UNIVERSAL EXPOSITION OF SAINT-LOUIS
1904

KINGDOM OF BELGIUM

DEPARTMENT OF INDUSTRY AND LABOUR
ADMINISTRATION OF MINES

THE
OFFICE OF ACCIDENTS IN MINES AND OF FIREDAMP
AND THE
TESTING STATION
OF THE ADMINISTRATION OF MINES
AT FRAMERIES

BY
VICTOR WATTEYNE
Chief Engineer, Director of the Central Administration
of Mines, at Brussels
Director of the Office of accidents in mines and of firedamp

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L. NARCISSE, ED.
4 et 4a, rue du Presbytère

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The Office of accidents in mines and of firedamp has for special mission the investigation of accidents with a view to prevent their recurrence.

The accidents in mines are, in Belgium, the object of very complete investigations on the part of the Inspectors of mines. First of all, by the care of the Inspector, assisted, when the accident has an exceptional importance, by the Principal Engineer of the district, an inquiry is conducted, in the course of which the spot is visited and all the witnesses of the accident are heard. Statements of the proceedings and reports are drawn up of ascertained facts.

The Chief district Engineer, if he has not already attended the inquiry, studies these documents and works out an abstract, and the whole is submitted to the examination of all the Inspectors of the district who meet every week at a technical committee. During these committee meetings each Engineer presents the observations he judges opportune and points out, eventually, the improvements he has seen applied elsewhere or conceived himself and which seem to him calculated to improve the conditions of the mine. Statements of the proceedings of the meetings are drawn up by the principal engineer.

The Chief Engineer Director of the District, specially examines these documents and states his observations as much with regard to eventual judicial consequences as to the means to be taken to prevent the return of these sad events. The General Inspector in his turn examines the papers, and states his observations in the same order of ideas.

This being done, on the one hand the minutes of the proceedings, with the opinion of the administrative authorities, is transmitted to the Judicial Powers, on the other hand all the papers with the conformable copy of the minutes of the proceedings are transmitted to the Department of Industry and Labour, where the special Office of accidents in mines and of firedamp holds its meetings.

This Office possesses therefore, for each of the accidents, a complete copy of the proceedings and thus possesses a set of documents concerning the dangers to which the workmen are exposed.

But it is not sufficient that these documents should exist, it is essential that they should be brought to the knowledge of the persons whose duty it is to watch over the safety of the workmen, to the Inspectors of mines and to the managers and engineers of the collieries.

This is what the office of accidents in mines and of fire-damp has undertaken to perform, by studying separately the different classes of accidents, by investigating which, in Belgium as well as in other countries the means are devised for avoiding them, and eventually for proposing other devices which the study of the accidents may have suggested.

Some of these studies have already been published and are exhibited in the belgian section; viz. firstly : *The Firedamp explosions in the Belgian coalmines* (1), and *The sudden outbursts of Firedamp* (2) by my predecessor the late Chief Engineer Roberti-Lintermans; more recently *The Shaft accidents* (3) (Watteyne) and *The accidents which have occurred in the chimnees* (4) (Watteyne and Denoël).

In these latter times we have approached a very important class of accidents the study of which is most instructive, it is that of the *Haulage and Inclined planes accidents ;* the study of the most deadly class of all, that of *Falls of stones,* will follow.

The first of the above mentioned papers having brought forward the fact, already recognised however, that the use of explosives is by far the principal cause of firedamp ignition, the late general Director Arnould had committed to me in 1894, the task of collecting the statistics relative to the use of explosives in belgian coal-mines.

The statistics which I have continued for the succeeding years, when I was intrusted with the Direction of the

(1) *Les inflammations de grisou dans les mines de Belgique.*

(2) *Les dégagements instantanés de grisou dans les mines de Belgique.*

(3) *Les accidents survenus dans les puits.*

(4) *Les accidents survenus dans les cheminées d'exploitation.*

Office of accidents in mines and which I have published either alone or in collaboration with M. Denoël, (1), has given us the opportunity of studying more closely the means of reducing as far as possible the use of such dangerous auxiliaries and to dive deeper in the important question of *Safety explosives.*

The latter question involved more than theoretical studies. Experimental studies became necessary, as well as for the lighting of mines, where recent improvements awaited the sanction of experience.

Having obtained, on the one hand, from the Belgian government the necessary fonds and the adjonction of a special assistant the Principal Engineer M. Stassart, and on the other hand the assistance of the *Compagnie des Charbonnages belges*, managed by M. Isaac, who has kindly placed at our disposal the reservoirs of firedamp which his works contain, we set to work, and have equipped last year the Testing station of Frameries of which the aim, the principal arrangements and the hitherto acquired results are sketched out in the pages that follow.

We think we ought to mention first another kind of experiments which the office of firedamp and accidents undertook when first instituted and directed by the Principal engineer late G. Schorn.

The results of these experiments were published in 1887, under the title : *First researches and experiments* (Schorn, Watteyne and Macquet). They were specially relative to the pressure of the gas and its distribution in the seams which contain much firedamp.

Whilst on the other hand our colleague M. Macquet

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(1) So far these statistics have been drawn up for the years 1888, 1893, 1894, 1895, 1897, 1899 and 1901, and continue to be completed every other year. These statistics are also exhibited.

proceded, at the coal-fields of Beaulieusart, with very interesting experiments on the variations of pressure which the sudden issues of gas produce in the neighbouring coal-faces, I was investigating with M. Soupart, at the colliery of *Belle-Vue* (Ouest de Mons), what was the amount of this pressure in the fronts actually in working, and in the seams still untouched. It is in the last case that we found the highest pressures; they reached the enormous figure of 42 1/2 atmospheres (625 pounds per square inch), in the *Mouton* seam, at a depth of 670 meters.

These experiments which were intended to throw some light on the still somewhat obscure question of the sudden outbursts of firedamp, may be taken up again some day when our most urgent investigations on safety lamps and explosives will be completed.

