and the Matagne Dynamite Factory, Liége—is to prove that under identical conditions, the various explosives now used in mining, are far from affording the same guarantees of security; to compare them one with another, in order to find out which is the safest and which are unsafe; to determine whether these guarantees persist under the most dangerous conditions; and, lastly, to recommend, to those engaged in mining, an explosive absolutely safe in the most unfavourable cases, where prudence may be conspicuous by its absence: as well as to afford the opportunity, to all interested in the subject, of judging for themselves as to the correctness of the results obtained.

The Produits Testing Station was laid down on the plan of that at Neunkirchen, with the modifications dictated by experience, or the desire to reproduce as faithfully as possible the dangers actually encountered in underground workings; and as a study of the part played by coal dust did not enter into the question, but only a comparison of the explosives themselves, it was possible to simplify the arrangements.

The French Firedamp Commission practically lays down as a principle that, to make absolutely sure of the degree of safety which may be depended upon in a given explosive, it must be tested by explosion in the open air, and under the most favourable conditions for incomplete explosion, because "it may always happen accidentally, through the imprudence or inattention of a miner, or other cause, that the explosion of substances employed in the underground workings may be determined before they are safely charged into the bottom of a shot-hole," and that "the danger presented by explosion in the open air is therefore not purely imaginary." The accident which would provoke explosion in the open air "is doubtless very difficult to imagine, but it is not quite impossible, and should be provided against."

These protestations against foreseen objections are not convincing. Given an explosive which requires the violent effect of a detonator to explode, it is difficult to imagine how it can be accidently exposed to so energetic a shock in underground workings. The French regulations require that explosives be always kept in a safe place, protected from accident. They are to be shut up in boxes, in such a manner that a fall of the roof would be powerless to explode them, the detonators being kept separate from the explosives. The following is the text of the Belgian regulations on the subject:—

Art. 53—"Powder, dynamite and detonators must be isolated from one another and kept in separate bags or boxes."

Art. 56—"Up to the time of using them the cartridges and fuses intended for blasting are to be deposited in a safe place, to be chosen by the chief miner."

As to imagine the deliberate use of explosives not charged into a shot-hole, but simply placed on an obstacle to be shattered, where has such a risk ever been run at defiance of the most ordinary dictates of common sense; where could such waste take place, in any case and under any pretext? If there were reason to fear the explosion of a substance through fall of the roof, measures of safety would be sought rather in requiring a minimum of resistance to shock than a minimum of explosion temperature. In fact, on account of the complexity and the slight stability of the phenomena which may take place during explosion in the open air, one can never be sure that a method of incomplete explosion, unforeseen and not tried in experiments calculated to establish the safety of an explosive, may not occur at any time.

One of the constituents of the explosive may (as acknowledged by the French Commission) on account of imperfect mixture, explode separately on the surface of the cartridge, and this element might be that of the two capable of giving out dangerous flames. It should not, however, be assigned a too high value, as that might induce another danger. The men, knowing that they had to deal with a resisting (stable) explosive, might be imprudent in the stemming, while the inventors, knowing that their explosive requires a strong tamping in order to act effectually, might go so far as to advise that stemming be performed with the hammer, in defiance of all thought of prudence; and the shot might be fired during the stemming. It is for these reasons that no arrangements have been made at the Produits Testing Station for causing explosions in the open air.

What are the most dangerous conditions of explosion that may be met with in practical mining? To realize something similar in our boiler," says the French Commission, at page 71 of its *Report*, "in the case of a shot which is not blown out, but under conditions certainly more dangerous than any which may happen in practice, we suspended, so as to be surrounded by firedamp, the explosives enclosed in a metal tube (lead or tin) closed at bottom and open at top. In this tube the explosive rested on 5 cm. to 6 cm. (2 in. to 2⅜ in.) of clay or sand, and was covered by a tamping of clay, sand, or even, in some cases, coaldust 10 cm. to 12 cm. (4 in. to 4¾ in.) thick. The explosion burst, and projected in the state of dust, that portion of the tube where the explosion occurred, the upper and lower portions generally remaining intact at the bottom of the boiler. The nature of the metal, and especially its thickness, might be varied; but no observations have been made in this connection, nor was there any interest in making them, except in the case of explosives which ignite firedamp in the open air.

As the tube burst, the hot gases certainly came more immediately into contact with the surrounding explosive atmosphere than in the case of a shot which does its work; and they are so much the hotter as the energy taken up by the bursting of the tube is less. The tubes used by the French Commission required an expenditure of dynamic force equal, on an average, to one-third the total energy of the explosive; and the force of shocks in rock is much greater. But the danger of these artificial cases is far from equalling that of a blown-out shot, all the hot gases of which are impelled forward in one direction, and at a high temperature, the work accomplished being insignificant as compared with the total effort of the charge. It is evident that the conditions are in the highest degree dangerous if the shot be blown out while it is being tamped, and still more so if this occur while the charge is being inserted. Several accidents of this kind have happened. A shock given to the detonator while the cartridges are being placed in the hole, or while the charge is being withdrawn in the case of a mis-fire, may occasion ignition while the explosive is not covered by any tamping; and these are evidently the most unfavourable circumstances.

