are now reduced to about 20,000, dispersed in small groups over the islands of Luzon, Mindoro, Tablas, Panay, Negros, Cebu, Paragan (Palawan), and Mindanao. A few also appear still to survive in Alabat, Busuanga, and Culioú. Of the Malay peoples by far the most numerous and important are the southern Bisayas (Visayas), and the northern Tagalas, both described as "civilized Christians," and numbering respectively 1,700,000 and 1,250,000. These two peoples are steadily encroaching on all the surrounding tribes, causing them to disappear by a gradual process of absorption or assimilation, and the time is approaching when the whole of the islands will be divided into two great nationalities bearing somewhat the same relation to each other that the High German does to the Low German branch of the Teutonic family.

SMOKELESS EXPLOSIVES.[1]

I.

THE production of smoke which attends the ignition or explosion of gunpowder is often a source of considerable inconvenience in connection with its application to naval or military purposes, its employment in mines, and its use by the sportsman, although occasions not unfrequently arise during naval and military operations when the shroud of smoke produced by musketry or artillery fire has proved of important advantage to one or other, or to both, of the belligerents during different periods of an engagement.

Until within the last few years, however, but little, if any, thought appears to have been given to the possibility of dispensing with or greatly diminishing the production of smoke in the application of fire-arms, excepting in connection with sport. The inconvenience and disappointment often resulting from the obscuring effects of a neighbouring gun-discharge, or of the first shot from a double-barrel arm, led the sportsman to look hopefully to gun-cotton, directly after its first production in 1846, as a probable source of greater comfort and brighter prospects in the pursuit of his pastime and in his strivings for success.

A comparison between the chemical changes attending the burning, explosion, or metamorphosis of gun-cotton and of gunpowder, serves to explain the cause of the production of smoke in the latter case, and the reason of smokelessness in the case of gun-cotton. Whilst the products of explosion of the latter consist exclusively of gases, and of water which assumes the transparent form of highly-heated vapour at the moment of its production, the explosive substances classed as gunpowder, and which consist of mixtures of saltpetre, or another nitrate of a metal, with charred wood or other carbonized vegetable matter, and with variable quantities of sulphur, furnish products, of which very large proportions are not gaseous, even at high temperatures. Upon the ignition of such a mixture, these products are in part deposited in the form of a fused residue, which constitutes the fouling in a fire-arm, and are in part distributed, in an extremely fine state of division, through the gases and vapours developed by the explosion, thus producing smoke.

In the case of gunpowder of ordinary composition, the solid products amount to over fifty per cent. by weight of the total products of explosion, and the dense white smoke which it produces consists partly of extremely finely-divided potassium carbonate, which is a component of the solid products, and, to a great extent, of potassium sulphate produced chiefly by the burning of one of the important solid products of explosion—potassium sulphide—when it is carried in a fine state of division into the air by the rush of gas.

With other explosives, which are also smoke-producing, the formation of the smoke is due to the fact that one or other of the products, although existing as vapour at the instant of its development, is immediately condensed to a cloud composed of minute liquid particles, or of vesicles, as in the case of mercury vapour liberated upon the explosion of mercuric fulminate, or of the aqueous vapour produced upon the ignition of a mixture of ammonium nitrate and charcoal, or ammonium nitrate and picric acid.

Until within the last half-dozen years, the varieties of gunpowder which have been applied to war purposes in this and other countries have exhibited comparatively few variations in chemical composition. The proportions of charcoal, saltpetre, and sulphur employed in their production exhibit slight differences in different countries, and these, as well as the character of the charcoal used, its sources and method of production, underwent but little modification for very many years. The same remark applies to the nature of the successive operations pursued in the manufacture of black powder for artillery purposes in this and other countries.

The replacement of smooth-bore guns by rifled artillery which followed the Crimean war, and the increase in the size and power of guns consequent upon the application of armour to ships and forts, soon called for the pursuit of investigations having for their object the attainment of means for variously modifying the action of fired gunpowder, so as to render it suitable for the different calibres of guns, whose full power could not be effectively, or in some instances safely, developed by the use of the kind of gunpowder previously employed indiscriminately in artillery of all known calibres.

