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JOSEPH A. HOLMES, DIRECTOR

NOTES ON THE PREVENTION OF DUST AND GAS EXPLOSIONS IN COAL MINES

BY

GEORGE S. RICE

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NOTE.

The continued recurrence of coal-mine disasters calls for renewed and more earnest efforts to prevent them. Both the miner and the mine owner must make this effort. Each must cooperate with the other in trying to prevent these disasters by seeing that every known precaution is followed, that no unnecessary risks are taken, and that every State law and every mine rule for safety is strictly obeyed by every man working in or about a mine.

In this paper by Mr. Rice, and in Technical Paper 21, by Messrs. Watteyne, Meissner, and Desborough, are to be found suggestions and recommendations that, if carefully followed, will largely decrease both the number and the extent of mine explosions in the United States.

J. A. HOLMES.
NOTES ON THE PREVENTION OF DUST AND GAS EXPLOSIONS IN COAL MINES.

By George S. Rice.

INTRODUCTION.

From time to time the Bureau of Mines has issued suggestions looking to the prevention of explosions in coal mines. Fortunately great mine explosions have not occurred as frequently in this country during the past few years as formerly, but, nevertheless, not a year passes without one or more great explosions in addition to the lesser explosions that endanger a great many more lives than are lost in them.

Each year the mining engineers of the bureau have visited a large number of coal mines not only to give instruction in first aid and the use of mine-rescue apparatus, but also to investigate mine gases, ventilation methods, or methods of rendering coal dust inert. Also, tests have been conducted at the bureau's experimental mine near Bruceton, Pa., for the specific purpose of studying coal-dust explosions and devising methods for their prevention. It is hoped that the information gathered as to dangers, which present many varied phases, and as to the success of the methods of prevention will, through its publication in this paper, benefit mine operators, foremen, and miners. Necessarily there is some repetition of matter presented in previous publications of the bureau and in the technical journals or the transactions of various mining societies. There are, however, some essentials that must be continually emphasized, and one of these is the necessity of making coal mines secure, so far as humanly possible, from explosions of gas and dust.

The author acknowledges the assistance given by all the mining engineers of the bureau in the preparation of this paper, and particularly that given by L. M. Jones and J. W. Paul.

SOME LESSONS FROM MINE DISASTERS DURING THE PAST FEW YEARS.

Although the explosibility of coal dust without the presence of gas (methane) has been universally conceded by mining men in this country, so that a mining man considers trite the statement that coal
dust in the form of a cloud will explode, yet, nevertheless, the development of means of preventing explosions has not made as rapid advance during the past year or two as it did during a few previous years. In certain mines in which disasters have occurred, investigations made by the engineers of the bureau have shown that there have been extensive stretches along the roadway and the sides of passageways in which there was much dry coal dust. Here and there on such roads there have been wet patches, some of considerable length, and these the mine officials have thought gave sufficient protection against a widespread explosion. Also during warm weather the dust precautions are neglected in many mines, possibly because the emphasis laid on the greater danger from dust in winter has caused relaxation of effort in warm weather. Further, many mine officials have thought that there is no danger if the entering air has a high relative humidity, although this condition is no protection in itself. It is only as the current deposits moisture that protection is given. In mines where only scattered places have been wet, an explosion well started has been known to jump the wet places, carrying its own ammunition of coal dust in the advance air wave, and has gained fresh energy on reaching dry places beyond.

Several great disasters during the past few years have occurred in mines rated as "nongaseous." A miner has gone to the face of a working place with an open light unaware that there had been an accumulation of gas since the last inspection, or since he had fired a shot; the gas has been ignited and the flaming has been sufficient to stir up coal dust and start a great coal-dust explosion that has swept the mine. Some of the mines so swept by explosions were well ventilated and their return air currents carried merely a trace of gas, but methane had suddenly escaped at certain faces where faults or clay slips had been encountered.

One conspicuous result of the investigations of the mining engineers of the bureau is that in not one of the many extensive explosions since the mine-accident investigations began in 1908 has there been anything perplexing or mysterious as to the agent that propagated an explosion through a bituminous-coal mine, although the origin of a few explosions may have been in doubt. Wherever an explosion has passed there has been ample evidence that there was sufficient or more than sufficient coal dust to feed it, if not at every point, then in accumulations at places along the passageways.

