman's experiments were interesting and suggestive, and should lead to further investigation of the imperfectly understood action of the cap upon the projectile, and upon the plate.

Correspondence.

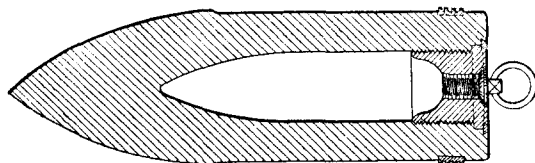
Prof. Arnold. Professor J. O. ARNOLD congratulated the Author on his valuable, interesting and suggestive Paper, which filled a gap in the literature of steel metallurgy. The statement in the Paper that the changes produced by the operations of hardening and tempering were mysterious, was very true, with reference to the exact molecular constitution of the steel at any given stage. This, however, was a matter of academic rather than of practical importance; practically the fundamental laws governing the operations of hardening, tempering and letting down, were fairly well known. To take the simplest example, iron containing 0.9 per cent. of carbon consisted entirely of the compound constituent, pearlite ($21\text{Fe} + \text{Fe}_3\text{C}$). This formula had passed out of the region of speculation and had been repeatedly proved, analytically. Such a steel really consisted of an intimate mechanical mixture of about 87 per cent. of iron with 13 per cent. of the normal carbide of iron. On heating this mixture to 700°C ., a molecular convulsion took place, accompanied by a considerable absorption of heat. After this molecular change, the carbon which before had been chemically associated with only 12 per cent. of the mass of iron, became molecularly associated with the whole mass. On rapid

quenching, the carbon was trapped in its new condition, causing the steel to assume the hardness of quartz. Then, on heating to about 200° C., the attenuated carbide alloy began to decompose, and at 400° C. it again passed into the relatively soft mechanical mixture already formulated. But, by arresting the tempering operation at any point by re-quenching, any desired degree of hardness might be retained. The carbon change-point, however, was greatly influenced by the presence of various elements such as tungsten, chromium, nickel, vanadium, etc. As an example, the case of tungsten might be selected. If a 0·9-per cent. carbon steel with 3 per cent. of tungsten was cooled from, say, 900° C., the change-point of the carbon was lowered nearly 100° C.; that was, the recalescence which would take place in the plain carbon steel at about 680° C. did not occur till about 590° C. in the carbon-tungsten steel. Hence, such steel could be sufficiently hardened at a much lower temperature than ordinary steel. Nevertheless, an enormous amount of work remained to be done in obtaining pyrometric records of the recalescence phenomena of the numerous combinations of the triple alloys of carbon, nickel and chromium which were in practical use at the present time.

Lieutenant-Colonel L. CUBILLO remarked that the Trubia arsenal had devoted special attention to the manufacture of armour-piercing projectiles. Since 1875, when this manufacture had been begun with the Palliser projectile, the subject had not been overlooked for a moment. The Palliser projectile, made of cast iron, had been cast in an iron mould, so that the point cooled in contact with a cast-iron chill. Fired against wrought-iron armour it had proved to be excellent; against mild-steel plates the results obtained had been mediocre. The chief difficulty in manufacturing Palliser projectiles had been to obtain a suitable mixture of cast iron giving to the projectile the proper gradual hardening from the point to the shoulder. At first, when in the manufacture of projectiles the work of the metallurgist had not been assisted by the metallurgical laboratory as effectively as it was now, it had been necessary to rely upon experience in determining the best mixture. Later on, the influence of silicon on the behaviour of carbon having become known, the formula for obtaining an iron containing the silicon and manganese requisite to produce good hardening had at once been fixed. At present, the process possessed only historical and retrospective interest; steel had supplanted cast iron in the manu-

Col. Cubillo. manufacture of armour-piercing projectiles. In Trubia two kinds of steel projectiles had been made. One (*Fig. 46*) was the chrome-steel projectile manufactured between the years 1885 and 1899 with the following average percentages of iron and chromium :—Carbon 0·8 per cent.; chromium 1·00 per cent. The weight of the steel castings had been such as to allow two projectiles to be formed of a calibre of 24 centimetres to 30 centimetres. They had been forged in the manner described by the Author, and after annealing the operations of turning, boring, etc., had been carried out. The most difficult operation had been the hardening; it had been performed by heating the projectiles in an upright gas-furnace at a temperature between 780°C . and 800°C .; then transferring them to an iron tank, wherein a jet of oil at a pressure of half an atmosphere acted upon the point of the projectile until the tank was full, the capacity of the tank being sufficient for holding a volume of oil, the weight of which was ten times the weight of projectile. The tests made on projectiles manufactured by this process had given excellent results.