In order to control the violence of explosion of gunpowder, by modifying the rapidity of transmission of explosion from particle to particle, or through the mass of each individual particle, of which the charge of a gun is composed, the accomplishment of the desired results was, in the first instance, and indeed throughout practical investigations extending over many years, sought exclusively in modifications of the size and form of the individual masses composing a charge of powder, and of their density and hardness, it being considered that, as the proportions of saltpetre, charcoal, and sulphur generally employed in the production of gunpowder very nearly correspond to those required for the development of the greatest chemical energy by those incorporated materials, it was advisable to seek for the attainment of the desired results by modifications of the physical and mechanical characters of, rather than by any modification in the proportions and chemical characters of, its ingredients.

The varieties of powder, which, as the outcome of careful practical and scientific researches in this direction, have been introduced into artillery service from time to time, and some of which, at any rate, have proved fairly efficient, have been of two distinct types. The first of these, produced by breaking up more or less highly-pressed cakes of black powder into grains, pebbles, or boulders, of approximately uniform size and shape, the sharp edges and rough surfaces being afterwards removed by attrition (reeling and glazing), are simply a further development of one of the original forms of granulated or corned powder, represented by the old F. G., or small arms, and L. G., or cannon powder. Gunpowder of this class, ranging in size from about 1000 pieces to the ounce, to about six pieces to the pound, have been introduced into artillery service, and certain of them, viz. R. L. G. (rifle large grain), which was the first step in advance upon the old cannon-powder (L. G.); pebble-powder (P.), and large pebble or boulder-powder (P. 2), are still employed more or less extensively in some guns of the present day.

The other type of powder has no representative among the more ancient varieties; it has its origin in the obviously sound theoretical view that uniformity in the results furnished by a particular powder, when employed under like conditions, demands not merely identity in regard to composition, but also identity in form, size, density, and structure of the individual masses composing the charge used in a gun. The practical realization of this view should obviously be attained, or at any rate approached, by submitting equal quantities of one and the same mixture of ingredients, presented in the form of powder of uniform fineness and dryness, to a uniform pressure for a fixed period in moulds of uniform size, and under surrounding conditions as nearly as possible alike. The fulfilment of these conditions would, moreover, have to be supplemented by an equally uniform course of proceeding in the subsequent drying and other finishing processes to which the powder-masses would be submitted.

The only form of powder, introduced into our artillery service for a brief period, in the production of which these conditions were adhered to as closely as possible, was a so-called pellet powder, which consisted of small cylinders having semi-perforations with the object of increasing the total inflaming surface of the individual masses.

Practical experience with this powder, and with others prepared upon the same system, but with much less rigorous regard to uniformity in such details as state of division and condition of dryness of the powder before its compression into cylindrical or other forms, showed that uniformity in the ballistic properties

[1] Friday Evening Discourse delivered by Sir Frederick Abel, F.R.S., at the Royal Institution of Great Britain, on January 31, 1890.

of black powder could be as well and even more readily secured by the thorough blending or mixing together of batches presenting some variation in regard to density, hardness, or other features, as by aiming at an approach to absolute uniformity in the characters of each individual mass composing a charge.

At the time that our attention was first actively given to this subject of the modification of the ballistic properties of powder, it had already been to some extent dealt with in the United States by Rodman and Doremus, and the latter was the first to propose the application, as charges for guns, of powder-masses produced by the compression of coarsely grained powder into moulds of prismatic form. In Russia the first step was taken to utilize the results arrived at by Doremus, and to adopt a prismatic powder for use in guns of large calibre.

Side by side with the development and perfection of the manufacture of prismatic powder in Russia, Germany, and in this country, new experiments on the production of powder-masses suitable, by their comparatively gradual action, for employment in the very large charges required for the heavy artillery of the present day, by the powerful compression of mixtures of more or less finely broken up powder-cake into masses of greater size than those of the pebble, pellet, and prism powders, were actively pursued in Italy, and also by our own Government Committee on Explosives, and the outcome of very exhaustive practical investigations were the very efficient Fossano powder, or *poudre progressif*, of the Italians, and the boulder and large cylindrical powders known as P^2 and C^2, produced at Waltham Abbey, which scarcely vied, however, with the Italian powder in the uniformity of their ballistic properties.

Researches carried out by Captain Noble and the lecturer some years ago with a series of gunpowders differing considerably in composition from each other, indicated that advantages might be secured in the production of powders for heavy guns by so modifying the proportions of the constituents (*e.g.* by considerably increasing the proportion of charcoal and reducing the proportion of sulphur) as to give rise to the production of a much greater volume of gas, and at the same time to diminish the heat developed by the explosion.

