

are readily observable, as the places where the face is farthest advanced. This mine is a double one, that is, it has two hoisting shafts. The roads are planned to serve either shaft, so when the output exceeds the capacity of one shaft the other can also be used. The average capacity of both shafts together should be not far from 3,000 tons of coal, gross weight. The pit-cars at this mine hold about one ton, gross weight. This is a somewhat larger capacity by 400 or 500 tons than the pit-cars have in the eastern part of the field. The engines hoist a car through the 500 feet to the top landing in ten seconds. Four cars per minute can be hoisted by the engine at either shaft. The ventilating is done by 24-foot forcing fan with straight paddles and spiral-expanding casing.

Fig. 3 shows a profile sketch of the head of a roadway in the mine, illustrating the method of propping and undercutting the coal face, and the settlement of the roof further back.

The settling of the roof is appreciable at the surface even when the seam is at a depth of 400 or 500 feet; but so gradual is it, and without vibration, that the deep mines have caused no trouble in going under railroad tracks, and even under brick buildings, as has been done at La Salle.

Mining Explosives.

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(Paper before Fed. Institute of Mining Engineers.)

Last winter the writer had the honor of delivering a course of Cantor lectures before the Society of Arts on the subject of "Explosives and their modern Development," and in the last lecture of that course dealt with mining explosives, and showed, to his own satisfaction at any rate, that all explosives which give rise to carbon monoxide as a product of their combustion, ought to be strictly tabooed for use in mines, not only because of the risk of injury to health and life from the poisonous nature of the gas, but also because even small traces of carbon monoxide render mixtures of coal dust and air highly explosive, a point which has, he thinks, been entirely overlooked in all experiments upon this most important subject. In reviewing the properties of the various mining explosives now in use, it will be convenient to classify them according to the way in which they produce the gas which gives the explosive effect. Class I.: Explosion due to simple combustion, as in the case of blasting gunpowder. Class II.: Explosion due to detonation of the whole of the explosive, as in nitro-glycerine, nitro-cotton, and some Sprengel explosives. Class III.: Explosion due to detonation of part of the explosive and combustion of the remainder, as in carbonite, westphalite, &c. This may at first sight seem to be an awkward and unreasonable method of classification, but inasmuch as the claims of any explosive for mining purposes must in the first place be based on its safety as regards the non-ignition of explosive mixtures in the workings of a mine, and as this in turn largely depends upon the way in which the explosive generates its force, the writer prefers to adopt it in view of the considerations he wishes to bring before the members.

The most characteristic types of the first class are ordinary black gunpowder and blasting powder, both mixtures of the combustibles carbon and sulphur with potassic nitrate as the oxidizing material, the great difference between the two being that whilst in ordinary gunpowder the proportions are so arranged as to give great heat energy to the explosion, in blasting powder a slight lowering of temperature is obtained by increasing the proportion of sulphur present, and reducing the oxidizing material, the result being that during explosion, the products of combustion although increased in volume, consist largely of imperfectly oxidized bodies which are themselves inflammable.

Composition of Powders.

Gunpowder.	Blasting powder.			
		England.	France.	Italy.
Potassic nitrate.....	75	65	62	70
Sulphur	10	20	20	18
Charcoal	15	15	18	12
	100	100	100	100

Products of Combustion.

	Gunpowder.	Mining powder.
	Fine grain.	
Carbon dioxide.....	50.62	32.15
Carbon monoxide.....	10.47	33.75
Nitrogen.....	33.20	19.03
Sulphuretted hydrogen.....	2.48	7.10
Marsh gas.....	0.19	2.75
Hydrogen.....	2.96	5.24
Oxygen.....	0.08	0.00
	100.00	100.00

Gunpowder itself is practically never used, and the only word that can be said in favor of the blasting powder is that it is cheap. It is absolutely unfitted for use in coal mines, and its abolition would do away with more than three-quarters the number of deaths annually returned as being caused by mining explosives. The great danger attending its use, however, consists in the combustible nature of the products evolved during decomposition, a factor in coal mine explosions which I venture to think cannot be overrated. On firing a charge of 1½ lb. of blasting powder, over 3 cubic feet of combustible gas, consisting chiefly of carbon monoxide, would be produced, and this when mixed with pure air, would give over 10 ft. of an explosive or at any rate rapidly-burning mixture, and experiments which have been made upon the effects of fire-damp and dust combined in causing colliery explosions show conclusively that even when firedamp is present in such minute quantities as to form a mixture very far removed from the point of explosion, it makes the mixture of coal dust and air highly explosive; and traces of carbon monoxide will do exactly the same thing when the air is laden with coaldust, whilst the temperature of ignition is lower than with methane, so that when the air of the mine is charged with coaldust, the probabilities are that a very large volume of explosive mixture is formed by the rapid escape of the products of combustion into the dust-laden air, and this being ignited either by the flame or by red-hot solid products driven out into it by a blown-out shot initiates a considerable area of explosion. As the explosion takes place, and as the carbon monoxide already produced is oxidized to carbon dioxide by the action upon it of water vapor present, and also by its direct combustion with oxygen, the hydrogen of the water vapor is set free, whilst the heated coaldust also yields certain inflammable products of distillation to the air, and partial combustion of the coal dust gives a considerable proportion of carbon monoxide once more, and this driven rapidly ahead of the