Let us return to our testing station :

It is obvious that in such a short sketch, we can only give a summary account of the important questions wich are the object of our experiments, referring for wider developments, and for details of a more technical description, to the works which I have, either by myself or in collaboration with MM. Stassart and Denoël, previously published on this subject (1).

A few photographs of the installation are shown in the Belgian section.

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(1) We draw attention, especially to the various notices we have published since 1895, in the *Annales des Mines de Belgique*, on the question of explosives, and also the work we have presented to the Congress of Mines and Metallurgy, Paris, 1900, and which has been published in the *Bulletin de l'Industrie minérale*.

The Testing Station at Frameries.

I. — Object and reason of the installation.

Although the testing station has been established to allow the study of whatever concerns the explosions in the mines and the various questions relative to firedamp and coal-dust, problems which will be taken up in succession, the object of our *present* work may be summarised by the following words : Study of the means to be used to combat the *causes of ignition* of firedamp and coal-dust in the coal-mines.

These causes, setting aside a few exceptional ones, are twofold, viz — quoting in order of importance — the use of *explosives* and the use of *lighting apparatus*.

Explosives.

The use of explosives is, and especially was, the principal cause of danger of explosion in the mines. It is this cause which previously to 1890, that is, before the generalisation of safety explosives and before the use of explosives of every description had been reduced by various means to a minimum, brought about the catastrophes the most numerous by far, and the most deadly. Within the decennial period 1880-1889, the number of victims of ignitions caused by the use of explosives reached 90 °/₀ of the total number of victims to the explosions in mines.

It may be asked what is the reason of such a preponderance, considering that the number of *lights* introduced in to the mines by the lighting apparatus is far greater than the number of shots.

It would be too long to examine here in detail the causes of the greatest danger of explosives; however we will mention the principal ones in a few words : On one hand, the safety lamps, though still imperfect, as we shall see, have acquired long since a fairly great degree of safety; on the other hand, the flame of a lamp, even when uncovered, cannot ignite a firedamp mixture unless its proportion of firedamp be high enough, say 6 1/2 to 7 °/₀, proportion which the aspect of the flame betrays in a very apparent manner a long time before; nor can it ignite a mixture of dust; the case is quite différent with the violent flames caused by the explosion of the charges; for the latter are not only liable, by the shock they produce in the atmosphere of the workings to call forth to the dangerous point an unexpected rush of firedamp, but they can ignite the clouds of dust which this very commotion has raised and in this way can bring about terrible catastrophes, whilst, in consequence of the apparent absence of firedamp, one may think oneself nearly in safety.

Let us remark that the endeavours made after 1887, in consequence of disastrous explosions, to attenuate the dangers of explosives, have brought about a very sensible reduction of the number of victims of the blasting. Thus within the following decennial period, from 1890 to 1899, in spite of the awful accident of Anderlues which, in 1892, made 160 victims, the total number of men killed by the mining explosions in Belgium has been reduced to 258, from the previous figure of 455, the proportion of victims of ignition caused by the use of explosives having fallen to 23 °/₀.

Such a result was too encouraging not to persist in the same path; and the object of our experiments is precisely to find out, if not explosives of absolute safety, — such do not exist and do not seem possible — at all event explosives of which the relative safety is great enough to attenuate in a large measure the causes of danger which could not be entirely removed, except by suppressing the use of this auxiliary.

About fifteen years ago the question of the safety explosives arose. For some time already there had been an attempt to discover the means of lessening the danger of the flames caused by blasting. It had been tried to surround the explosive with water, which, pulverised by the explosion, extinguished the flames at the moment of their production; hence the Abel and Settle cartridges, the wet moss, gelatinised watertamping, etc. These means had an ephemeral vogues, the practical difficulties and lack of safety in their use have caused them to be forsaken.

The use of water has led to the idea of incorporating in the explosive itself solid matter containing much hydratation water and which, being decomposed by the heat evolved by the explosion, would act, as it was believed, like the free water in the above-mentioned processes. Such are the safety explosives known under the names of *Wetterdynamites* and *Grisoutites* (Ardeer powder) and other names, adopted by the manufacturers.

But nearly at the same period, the researches were directed towards the manufacture of explosives of such composition, that their *temperature of detonation*, calculated according to the data of thermo-chemistry would be low enough not to cause the ignition of firedamp or coal dust.

The very remarkable works of the french Commission of firedamp, published in 1888, have been pursued in this direction.

It may even be said they inaugurated is.

We cannot however refrain from pointing out that an engineer, as distinguished as modest, of our belgian Body of Inspectors of mines, had anticipated it several years before. In 1881, M. E. De Jaer, at the time Chief of the 1st mining district, and who became afterwards, for a very short time, general Director, in a report addressed to the Minister of public Works, advised the opening of a competition and the granting of a prize to the inventor of a powder or substance exploding without flame, which he considered bij no means unattainable on account of the thermic phenomena which accompany the chemical reactions.

Whatsoever this may be, there is no doubt that the works of the french Commission of firedamp constituted for a long while the most complete doctrine on safety explosives. The notion of *deferred* or *delayed ignition* of firedamp, brought to light by MM. Mallard and Le Châtelier was very fruitful in consequences and allowed the Commission to determine a precise formule to which the explosives had to answer in order te deserve the qualification of safety explosives.

Nevertheless it was soon recognised that this formule failed to account entirely for the behaviour of explosives in the presence of mixtures liable to ignition. Numerous experiments have shown, amongst some other evidence, that the same explosives, having in consequence the same temperature of detonation, which did not ignite the fire-damp with light charges, ignited it, every one of them, when thwis charge as increased.

Even the importance of the influence attributed to the *detonating temperature* has been contested by certain experimenters who have attributed the preponderating influence to other agencies.

In a paper which I, together with M. Denoël, laid before the Paris Congress, in 1900, we have analysed and discussed the current theories, patronizing the one which seemed to us, in the state of knowledge acquired at the time, to account in the most complete manner possible for the behaviour of safety explosives.