COAL-DUST EXPLOSIONS IN VARIOUS FIELDS.

ANTHRACITE FIELDS OF PENNSYLVANIA.

In the Pennsylvania anthracite fields most of the serious explosions are explosions of fire damp, as in those fields an explosion of coal dust does not appear to be self-propagating. Although the area
COAL-DUST EXPLOSIONS IN VARIOUS FIELDS.

covered by an explosion of gas in an anthracite mine has usually been confined to one part of the mine, a large amount of afterdamp has circulated through other parts of the mine, and has extended greatly the deadly effects. Several such explosions have probably originated from open lights; in others the use of explosives was involved. Generally, the main ventilating currents in the anthracite mines are strong; the dangers arise from accumulations of gas at the faces or in old workings not reached by the currents. More general use of safety lamps or of permissible electric portable lamps and of permissible explosives would aid greatly in preventing such explosions. The extraordinary record of the gaseous mines of Belgium may be cited as illustrating the advantages of locked safety lamps, permitted explosives, and close inspection. Although since 1891 there have been many instantaneous outbursts of inflammable gas in those mines, there have been no explosions.

APPALACHIAN BITUMINOUS-COAL FIELDS.

The larger number of mine-explosion disasters in the Appalachian bituminous-coal fields during the past two years have resulted from the ignition of accumulations of methane by open lights. Mixed lights—safety lamps in some workings and open light in others—have also proved dangerous on account of leading to carelessness. It is undoubtedly true that the danger would be vastly lessened by the use of safety lamps exclusively. A second source of danger has been the ignition of a cloud of coal dust by the electric arcs incident to trolley-motor haulage. Formerly the use of long-flame explosives was a great source of danger, but the extensive substitution of permissible explosives in these fields has proportionately lessened the number of ignitions from explosives.

INTERIOR COAL FIELDS.

In the eastern and western interior fields, stretching from Indiana to Oklahoma, the greatest source of danger still continues to be the use of long-flame explosives, such as black blasting powder. In the southwestern extension of the interior fields the use of both dynamite and black blasting powder is a source of danger. These explosives are sometimes placed in the same hole, a particularly dangerous practice. Permissible explosives have been introduced, but the great bulk of the coal in these fields is shot down by the long-flame explosives. Shot firing by special shot firers when all the other men are out of the mine is generally practiced in the interior fields. Even with this system many explosions have resulted and still continue to result, and the danger to the many has been transferred to the shot firers. The system of using shot firers is good in itself, but the coal
should be undercut or sheared and shots in the solid condemned before general improvement can be expected. The precautions against the propagation of coal-dust explosions through the mines in the interior fields are not as complete as they should be. The conditions are peculiarly bad in the mines of the southwestern extension of the interior field; explosions in that part of the field are of almost monthly occurrence. Shot firers are killed and mines are damaged.

In the western interior region a theory prevails that explosions are less likely to occur if there is little or no ventilation at the time of shot firing. Tests at the bureau’s experimental mine at Bruceton, Pa., have indicated that an explosion may start from a single shot as readily in a quiet atmosphere as in a strong current. However, if there has been preliminary raising of coal dust in the air by rapid shot firing, undoubtedly the dust is more likely to remain suspended in the air when there is a strong current than when the air is quiet, so that possibly the danger of a dust explosion being propagated is slightly increased by the current. On the other hand, if a mine makes any gas, it is probable that any lessening of the danger of propagation by stopping the fan is offset by the accumulation of gas (methane) at the faces. Moreover, it must be remembered that explosions have been propagated by coal dust alone through the experimental mine where before the explosion there was a perfectly quiet atmosphere.

ROCKY MOUNTAIN FIELDS.

In the Rocky Mountain fields the mining methods are more akin to those of the Appalachian fields than to those of the interior fields. Explosions during the last few years have originated from ignitions of fire damp, ignitions of dust through the use of long-flame explosives, ignition by electric arcing, and in one instance from a mine fire. The urgent problem in this field is to render coal dust inert, for where the watering method is employed it is in some places difficult to get water enough, and the natural dryness of the atmosphere requires the use of a large quantity of water to wet and keep wet the dust of the mines as the air currents, entering with a low relative humidity, absorb the moisture rapidly.

COMMENTS ON CAUSES OF GAS AND DUST EXPLOSIONS.