explosion, forms, with more coaldust and air, a new explosive zone, and so, by waves and throbs, the explosion is carried through the dust-laden galleries of the mine. In this way any explosive which generates inflammable products of incomplete combustion is unsafe, and should never be used even in mines where firedamp is unknown, as such explosives are quite capable of setting up an explosion with coaldust alone. A still greater danger arises if any trace of firedamp exists in the mine, as this, together with dust, provides an already explosive atmosphere, whilst the products evolved by blasting powder are capable of playing the same part as sulphur on a match, and causing ignition of the explosive mixture. Firedamp, as has been shown by the numerous experiments made since Sir Humphry Davy's memorable researches, is not easily inflamed, and explosive mixtures containing it not only require a temperature of over 1,200 degs. Fahr., but require this temperature to be applied for several seconds, sometimes as much as ten, before ignition takes place. This phenomenon is due to the absolute ignition point of methane being extremely high, far higher than the temperature at which it decomposes into hydrogen and acetylene, and the result is that at temperature such as 1,200 degs. Fahr., decomposition of the methane molecules first takes place, and the liberated hydrogen then igniting raises the mass to the true ignition point of the methane. This dual action requires an appreciable time, and it is this alone which gives the comparative safety in mines where any trace of firedamp exists. If we take the temperature developed by the more prominent explosives, we find them to be far above the ignition point of explosive mixtures of methane and air for a steadily applied heat.

	Degs. Cent.	Degs. Fahr.
Blasting gelatine.....	3,220	5,828
Nitro-glycerine.....	3,170	5,738
Dynamite.....	2,940	5,284
Guncotton.....	2,650	4,802
Tonite.....	2,648	4,798.4
Picric acid.....	2,600	4,712
Roburite.....	2,100	3,812

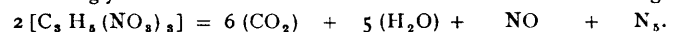
Whilst the ignition point of explosive mixtures of the various combustible gases which could be present in the working of the mine, either produced by the use of improper explosives, or liberated by the coal, are about:—

	Degs. Cent.	Degs. Fahr.
Hydrogen.....	620	1,148
Methane.....	660	1,220
Ethylene.....	580	1,076
Ethane.....	605	1,121
Butylene.....	540	1,004
Carbon monoxide.....	640	1,184
Ordinary coal gas.....	648	1,198.4

It is manifest, therefore, that if the products of explosion escaped into the mine at this temperature, any explosive mixture in the mine must be ignited. This temperature, however, only exists whilst the gases are under the pressure generated by the explosion, and directly they blow out into the workings, expansion instantly cools them below the temperature necessary to bring about the changes leading to the ignition of mixtures of methane and air, or methane, air and coal dust. It is important that it should be fully realized that the factor of safety entirely depends upon the retarding influence of the chemical changes necessary before the ignition takes place, and it is the absence of this with explosive mixtures of other gases that constitute a real source of danger. Fortunately the inflammable constituent of pit gas is practically only methane, and with the use of proper explosives, i.e., explosives which can be completely detonated, and which give neither combustible products nor burning solids on explosion, a very fair degree of safety is attained. Directly, however, inflammable gases other than methane are introduced, the margin of safety disappears, and with explosive mixtures which contain carbon monoxide, hydrogen, or ordinary illuminating coal gas, the point of ignition being the true one, no time is given for the products of the explosion to cool themselves down below the ignition point, and the gaseous mixture is fired. It will always be noticed that in making trials with various explosives where pit gas is used for the mixture in which the explosive gas is fired, ignition is rare, whilst with mixtures of air and coal gas, ignition is the rule rather than the exception, and surely no one can believe that this depends upon the few degrees higher point of ignition which the methane is supposed to possess, and it is this obliteration of the factor of retarded ignition which makes it imperative to discard any explosives generating combustible products of incomplete combustion for use in fiery mines. It is also evident that the more rapid the explosion the safer will it be, and no explosive should be used which relies upon simple combustion either as the primary or secondary principle in its action. A still greater source of danger found in the explosion of blasting powder is the excess of sulphur which it contains, and which during explosion shows its presence by the evil odour of the escaping gases which contain over 7 per cent. of sulphuretted hydrogen, whilst under certain conditions traces of carbon bisulphide are also produced. As has been already pointed out, the ignition point of carbon monoxide is about the same as ordinary coal gas, and may be taken as being 1,134 degs. Fahr., but the vapour of carbon bisulphide has an extremely low point of ignition, and the admixture of only 3 per cent. of its vapour with carbon monoxide lowers the igniting point to below 400 degs. Fahr. Blasting powder and other explosives of the first class should unhesitatingly be discarded, not only as being unsafe in use, but also as deleterious to health, the products of incomplete combustion all having a distinct toxic effect on the system.

Taking now explosives of the second class, we come to nitro-glycerine, nitro-cotton, and some of the Sprengel explosives, and the distinctive characteristics of this division is that all the members of it are capable of complete detonation, provided always that the right sort of detonator is employed. Nitro-glycerine, which first inaugurated the modern era of high explosives and commenced its career as blasting oil, stands apart from all other nitro compounds, owing to the fact that it contains more oxygen than is necessary to complete the oxidation of the carbon and hydrogen found in its molecule.

Nitro-glycerine. Carbon dioxide. Water. Nitric oxide. Nitrogen.



The result being that it evolves no combustible products, whilst its rapidity of detonation would make it the safest and best of all the blasting explosives were it not for the danger inseparable from its physical conditions and sensitiveness to shock. Some of the best of the nitro-glycerine class of explosives, such as blasting gelatine, are amongst the worst offenders as regards the evolution of combustible products of combustion, as the deficiency in oxygen of the nitro-cotton employed is not made up for by the excess present in the nitro-glycerine used. Nitro-cotton alone has from time to time been used for blasting work, but in this case we obtain the maximum amount of combustible products. Several explosives have been made on the principle of mixing nitro-cotton with oxidizing materials, but the only one of these still in the market is tonite, in which the generation of carbon monoxide is reduced by mixing the nitro-cotton with mineral nitrates. Such mixtures, however, give rise to a residue of fused salts, which,