Our theory assigned a great importance to the notion of *deferred ignition*, and we drew the inference that experiments were necessary to determine the *limit-charge* for each explosive, that is, the highest charge which could be detonated in the presence of an explosive mixture without igniting it, this limit-charge being the measure of the degree of safety of the explosive.

We will quote here a few lines from the conclusions of our paper :

« The safety of the explosives in presence of firedamp and coaldusts liable to be ignited, is proportional to the difference between the duration of *deferred ignition* and that of the complete cooling of the products of the explosion.

» The first limit depends at the same time on the exterior circumstances and the nature of the explosive, the second depends on the nature and the weight of the detonating explosive.

» For any given explosive, safety is never more than relative and can only be conceived below a certain limit of charge.

» The principal conditions on which depends the relative value of different explosives from the point of view of safety are : the temperature of detonation, the initial pressure and the velocity of the explosion. These elements are characteristic for a given explosive, supposing its chemical composition be homogeneous and its physical state determined. From their more or less happy combination depends the difference between the duration of *deferred ignition* and that of the expansion of a given weight of the explosive. Their influence on the figure representing this difference is still imperfectly defined, which causes from the extreme complexity of the intervening phenomena.

. . . .

« From a practical point of view, it results from the insufficiency of our actual knowlegde, that we cannot squeeze into a formula at the same time simple and exact the manifold, conditions on which depends the safety of the explosives in presence of firedamp and coal dust.

» But we possess the means of *determining experimentally* the *limit charge* of safety which is the expression of the difference between the duration of deferred ignition and that of the expansion of gas evolved by the unit of weight of the explosive. It summarizes at the same time the influence of the physical and chemical nature of the explosive and that of the weight of the charge; therefore it imparts the truest idea of the degree of relative safety of the different explosives.

» The limit charge ought te be determined in identical conditions for all explosives, and approaching as near as possible to the most dangerous conditions which are likely to be met with in practice in the coal-pit workings.

» It follows, that a safety explosive ought to be characterized by a sufficiently high limit charge; strictly speaking it should be equal to the maximum of the charges used in practical mining with such explosives. Thus safety would be secured independently of all the precautions with which the use of explosives ought always to be surrounded, but which may happen to be omitted through the negligence of those who fire off the charges. »

The working out of this *determination* is the clearly indicated aim of our present experiments on explosives.

Lamps.

The necessity of establishing a station of experiments was also felt in another order of ideas.

The lighting apparatus authorized for the mines containing firedamp were explicitely indicated by the Regulations of 1884.

Since the drawing up of these regulations new types of lamps have been divised which seemed to offer superior qualities and of which several are used already in other mining countries.

It was of consequence that our country should not be left behind others in a question which concern the safety of the workmen.

But, as the admission of other lighting apparatus than those prescribed was incompatible with our present regulations, a revisal was necessary.

This revisal however could not take place before thorough experiments should show the superiority of the new types and the inoffensive character of certain proposed innovations.

Let us explain these statements with precision :

The only lamp authorized by the regulations which rule us still is, with a few exceptions, the Mueseler lamp fed with vegetable oil.

This lamp was, at the time the regulations were drawn up, the safest of all in existence, and as a matter of fact, its safety in rapid draughts or currents charged with gases liable to ignite, at their highest degree of liability to ignition, is very great indeed, *provide these draughts are horizontal.* But it is quite different whenever the draughts are oblique or vertical. It is now recognised and our experiments allow an easy illustration of the fact, that in such currents the flame of the Mueseleer-lamp passes almost directly into the upper sieve, and from that moment, if the draught is somewhat rapid, the passage of the flame outside — which means the explosion of the surrounding atmosphere, if it contains firedamp — is a matter of but a few seconds.

Now, air currents of this description are frequent in mines. A rapid ascensionnal draught in also produced whenever a workman drops his lamp; and it this takes place in an atmosphere liable to ignition, an accident is likely to occur.

It seems moreover that several of the painful catastrophes which have occured in these latter times, can be attributed to causes of this description.

Such are the catastrophes of the *Escouffiaux*, in 1887 (35 victims), that of Anderlues in 1892 (160 victims) and more recently that of Crachet-Picquery in 1898 (16 victims).

This shows that the question of the lighting of mines was well worth examining.

Other modifications besides those relative to the form of the lamps are also proposed.

We will mention the use of another oil than the « pure vegetable oil » imposed by the regulations. Lamps fed with a volatile essence, especially *benzine* have been long since allowed in foreign countries. Now, these lamps give a far better light, which is in the highest measure favourable to the safety in the mines, where many accidents might be avoided by better lighting. It was essential to investigate whether the use of volatile essence does not imply special dangers and that is what we have done.

There is also the internal relighting without opening the lamp, which the regulations of 1884 did not foresee and could not foresee since the practical apparatus permitting this relighting did not exist or only existed recently at this period.

This manner of relighting has the immense advantage of freeing the workman 's mind from all temptation of opening his lamp when it is out and lighting it up anew by means of an unprotected flame. It allows also, in case of accident, the workman who remains unharmed but generally deprived of light by the fact of the accident itself, to accomplish his escape in better conditions and to reach a place of safety, guided by the light he has thus been able rekindle.

But does this relighting itself not constitute a special danger? This is the very thing our apparatus permitted us to experiment.

The necessity of a double installation for experiments as well for explosives as for the lighting apparatus being recognised, a difficulty arose which prevented this installation from being made no matter where. It was indeed of consequence, and I always stuck to this opinion, that these experiments should be performed not with lighting gas, as had been often done previously, nor with any other artificial gas, as it has also been practised, but with genuine firedamp, real mine-gas, the very gas which produces the dangers we are striving to fight.

For the experiments on explosives the question is specially important, for, if many other gazes are explosive, they do not possess in the same degree as firedamp, the property which plays such an important part in the theory of safety explosives, the *deferred ignition*.

The difficulty was to procure this gaz in good conditions of purety and in sufficient quantity for the experiments, sometimes necessarily protracted, to be effected.