Fig. 46.



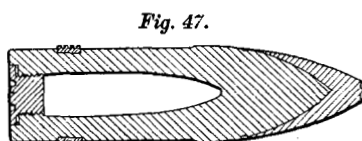
CHROME-STEEL ARMOUR-PIERCING PROJECTILE FOR 24 CENTIMETRE GUN.

A few ruptures, however, had been noticed, which occurred with every method of hardening. In nearly every case the rupture of the projectile had taken place midway between point and shoulder, across a plane normal to the longest axis of projectile. As a rule these fractures had happened at times of sudden change of temperature. The armour-piercing projectiles at present manufactured for quick-firing guns (*Fig. 47*) were of nickel-chrome alloys. As in every kind of nickel steel, the quantity of carbon was not high; the average composition of these projectiles was carbon 0·55 per cent.; chromium 0·65 per cent.; nickel 2·60 per cent. The projectile was provided with a cap of steel, having the same composition as the projectile. Forged with the care required by nickel steel, they were then annealed, and after the machine-shop operations they were hardened twice. The first time the projectile was heated to 740°C ., and wholly immersed in a bath of oil, the temperature of which was 24°C .; the second time only the point

was hardened, in water which flowed in a jet on to the inside Col. Cubillo, and the outside. The temperature for this second tempering was 780°C . for the projectile, and 22°C . for the water. The caps were hardened in water, the top part only being heated to a bright red heat; then they were immersed in water. The precaution recommended by the Author in regard to heating and cooling the projectile—especially its point—were useful and worthy of consideration by all concerned with the manufacture of armour-piercing projectiles.

Messrs. SCHNEIDER & Co., of Le Creusot, pointed out that the numerical coefficients given by Mr. Delmas related to the formula of the Gâvre Commission, not to the formula of Colonel Jacob de Marre. Consequently, those coefficients were not comparable with K_2 in Table I. of the Paper. Further, they related to trials of plates chosen at random from completed lots, and represented the results of firing under average conditions: the results obtained with such plates could not be compared with those obtained from plates specially made for trial.

The AUTHOR, in reply, remarked that Professor Arnold's lucid remarks on the changes which took place in steel during the processes of hardening and tempering were of practical importance. It was interesting to find that Colonel Cubillo's methods of manufacture agreed closely with those described in the Paper. If, as Messrs. Schneider & Co. stated, the numerical coefficients given by Mr. Delmas related to the formula of the Gâvre Commission, and not to the formula of Colonel Jacob de Marre, then they were comparable with K , instead of K_2 , in Table I.



NICKEL-CHROME-STEEL ARMOUR-PIERCING PROJECTILE FOR 15-CENTIMETRE QUICK-FIRING GUN.

Messrs.
Schneider.

The Author.

17 February, 1903.

JOHN CLARKE HAWKSHAW, M.A., President,
in the Chair.

The PRESIDENT said he regretted to have to announce the death of Field-Marshal Sir Lintorn Simmons, Honorary Member. There was no need to recall to the members his distinguished career as a soldier in the Crimea and elsewhere, and in the many responsible positions which he had afterwards filled so ably. By his connection with the Railway Department of the Board of Trade in early

life he had been brought into contact with many of the older engineers, and many of them had enjoyed his friendship throughout life. At their meeting that evening the Council of the Institution had passed the following resolution:—"That the Council deeply regret the death of Field-Marshal Sir John Lintorn Arabin Simmons, R.E., G.C.B., Honorary Member, and desire to convey to his family an expression of sympathy in their bereavement."

The discussion on the Paper on "The Manufacture and Efficiency of Armour-Piercing Projectiles," by Mr. David Carnegie, occupied the evening.