In the Produits Testing Station, attention was only turned to reproduce, easily and without danger, an unlimited number of blown-out shots; and it was with this view that the testing station was established in a large open space, surrounded by walls, behind the surface buildings of pit No. 25, at Flénu. The shot-hole was reproduced by a Krupp cannon of crucible mild steel, measuring 55 mm. (2⅛ in.) calibre and 58 cm. (23 in.) deep, the metal being 172 mm. (6⅞ in.) thick, which corresponds with an external diameter of 50 cm.(20 in.); the outside length of the breech is 70cm. (20 in.), leaving 20 cm. (8 in.) for the thickness of steel at the breech end.

The mine drift or heading is represented by an old boiler 1·5 m. (5 ft.) in diameter, and 10·9 m (36 ft.) long. One end is open and the other closed, over a length of 30 cm. (12 in.), by a solid mass of masonry in which the cannon is laid parallel with the boiler, but 20 cm. (8 in.) below its centre line. The cannon is pointed slightly upwards, so that the issuing flames may strike the roof of the "heading" (boiler) at the end of the gas chamber, which stops at 4·55 m. (15 ft.) from the face of the back wall, flush with the muzzle. In this way the flames traverse the mixture of gas and air (which may happen to be not thoroughly mingled) in their most inflammable zones. In order to give greater stability to the "heading" the boiler is sunk 60 cm. (2 ft.) below the ground level; and earth is piled up over the mass of masonry, against which the boiler abuts. Besides, to deaden the effects of recoil, the boiler has been strengthened by connecting it, through an angle-iron, with a heavy ring or collar bedded in the masonry. The outer wall bears on the boiler, projecting by 40 cm. (16 in.) beyond the inner back wall. The apparent length of the "heading" is therefore 10·2 m. (33½ ft.) outside, and 10·6 m. (35 ft.) inside, a trench being made in front of the boiler for taking off the gases and smoke of the explosions. At first, this trench was only 2½ m. long; but gradually its length was increased to 12 m. (39 ft.) for favouring the expansion of the gases. In this manner the effects, in the case of an explosion, were confined as much as possible, while the vacillation of the accompanying flames were facilitated.

The total capacity of the "heading" is 18·73 cubic metres (625 cubic feet); and an impermeable screen stretched transversely 4·55 m. (15 ft.) from the end, serves to isolate from the shot a gas chamber of 8 cubic metres (282½ cubic feet) capacity. The working of the apparatus is very simple, the operation being accomplished in less than a minute. At the right distance a double-channel iron hoop is riveted inside the circumference of the "heading," forming a groove of about 2 cm. (⅞ in.) A sheet of paper soaked in paraffin, the edges of which are bent into the groove, is fixed to it by an elastic bandage, the latter being short enough for its tension to ensure tightness of the joint. The seam between the channel iron and the boiler was also rendered tight by caulking with hemp and red lead, or with metallic lead.

For the explosive gas, lightning gas was used, the apparatus being placed in communication with the gas main supplying the surface buildings of the colliery. A meter in the pipe permits of rapidly introducing the desired proportion of gas; and the gas pipe terminates on a line with the cannon and 50 cm. (1 ft. 8 in.) in front of it. To effect a mixture of the gas and air, an agitator is suspended from the roof of the heading, being worked from the outside of a copper wire, the edges of the hole through which the wire passes being rounded off. This stirring is sufficient for the object in view, although it may happen sometimes that the mixture is not quite homogeneous. To exactly fulfil the conditions which occur in practice, it would have been better to have experimented with natural fire damp; but when this cannot be obtained the author sees no reason why *formene* should be employed, as fire-damp is not pure *formene*. Sometimes the hydrogen which it contains makes it more inflammable than *formene*, while, rendered impure by carbonic anhydride and nitrogen, it loses much of its sensitiveness; besides, it is proved that, with lightning gas of medium composition, mixtures are obtained, the explosibility of which is not less than that of most samples of fire-damp. Moreover, it has been proved that air containing 10½ per cent. of this gas is practically as dangerous as the most explosive.