The kind intervention of the *Compàgnie de Charbonnages belges*, which possesses the unenvied privilege of owning the mines containing more firedamp than any in the whole world, has removed this difficulty. This Company has allowed very willingly in the interest of the miners, that the experiments which the Belgian State had decided to undertake, should be carried out on its own premises, and it placed at our free disposal land and subterraneous reservoirs of great importance full of the dangerous gas, the supply of which is almost inexhaustible (1). From these reservoirs we draw the firedamp after having confined it with appropriated works.

II. — **Mode of experimenting.**

Explosives.

From what I have said above, it follows that we have to determine the limit-charge of explosives in the most dangerous conditions which can be met with in mining practice.

With this object in view we fire increasing charges of the explosive in a firedamp atmosphere brought to its explosive maximum, introducing them into an open mining chamber or borehole the walls of which are sufficiently resisting to act always like a gun, that is to say to blow out or discharge the flames into the atmosphere without bursting its walls.

The atmosphere in which we operate is charged with 7 1/2 to 8 °/₀ of pure firedamp. We add no dust, the presence of dust in an atmosphere so charged with firedamp would not increase the sensibility to explosion especially in presence of short-flamed and rapid explosives, the only ones which are here interesting.

This atmosphere is produced in a tube or gallery having the same sectional dimensions as a real mine drift, this to get as near possible the conditions of practice, for the section of the gallery may possibly exercise its influence on the behaviour of the explosives detonating therein.

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(1) Let us mention that the intelligent assistance of the Direction and staff of this Society has been and still is a great help to us, in realising the installation and performing the experiments. V. W.

The borehole is drilled out of a block of steel solid enough to stand all charges : we know that the shots, which explode without breaking their walls or which « blow out », or *font canon*, according to the expression used in our country, are incomparably the most dangerous.

The emission of flames reaching its maximum when the shots are slightly tamped or stemmed, we use no tamping at all. Let us say at once that this last condition constitute an exageration. Indeed it is not customary to fire the charges unless previously covered with stemming of a certain length and more or less rammed down. And it is proved that the presence of the tamping exercises on the safety an important and favourable influence. It follows that it will be useful in the future, after the first series of our experiments will be finished, to determine with precision the influence of tamping, so as to render the results of our experiments more directly applicable.

Other conditions of our experiments are also somewhat different from those in practice and these differences exercise their influence in different ways with regard to the safety. Such is the nature of the wall of the blasthole. The metallic wall of our steel cannon certainly conducts the heat better than the stone wall of a real borehole, hence a more rapid abatement of the heat evolved. There is also the diameter of the hole which in practice is determined by the diameter of the cartridges used, whilst the necessary invariable diameter of our chamber is nearly always superior to that of the cartridges.

We hope to be able in the future to remove these differences and others as well and to realise nearly completely the very conditions obtained in the mine workings, but our experiments must first be pursued as we are doing at present so as to obtain comparative result for the different explosives on which we have to experiment.

These observations however already show that the series of our experiments is not yet exhausted and that our mission is far from being finished.

Other experiments may also have to be made so as to penetrate deeper into the theory of safety explosives and to determine separately the different factors acting on the safety of the explosives, factors of which the limit charge gives the total result, such as the initial velocity, the pressure, the total heat evolved, the length and duration of the flames, etc. In our last work on explosives (*Annales des Mines de Belgique*, t. VII, 4e livre), we pointed out the ingenious apparatus due to M. Bichel, Director of the *Sprengstoff A. G. Carbonit* of Hamburg, and which allow several of these determinations; their use will give rise to interesting studies.

But there is one element the determination of which imposes itself immediathy and must necessarily accompany that of the limit charge; it is the strength or the force of the explosive. It does not suffice indeed that the explosive be a safety one, it must besides be powerful enough to explode the rocks. This strength is really an element of safety : Indeed if the degree of safety of an explosive cannot be obtained without reducing the power proportionately, one would be obliged, for obtaining the desired effect, to employ higher charges and one would be travelling in a circle; it goes without saying that an explosive which has for instance a limit charge of 400 gramms but which has a weak strength would have no superiority over one with a limit charge of only 200 grammes but of which the force would be double.

The strength of the explosive is measured by the widening of the interior capacity of a lead block (Trauzl method) under the action of a low charge.

Whatever may be reproached tot his well known method, it is of all those used in similar experiments the one which seems to us the most recommandable as being the one by which the explosive gives in the best way the measure of it real work, and, if practised with care, good tamping and charges calculated so as to obtain the same widening, we think it supplies useful indications.

Having determined for each explosive under consideration the limit charge and power, we shall be enabled to establish a classification and indicate those which should be used in preference to others in the mines containing firedamp.

There is an observation which I have made already several times concerning safety explosives, which I think it as well to repeat here in order to avoid all misunderstanding.

However high an explosive may be classed in the scale of safety explosives, one ought however to consider it in practice as a dangerous auxiliary and not make use of it unless it is well ascertained that the atmosphere surrounding the place where a shot is to be fired presents no danger of explosion. The safety of explosives is moreover always uncertain even when even the limit charge is higher than the one used, for even a careful manufacture is neven exempt from all negligence, and slight differences of composition, homogeneity, consistance, granulation, etc., can always take place and exercise a certain influence on the degree of safety of the explosive. I have said so many times and say it again : Incomparably more has been done for the safety of mines when the blasting of rocks has been performed without the help of explosives than when the best safety explosive has been used.

Lamps.

Let us remind that in a still atmosphere the simplest lamp, the Davy Lamp, gives full security if its wire gauze is in good condition.

But it is quite different in a draught, and the stronger the draught, the greater the risk which the lamp runs of igniting the surrounding atmosphere. For certain lamps these currents are specially dangerous whenever they have vertical or inclined directions, either ascending or descending.

To experiment the degree of safety of the lamps we place them in a gallery through which passes a current of air mixed with firedamp at the highest degree of explosiveness, and of which we vary the velocity until we exceed the utmost velocity which can occur in the mines. We subject them also to vertical or inclined draughts. The experiment is carried on long enough to make certain that no explosion will take place; the persistance of a certain fixed degree of redness of the wire gauze is a token that no explosion will take place.