These researches served, among other purposes, to throw considerable light upon the cause of the wearing or erosive action of powder-explosions upon the inner surface of the gun, which in time may produce so serious a deterioration of the arm as to diminish the velocity of projection considerably, and so affect the accuracy of shooting, a deterioration which increases in extent in an increasing ratio to the size of the guns, in consequence, obviously, of the large increase in the weight of the charges fired.

Several causes undoubtedly combine to bring about the wearing away of the gun's bore, which is especially great where the products of explosion, while under the maximum pressure, can escape between the projectile and the bore of the gun. The great velocity with which the very highly heated gaseous and liquid (fused solid) products of explosion sweep over the heated surface of the metal gives rise to a displacement of the particles composing it, which increases as the surface becomes roughened by the first action upon the least compact portions of the metal, and thus opposes greater resistance; at the same time, the effect of the high temperature to which the surface is raised is to reduce its rigidity and power of resisting the force of the gaseous torrent, and lastly some amount of chemical action upon the metal, by certain of the highly heated non-gaseous products of explosion, contributes towards an increase in the erosive effects. A series of careful experiments made by Captain Noble with powders of different composition, and with other explosives, afforded decisive evidence that the material which furnished the largest proportion of gaseous products, and the explosion of which was attended by the development of the smallest amount of heat, exerted least erosive action.

It is probable that important changes in the composition of powders manufactured by us for our heavy guns would have resulted from those researches, but in the meantime, two eminent German gunpowder manufacturers had occupied themselves independently, and simultaneously, with the important practical question of producing some more suitable powder for heavy guns than the various new forms of ordinary black powder, the rate of burning of which, especially when confined in a close chamber, was, after all, reduced only in a moderate degree by the increase in the size of the masses, and by such increase in their density as it was practicable to attain. The German experimenters directed their attention not merely to the proportions in which the powder ingredients are employed, but also to a modification in the character of charcoal, and the success attending their labours in these directions led to the practically simultaneous production, by Mr. Heidemann at the Westphalia Powder Works, and Mr. Düttenhofer at the Rottweil Works near Hamburg, of a prismatic powder of cocoa-brown colour, consisting of saltpetre in somewhat higher proportion, of sulphur in much lower proportion, than in normal black powder, and of very slightly burned charcoal, similar in composition to the charcoal (*charbon roux*) which Violette, a French chemist, first produced in 1847 by the action of superheated steam upon wood or other vegetable matter, and which he proposed for employment in the manufacture of sporting powder. These brown prismatic powders (or "cocoa-powders," as they were termed from their colour), are distinguished from black powder not only by their appearance, but also by their very slow combustion in open air, by their comparatively gradual and long-sustained action when used in guns, and by the simple character of their products of explosion as compared with those of black powder. As the oxidizing ingredient, saltpetre, is contained, in brown or cocoa powder, in larger proportion relatively to the oxidizable components, sulphur and charcoal, than in black powder, these become fully oxidized, while the products of explosion of the latter contain, on the other hand, larger proportions of unoxidized material, or only partially oxidized products. Moreover, there is produced upon the explosion of brown powder a relatively very large amount of water-vapour, not merely because the finished powder contains a larger proportion of water than black powder, but also because the very slightly charred wood or straw used in the brown powder is much richer in hydrogen than black charcoal, and therefore furnishes by its oxidation a considerable amount of water. The total volume of gas furnished by the brown powder (at 0° C. and 760 mm. barometer) is only about 200 volumes per kilogramme of powder, against 278 volumes furnished by a normal sample of black powder, but the amount of water-vapour furnished upon its explosion is about three times that produced from black powder, and this would make the volume of gas and vapour developed by the two powders about equal if the heat of its explosion were the same in the two cases; the actual temperature produced by the explosion of brown powder, is, however, somewhat the higher of the two.

Although the smoke produced upon firing a charge of brown powder from a gun appears at first but little different in denseness to that of black powder, it certainly disperses much more rapidly, a difference which is probably due to the speedy absorption, by solution, of the finely divided potassium salts by the large proportion of water-vapour distributed throughout the so-called smoke.