To introduce dust into the phenomena, two methods were employed. Sometimes form 8 to 10 litres were strewed upon a board within reach of the flame from a shot. The board was laid upon two bricks placed on end, one of its ends resting on the cannon 12 centimetres (5 in.) below the centre line of the hole. With this arrangement the flames only licked the dust near the hole, drove them forward and brought them into a state of suspension in the surrounding atmosphere. Whatever was done and whatever might be the composition and degree of fineness, more or less dust was always floating in the air; and the finer portions remained permanently suspended in the "heading." At other times—for instance, if it was desired to constitute an inflammable atmosphere by the aid of dust alone and without gas—a rag was hung to the agitator so as to drag over the dust on the board. It should also be noted that the draughts due to the working of the agitator were sufficient to raise enough dust. Lastly, to cause clouds of dust outside the scope of the agitator a broom was brought into requisition.

Ample measures were taken for observing what passed inside the "heading" and for avoiding any dangerous effects of a gas explosion. In a casemated chamber which contains the gas-meter and the electric firing apparatus, the charges are prepared. Of course there could be no question of any other than the electrical method of firing, which is the only safe one. The Belgian Firedamp Commission, appointed in 1888, gave preference to induced currents, the sparks which they may produce being easily avoidable, and their drawbacks being less than those of batteries. A static induction machine of Bornhardt or Ebner, with Bornhardt detonators, charged with 0·54 gramme of fulminade, were used for firing; and Nobel detonators, containing a gramme of fulminade No. 5, were exploded by a Scola and Ruggieri contact-maker. The Bornhardt or Nobel detonators were sufficiently to ensure complete detonation, even with grisoutite; and it should be remarked that it is not so important that the detonators contain a large charge as that there be a great density of charging, both as regards the intensity of the shock and the degree of safety.

In researches which have hitherto been made as to the properties of explosive mixtures, with or without coal-duust, and of the comparison of various explosives as regards safety, too little attention has been directed to the temperature of the place where the explosion occurs. It is not that there was any doubt as to the influence which this temperature might exert on the explosibility of these mixtures; but no thorough investigations have been made in connection with this subject, so that they still remain to be carried out. Galloway, in a study of the influence exerted by climacteric conditions on firedamp explosions has only considered the question of temperature, so far as variations of the thermometer (in the atmosphere at the surface of the colliery) may be repeated in the underground workings, while causing considerable variations of volume, and outbursts of gas similar to those brought about by barometric fluctuations; but, as regards the influence of the temperature of air-currents in the mine itself, there is scarcely any question. It would appear that the special commissions which have made investigations into mine accidents, and especially as to the danger of explosives, have generally had no other thought than of experimenting under conditions comparable with those of underground workings.

The author remarks that Hall and Clark, in their investigations as to the explosibility of coaldust, arrived at their conclusions only in the case of dry mines at a high temperature. With respect to Sir Frederick Abel's experiments, the author quotes from the report of the English Firedamp Commission as to heating the air, in order to obtain such results as are produced by coaldust in most underground workings where the normal temperature is relatively high. As dry mines are precisely hot mines, and *vice versa*, at any rate generally, he thinks it possible that, in studying the influence of dust on explosions, the effects of dryness of the dust may have been sometimes confounded with those of their temperature.

Herr Wullmer and Herr Lohmann, in their report on the experiments made at the physicial laboratory of the Aix-la-Chapelle University, state that they made no experiments with respect to the relation between the temperature of ignition and the temperature and pressure of the explosive gas. Its easy ignition in contact with large incandescent surfaces leads to the supposition that the temperature of ignition falls, and that of the gas rises, but those authors do not consider that, practically, there is any appreciable connection between these variations. The statistics of the German Commission and its experiments with explosives are not more instructive. Nor has the French Commission on explosive substances determined what might be the influsnce of temperature of the atmosphere, where a mine shot is fired, upon its inflammability. But it was, in the opinion of the author, during the experiments at Schlebusch, at the manufactory of the Dynamite Actiengesellschaft, that this influence was clearly manifested.

It was at the time when experiments were made for arriving at the best composition for grisoutite. Various mixtures had been compared, with charges varying from 80 to 200 grammes, without tamping, or with coaldust tamping, and in mixtures impregnated with coaldust and containing 0 to 16 per cent. of gas. The temperature had not exceeded 30 degs. Cent. (86 degs. Fahr.), and no ignition had taken place; but at the thirteenth experiment, with a temperature of 35 degs. Cent. (95 degs Fahr.) an explosion occurred. After a great deal of discussion, it was determined to attribute the cause to the temperature. Two more experiments were made at 30 degs., under the same conditions; but no explosion ensued. When, however, the temperature was again raised to 35 degs., explosion again occurred. There was no more room for doubt; to avoid a fresh ignition the gases of detonation must be cooled down. In principle it was possible to arrive at this result by charging a portion of volatilisible salt on the top of the explosive; and two experiments in this direction confirmed this supposition. The result might be still better attained by increasing the proportion of hydrated salt, incorporated in the explosive, for the same quantity of explosive substances. Thus,