The influence of the nature of the oil, is determined by subjecting comparatively to the same tests lamps of the same description fed with different oils.

In order to test the danger of relighting underground, we have endeavoured to place ourselves in the extreme conditions of danger, which may be met with in practice : such as the case of a lamp put out in the firedamp after having been in such conditions that the gauze would have become very red, and that the miner, inconscious of the danger should relight in full firedamp and without waiting for the gauze to lose its heat. We easely reproduce these conditions in our testing gallery : the lamp is raised to a degree near to explosion; we put out the firedamp flame by suppressing suddenly the flow of the gas, and then immediatly afterwards restoring the normal current, we cause the lamp to be relighted while the wire gauze is still red hot.

To remove the objection that the atmosphere of deep mines is a great deal denser than that of our apparatus, which is slightly expanded by the aspirator while the former, on account of the depth, bears an overpressure amounting to about 2 meters of water for each 1500 meters depth, we also test the relighting in a little apparatus invented by my assistant, the principal Engineer M. Stassart, in which the firedamp atmosphere is introduced at the required degree of over pressure.

We may state at present that with certain systems of re-lighters our severest trials have not detected the slightest passage of the flame through the wire gauze on account of the lighting up again.

We wish also to mention at once that our comparative tests on lamps fed by different oils, have not shown that mineral oils would entail any danger sensibly greater than the purest vegetable oils.

III. — Arrangement of the Apparatus.

A complete description of our installation has been published with explanatory views and maps in our work issued towards the end op 1902 in the *Annales des Mines de Belgique* on the « Use of explosives in the Belgian coal-mines in 1901 ».

We shall only retrace here the principal features.

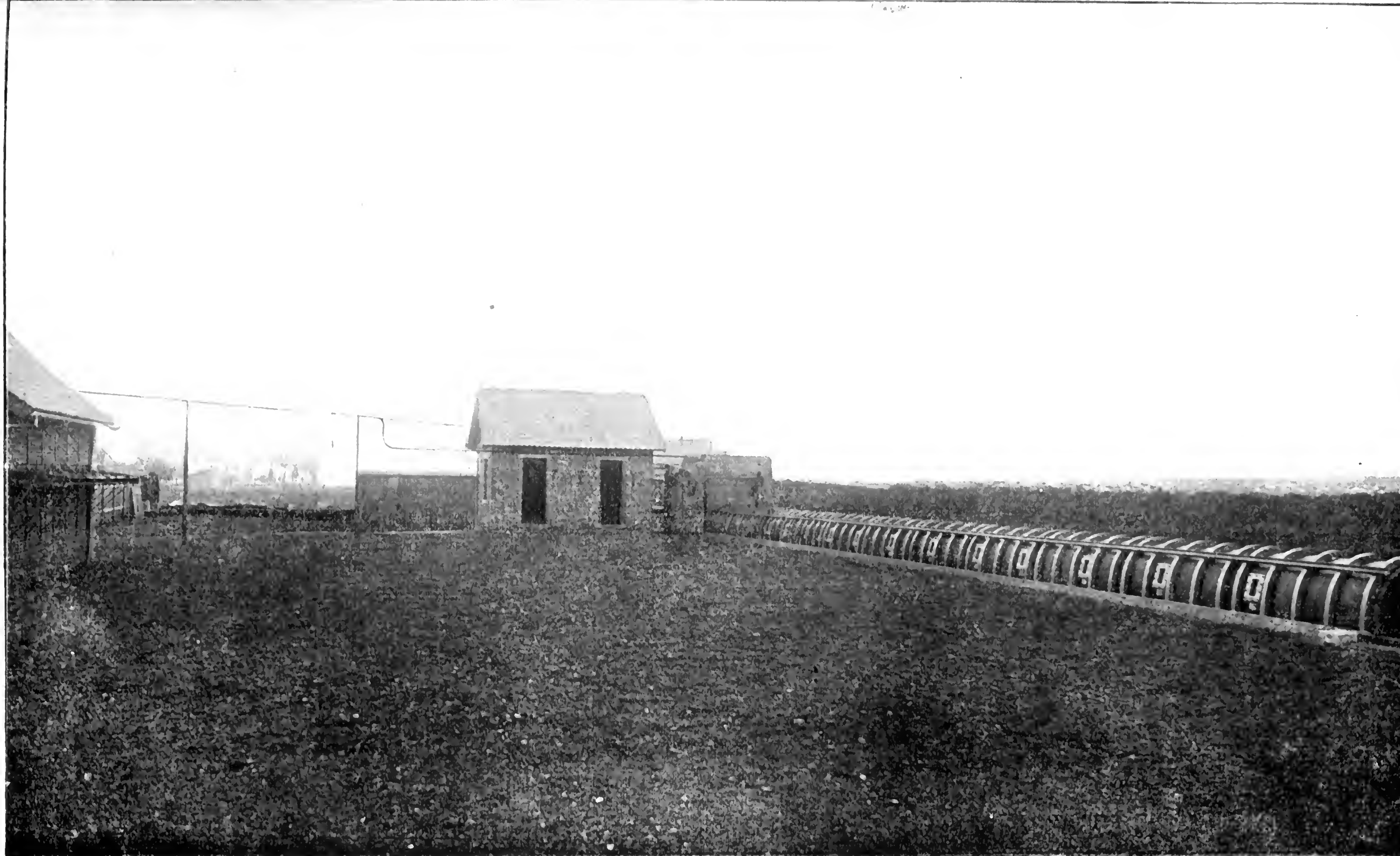

Fig. 1. -- Testing gallery for explosives.