This class of powder was substituted with considerable advantage for black powder in guns of comparatively large calibre; nevertheless it became desirable to attain even slower or more gradual action in the case of the very large charges required for guns of the heaviest calibres, such as those which propel shot of about 2000 pounds weight. Accordingly, the brown powder has been modified in regard to the proportions of its ingredients to suit these conditions, while, on the other hand, powder intermediate with respect to rapidity of action between black pebble powder and the brown powder, has been found more suitable than the former for use in guns of moderately large calibre.

The recent successful adaptation of machine guns and comparatively large quick-firing guns to naval service, more especially for the defence of ships against attack by torpedo boats, &c., has rendered the provision of a powder for use with them, which would produce comparatively little or no smoke, a matter of very considerable importance, inasmuch as the efficiency of such defence must be greatly diminished by the circumstance that, after a very brief use of the guns with black powder, the objects against which their fire is destined to operate, become more or less completely hidden from those directing them, by the dense veil of powder-smoke produced. Hence much attention has been directed during the last few years to the production of smokeless, or nearly smokeless powders for naval use in the above directions. At the same time, the views of many military authorities regarding the importance of dispensing with smoke in land engagements has also created a demand, the apparent urgency of which has been increased by various circumstances, for a smokeless powder suitable for field artillery and small arms.

The properties of ammonium nitrate, of which the products of decomposition by heat are, in addition to water-vapour, entirely gaseous, have rendered it a tempting material to work upon in the hands of those who have striven to produce a smokeless powder, but its deliquescent character has been the chief obstacle to its application as a component of an explosive agent susceptible of substitution for black powder for service purposes.

A German chemical engineer, F. Gäus, conceived that, by incorporating charcoal and saltpetre with a particular proportion of ammonium nitrate, he had produced an explosive material which did not partake of the hygroscopic character common to other ammonium-nitrate mixtures, and that, by its explosion, the potassium in the saltpetre formed a volatile combination with nitrogen and hydrogen, a *potassium amide*, so that, although containing nearly half its weight of potassium salt, it would furnish only volatile products. The views of Mr. Gäus regarding the changes which his so-called *amide powder* undergoes upon explosion were not borne out by existing chemical knowledge, while the powder compounded in accordance with his views proved to be by no means smokeless, and was certainly not non-hygroscopic. Mr. Heidemann has, however, been successful, by modifications of Gäus's prescription and by application of his own special experience in powder-manufacture, in producing an ammonium-nitrate powder possessed of remarkable ballistic properties, furnishing comparatively little smoke, which speedily disperses, and exhibiting the hygroscopic characteristics of ammonium-nitrate preparations in a decidedly less degree than any other hitherto prepared. The powder, while yielding a very much larger volume of gas and water-vapour than black or brown powder, is considerably slower than the latter; the charge required to produce equal ballistic results is less, while the chamber-pressure developed is lower, and the pressures along the chase of the gun are higher, than in the case of brown powder.

The ammonium-nitrate powder contains, in its normal, dried condition, more water than even brown powder; it does not exhibit any great tendency to absorb moisture from an ordinarily dry or even a somewhat moist atmosphere, but if the amount of atmospheric moisture approaches saturation, it will rapidly absorb water, and when once the process begins it continues rapidly, the powder-masses becoming speedily quite pasty. The charges for quick-firing guns are enclosed in metal cases, in which they are securely sealed up; the powder is therefore prevented from absorbing moisture from the external air, but it has been found that if the cartridges are kept for long periods in ships' magazines, in which, from their position relatively to the ships' boilers, the temperature is more or less elevated, sometimes for considerable periods, the expulsion of water from some portions of the powder-masses composing the hermetically sealed charge, and its consequent irregular distribution, may give rise to want of uniformity in the action of the powder, and to the occasional development of high pressures. Although, therefore, this ammonium-nitrate powder may be regarded as the first successful advance towards the production of a comparatively smokeless artillery powder, it is not uniformly well adapted to the requirements which it should fulfil in naval service.