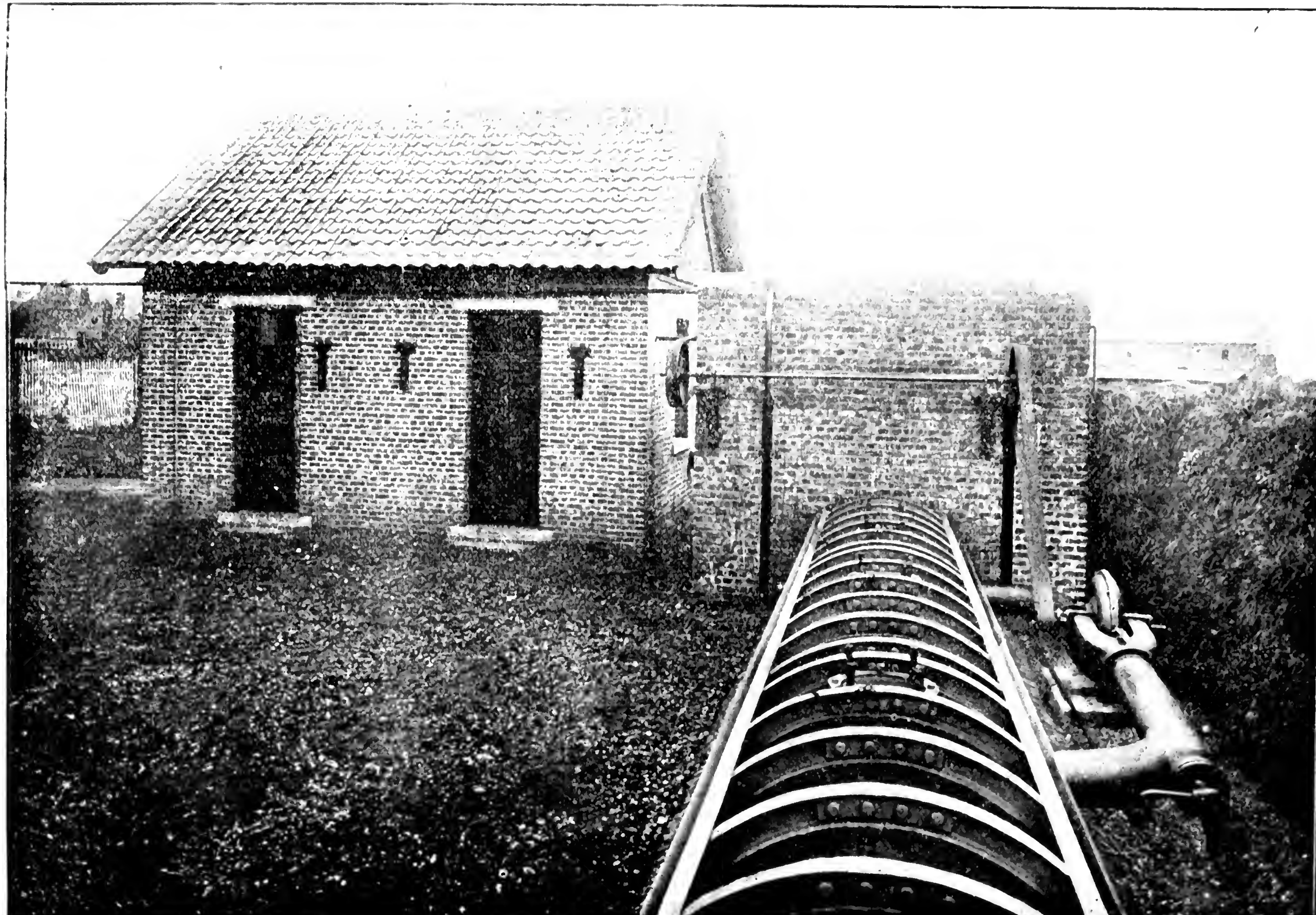

Fig. 2. — Testing gallery and mixing-fan.

EXPLOSIVES.

The iron hooped wooden gallery is 30 meters long and has an elliptical section 1^m85 high by 1^m40 wide.

It is open at one end, while the other end is supported by a solid mass of masonry in which is fitted the steel block perforated with a hole representing the borehole. The first five meters of the gallery next to the masonry can be closed off from the remainder and form a hermetically sealed space which is the explosion chamber. The latter has about 10 cubic meters of capacity. In this chamber we introduce the necessary proportion of firedamp, which we measure with a gas-meter.

This firedamp has to be thorough mixed up with the air which the chamber contained. To produce this mixture, we first introduce the firedamp at the bottom of the gallery through a long horizontal tube which is perforated underneath with small and numerous holes of increasing diameter as they recede from te starting point; then also, and we lay special stress on this point, we connect the explosion chamber at both ends with a small exterior tube fitted with a fan which is made to rotate rapidly as long as the introduction of the firedamp lasts (see fig. 2); in this way the whole atmosphere of the chamber passes several times through the fan producing an energetic churning of the gas.

We had the opportunity of ascertaining by analysing the air of the gallery collected at various points, that the homogeneousness is practically absolute.

These analyses, which we renew each time we start a new series of experiments, allow us also to check the amount of pure firedamp existing in the gallery, which amount would be liable to vary if the composition of our natural firedamp should undergo any modifications, which more-over happens very seldom. The cutting off of the 10 cubic meters capacity is produced in a simple manner by a paper diaphragm the circonference of which is nipped in an iron frame of similar shape and dimensions to the interior perimeter of the gallery.

Paper discs are also used to close the safety holes made at equal distances in top of the gallery. These discs supersede with advantage the heavy plugs formerly in use and which, although fastened with strong chains, were often blown far away by the explosion, to the great danger of the neighbourhood.

The firing of the shots is practised from the observation place by means of electric connexions. Small glas-windows fitted from distance to distance easily allow to observe the luminous phenomena which are produced inside the gallery.

After each experiment the expulsion of the fumes and gases is activated by an aspirating fan which is fitted up in a special building and connected at will with the bottom of the explosion chamber by a large pipe which passes through the block of masonry. This expulsion requires from four to six minutes.

The leaden blocks which we use at present for measuring the strength of the explosives are 0^m20 high and have a diameter of 0^m20. The hole is 0^m120 long and its diameter is 0^m025.

The uniform widening which we have mentioned before, and which we endeavour to obtain by various charges of the explosives under examination, is that produced by 10 grammes of Guhr-dynamite at 75 % of nitro-glycerine.

The explosion is caused by a detonator n° 8 (2 gramm.); 15 cubic centimeters of sand are poured on the charge and the tamping is done with clay. Finally a tight wedging up with a strap and wedges completes the preparation.

As we have said already, the gallery is intended in future to be used for other experiments than the tests of safety explosives. Hence its great length, which can be brought to 100 meters and even be lengthened by ramifications; and so we shall have before us an artificial mine were we shall be able to study the various phenomena which take place during the explosions, and specially the action of the coal-dust.

The Lamps.

The apparatus for testing the lamps consists also of a tube or gallery, but this has only a section sufficient for the lamps to be placed conveniently ($0^m31 \times 0^m14$); the lamp being only influenced by the gaseous streams which pass over it, a greater section would be useless and would offer the great inconvenience of requiring an enormous consumption of firedamp.

Draughts of a stated velocity and containing a fixed amount of firedamp are produced in this gallery. All this is performed by producing depressions at one end while the air and firedamp penetrate at the other end of the gallery.

The depression is caused by a steam Koerting in which one of the ends of the experimental channel penetrates. The other end is not entirely free, being closed by a partition perforated with holes which are apertures with thin-walls the size of which can be made greater or lesser according to the volume of air required for each aspiration of the Koerting.

The firedamp is introduced in the gallery at little distance from the aperture which gives passage to the air, but before reaching this point, it is also made to pass through a thin-walled aperture of which the size can be regulated at will according to the quantity of which the introduction is required in a stated time.

The respective passages of air and firedamp through these apertures correspond to two different depressions caused by the same aspirator : these are the depressions which are made to vary by acting on the koerting 's valve or on the entrance valve of the gas.

These depressions are measured by Schondorf gauges regulated previously to the required depressure, and œhich are brought again to the normal level.

To each pair of depressions correspond a velocity of draught and a proportion of firedamp. A twofold table recording the results of a long series of previous experiments of gauging is before the operator and indicates the depressions to be produced in order to obtain a given draught (from $0^{m}50$ to 20 meters a second) with a given proportion of firedamp (from 4 °/₀ to 14 °/₀ of CH^4).

It is evident that the gauging is only correct for gas containing a fixed proportion of pure firedamp or formene; a new gauging is required every time the composition of natural firedamp is modified.

To obtain an intimate mixture of firedamp with air we introduce the firedamp into the gallery through a mixing box consisting in 36 tubes each of them perforated on the circumference with twelve narrow apertures disposed in spirals. The air passes inside these tubes and the firedamp penetrates through the small apertures. The gas comes in contact with the moving air through 36 × 12 = 432 thin streams, and thanks to the eddies produced on leaving the box, the mixture is very thorough without requiring any further mixing.

The gallery contains vertical and inclined portions. Special valves fitted inside allow the production, at will, of horizontal, inclined and vertical currents.

The apparatus for the test of re-lighters in an atmosphere under pressure consits of a sheet iron box in, to which the air is forced by a water sucker actioned by the water-main of the colliery under pressure. The firedamp is gauged by passing through a gas-meter. A little fan performs the mixing up. The pressure is shown by a water gauge.

The following extract of a lecture we delivered in August last, jointly with M. Stassart at the *Association des Ingénieurs sortis de l'école de Liége*, and of which a summary was published in the *Revue universelle des Mines*, tome IV, 4e série, specifies the object and the arrangement of this apparatus which was not yet constructed when we published in the *Annales des Mines de Belgique*, the description of the station of experiments.

« It is a known fact, writes M. Stassart, that atmospheric pressure of the underground works is greater than that of the surface and that this is increase augments with the depth.

» I have measured the increase in different deep coal-pits:

at 1,150 meters at n° 18 of the *Produits*;
at 1,000 meters at n° 10 of the *Agrappe;*
at 940 meters at St-Andrew 's pit of the *Poirier*.

» Besides the weight of the air, different causes intervene to fix this value, such as : temperature, hygometric degree, decrease of pressure corresponding to resistance. Nevertheless for the belgian collieries we may adopt an average value of 118 millimeters of water for each 100 meters. It follows that at 1,500 meters the extra-pressure would be $1^{m}800$.

» In these conditions it was thought necessary to question whether a lamp, found secure as far as relighting is concerned, by the tests hitherto executed, would still offer the same security at the bottons of the pit. For in the latter case the weight of the exploding firedamp is greater with regard to the same surface of cooling wire gauze.

» To elucidate this point, I have used the small apparatus (fig. 3) intended to test the relighting under pressure. It is composed of a water and air-tight iron box of 0^{m}40 × 0^{m}40 × 0^{m}40, with two windows *A* and four safety valves *B'* loaded with springs. The rod which acts on the relighter passes through a stuffing box *C*.

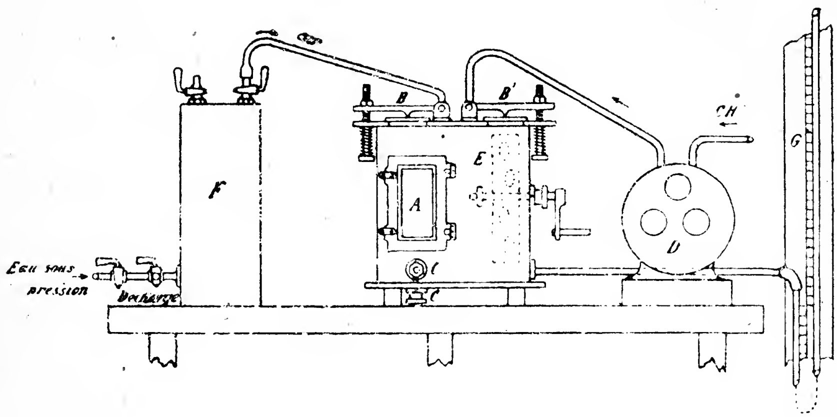

FIG. 3.