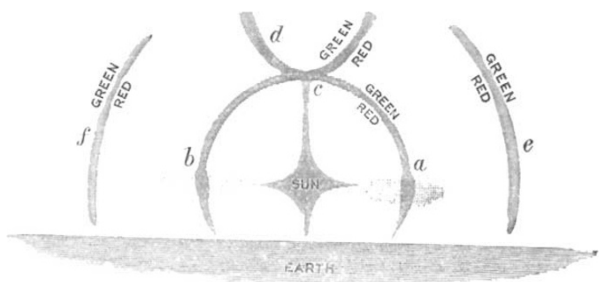
Attention was first seriously directed to the subject of smokeless powder by the reports received about four years ago of remarkable results stated to have been obtained in France with such a powder for use with the magazine rifle (the Lebel) which was being adapted to military service. These reports were speedily followed by others, descriptive of marvellous velocities obtained with small charges of this powder, or some modifications of it, from guns of very great length. As in the case of mélinite, the fabulously destructive effects of which were much vaunted at about the same time, the secret of the precise nature of the smokeless powder was so well preserved by the French authorities, that surmises could only be made on the subject even by those most conversant with these matters. It is now well known, however, that more than one smokeless explosive has succeeded the original powder, the perfection of which was reported to be beyond dispute, and that the material now adopted for use in the Lebel rifle bears, at any rate, great similarity to preparations which have been made the subject of patents in this country, and which are still experimental powders in other countries.

(*To be continued.*)

SOLAR HALOS AND PARHELIA.

THE recent appearance of solar and lunar halos, parhelia, and paraselene, has called forth a considerable amount of correspondence from all parts of the country, and the accompanying figure may be taken as a composite representation of the solar phenomenon observed. A glance at the times at which the halos were observed on the 29th ult., makes it apparent that they occurred earliest in places of highest latitudes. At Driffield, in lat. 54°, the halo, with its attendant parhelia, was observed at 1.34 p.m., and the whole phenomenon disappeared at 2.8 p.m.; at Burton-on-Trent, lat. 52° 48′, the halos and parhelia were first observed at 2 p.m., and lasted more or less distinctly until 3 p.m.; whilst about a degree south of this, at Oxford, Colnbrook, and Walton-on-Thames, the phenomena occurred from about 3.30 to 4.30. The uniform difference in the times when the halos were observed at the places of different latitudes necessarily follows from the fact that they are formed by the action upon solar rays of prismatic crystals of ice suspended in the air by the ascending currents which especially occur in the spring and autumn. Those prisms that are in such positions that the rays from the sun in transmission through them suffer minimum deviation are the cause of the formation of halos, and since the angular distance of the sun equal to minimum deviation is about 22°, this must be the radius of the halo, and the external circle, being produced by two such refractions in succession, has a radius of about 46°.

The halos recently observed do not differ in the main from those frequently seen in higher latitudes, and consisting of (1) a first circle or halo concentric with the sun, red within, violet without, and at an angular distance of 22° or 23°; (2) a second circle or halo, similar to the preceding, but at an angular dis-



a was seen at 3.35 p.m.; *b* at 3.45 p.m.; *c* and *d* at 3.50 p.m.; *e* at 4.0 p.m; *f* at 4.10 p.m.

tance of 46°; (3) a portion of the *parhelic* circle appearing horizontal and diametral, and at the points of junction of this circle with the two halos, there is increased luminosity, which have been taken for images of the sun; (4) horizontal arcs, tangents to the circular halos, and a vertical line making a cross with the horizontal portion of the parhelic circle.

Mr. John Lovell thus describes the phenomena observed at Driffield:—"A splendid solar halo, with its attendant parhelia, was observed this afternoon at 1.34 local time. The halo (diameter 45°) was almost perfect, the lower part only being slightly obliterated by the thick atmosphere near the horizon. Attached to the upper side, an inverted portion of a similar halo appeared, brilliantly illumined on the concave side, the lower part giving out a dull red light. Again, 22½° above this, and also inverted, about 60° of arc beautifully coloured with rainbow colours was clearly visible, the red side lowest. This arc, if it had been produced, would have circled the zenith. The mock lights on each side of the halo were drawn out into long cones of intensely bright light, while the inner sky of the halo was of a very dark shade. The most noteworthy feature of the display was a brilliant patch of pure white light in the north-western sky, at a distance of 90° from the western mock sun, and undoubtedly emanating from it, and which remained visible for nearly ten minutes. The whole phenomena disappeared at 2.8 p.m., the sky then being covered with streaky cirro-stratus haze from the north-north-west."

The patch of white light referred to by Mr. Lovell was doubtless produced by the junction of the parhelic circle with one of the halos concentric with the sun. It is perhaps hardly necessary to note the relation that exists between halos and cirro-