» The iron box is connected with the gasometer; a gas-meter *D*, cutting the main, allows the gauging of the firedamp introduced; a paddlewheel *E* performs the mixing.

» The box can be connected on the other hand with a reservoir *F* containing air. This air is forced in such quantity as required, into the box, by the action of water under pressure taken from a feeding-pipe of the colliery. Thus pressure can be procured at will. A water gauge *G* two meters high, is used to measure the pressure.

» Finally, Bunsen burners, supplied with firedamp raise the temperature of the enclosure to 40°. »

Fig. 4. — Gasometer, purifier, condenser and adducing pipes.

Apparatus for adducing the firedamp and other installations (fig. 4).

The firedamp proceeds from extensive works performed from 1878 to 1892, in the pit n° 3 at the depths of 600 and 700 meters. A dam cuts off these works and the gas which issues is collected and brought to the surface by pipes of 51 millimeters diameter and 1,000 meters long. The quantity evolved daily is about 400 cubic meters. The proportion of CH^4 contained in this gas is about 80 %, that of CO^2 is 2 1/2 %.

The firedamp is lead to a gasometer of 150 cubic meters capacity.

In case the gas should lack a sufficient pressure, we have established a steam aspirator followed by a condenser.

There is also a lime purifier to absorb the excess of carbonic acid.

Close to the gas receiver is a small tubular gallery intended for the gauging of the anemometers used for measuring the currents of air in the mines; for, to give exact indications, these instruments must be gauged very minutely, and to be gauged anew after each repair or modification caused by long or frequent use.

This additional installation suggested by the General Director of the Mines, M. J. De Jaer, will render great services.

Below we gives the description of our anemometer gauging station extracted from the above mentioned lecture.

« The « manege » is the apparatus generally used to gauge the anemometers.

» It offers, nevertheless, causes of error resulting from the motion imparted to the surrounding air by the action of the apparatus itself (Mitwind) and from the curvilineal trajectory of the anemometer.

» M. Althans has for the first time used the method of the gasometer at the gas-works of Breslau. These experiences have not been repeated as far as we know, on account of the expense necessitated by the use of a gasometer.

» In the present case, a gasometer was necessary for the laboratory; we did hot hesitade to adopt it for gauging the anemometers.

» The anemometer to be gauged is placed in a main of 0^m25 diameter connected with the gas-meter.

» It is sufficient to work a sluice, in order to obtain such delivery and in consequence such velocity as is required.

» The meter is unlatched by a rod worked from the outside, a window allows one to observe the indications of the dial.

» The volume delivered by the gasometer in a stated time is proportional to the fall of the receiver. This is measured by an index connected with the receiver and moving along a graduated rule.

» To take into account the obliquity of the receiver under the action of the wind this measuring implement is duplicated. The density of the air is greater in the gasometer than in the section containing the anemometer; manometric measures supply the corrective elements.

» The gauging by the gasometer takes a long time : it will only be used to obtain standard anemometers. These will be used for gauging the anemometers of manufacturers and of the Administration of Mines. »

A photometric equipment to measure the lighting power of the lamps, and apparatus for analysing the firedamp, complete the station of experiments.

For the installation of all these apparatus and for the choice of experimenting methods, we have taken advantage of what had been previously performed abroad, especially in Germany, where they have been conducting similar experiments under very good conditions for some time already. We have innovated but little, satisfied, as being the last in the field, to introduce here and there a few improvements which the experience of others has suggested to us.

IV. — Acquired results.

The experimental method for the solution of the problems related to safety explosives especially, is, as we have stated, the only possible method.

But to be entitled to consider the results as established facts and to draw sure conclusions, it must be pursued for a long time, and the trials must be repeated often in order to meet the numerous conditions of practise and discard the perturbing causes resulting from the unavoidable imperfections of the processes even when most minutely applied.

If, besides these considerations, we remember those already ventilated before, we come to the conclusions that final results are still far from being acquired, and furthermore will never be so in the absolute sense of the word *definite*, for the question of firedamp and explosive is not among those which can be resolved entirely; by successive stages alone can we reach a better situation, without ever expecting a « final solution. »

Our station of experiments faces a wide program of problems of which we propose to the study and of which we have first handled the most urgent.

The task will also be one of verification and control :

such as the control of the explosives put on the market and of which the composition and degree of safety must be checked periodically. Our station may therefore be considered in a certain sense as a permanent institution.

We shall state however that already now important results for mining pratice and for the miners safety have been acquired.

Concerning explosives, we have firstly imposed on ourselves the task of subjecting to the control of experience the explosives entered as safety explosives in a temporary list, which we have drawn up, with the cooperation of M. Denoël, partly from theoretical considerations, partly from experiments made abroad and which has been published in the *Annales des mines de Belgique*.

The reservations we made while publishing this list when we did not dispose of the means of experimenting which we preconised, and which alone, — as we wrote then — could allow us to emit an opinion based on a knowlegde of the case, have been justified. Certain explosives, to which the admitted theories attributed a high degree of safety, have proved unworthy to appear on this list. Others, composed according to other principles, have shown a much better result.

It has happened then, that manufacturers of explosives informed of the failure of some of their products have forsaken the manufacture of the latter, and, guided by our experience have followed new tracks which appear fruitful; and henceforth new explosives far safer than the old ones are introduced into the mining industry, while the most deficient have desappeared already.

Although therefore nothing definite, suitable for publication has been acquired concerning the important question of explosives, not only solutions are anticipated but real results of benefit to the miners safety have already been acquired in consequence of our experiments.

As for the safety lamps where the question is less complex, conclusive tests have allowed us already to work out and draw up a complete preliminary scheme of new regulations for the lighting of firedamp mines, which regulations will also be in harmony with the most recent progress of this branch of the art of mining.

Moreover the numerous public experiments we have performed before many technical Associations, before the managers of collieries and before numerous miners, foreman and labourers, have vulgarised certain ideas of safety, familiar only to specialists and have also dissipated many prejudices, thus removing serious hindrances to progress.