The mine explosions of the past few years under existing conditions can not be held to have originated through gross carelessness so much as through the agencies that are employed; for example, the

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*a* Coal dust is probably more inflammable in mines where there is a small quantity of methane present, although this point has not yet been determined. The Bureau of Mines is now at work on this problem.

*b* Coal dust in air.
RESULTS OF SOME TESTS AT THE EXPERIMENTAL MINE.

Experiments of several kinds have been carried on during the past few years at the bureau's experimental mine. Those pertinent to this discussion relate to (1) the nature of coal-dust explosions, (2) the prevention of coal-dust explosions, and (3) the arresting of coal-dust explosions.

In regard to the nature of coal-dust explosions, the tests have demonstrated (a) that an explosion of coal dust may become rather violent after it has traveled three or four hundred feet along a passageway; (b) that it may reach a violent stage in 500 to 800 feet from the origin, depending on conditions; (c) that an explosion may be made at will in an entry or passageway in which the roof, sides, and floor are wet to the touch, if sufficient dry coal dust is present; (d) that a high relative humidity of air, which may even be nearly 100 per cent, has in itself no appreciable effect in preventing a coal-dust explosion originated by a blown-out shot, a result that may appear to nullify the recommendation to humidify the ventilating current, as advocated by the Bureau of Mines and by various persons, but does not, since, as repeatedly emphasized, the purpose of humidifying is both to prevent an unsaturated air current from absorbing moisture from the coal dust and to cause moisture to be deposited along the roadways; (e) that a single shot improperly placed and loaded with long-flame explosive may cause the ignition of coal dust; (f) that it makes no perceptible difference, so far as the origination of an explosion is concerned, whether the air is moving one way or the other at the point of origin or is quiet, but that the important factor is the presence of sufficient dry coal dust; (g) that pressures as high as 120 pounds per square inch have been measured at right angles to the movement of the explosion, the pressure in the line of advance of the explosion being no doubt much greater; (h) that com-

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[Notes and references integrated into the text]
THE PREVENTION OF DUST AND GAS EXPLOSION.

Comparatively small quantities of coal dust, 1 pound per linear foot of entry, equal to about one-fifth ounce per cubic foot of space, will propagate an explosion; a smaller quantity has not yet been tried in the mine. This small quantity scattered on roof, side projections, and floor is barely noticeable.

PREVENTING AND CHECKING EXPLOSIONS.

WETTING THE DUST.

As regards preventing or checking gas and dust explosions, the bureau's experiments have indicated that an explosion can not originate in thoroughly wet coal dust, because the dust will not be thrown into the air as a cloud by the shock from a shot or by other means, but that it is not easy to wet piles of coal dust even with well-humidified air currents. This is an important feature not fully understood hitherto. When a saturated air current passes through a mine it dampens the roof, floor, and sides, but the coal dust itself when in accumulations appears to repel drops of moisture; even with long exposure dust like that from the Pittsburgh seam takes up only 1 or 2 per cent of moisture, though the walls and floor may become damp. The surprising result of this series of experiments makes it evident that it is necessary to remove coal-dust accumulations, so that, after a passageway has been well dampened, any particles of dust falling on wet surfaces will themselves become wet. It has been observed after some dust-explosion disasters that the explosion has traversed entries in which there was standing water along the bottom, but on the other hand examination of the benches and projections along the sides of such entries has disclosed quantities of dry dust. Also it has been observed that timbers frequently carry on their upper surfaces quantities of dust sufficient to propagate an explosion. Consequently, the bureau is led to emphasize two precautions, namely, first remove all accumulations of dry dust and then keep the entries wet or use a coating of rock dust. There will then be little danger of explosion.

USE OF ROCK DUST.

At the bureau's experimental mine experiments have been made with rock or shale dust as an alternative to watering. The dust has been made from the draw slate over the Pittsburgh bed with a hammer crusher having a fine screen, 95 per cent of the dust passing through a 20-mesh sieve. Tests have been started only recently, but the results obtained supplement and corroborate those obtained at the experimental galleries in France and England, showing that

*The theoretical amount of Pittsburgh coal dust, if complete combustion takes place and all the oxygen is consumed, is 0.12 ounce per cubic foot of space.*
when inert dust or rock dust is placed on all projections and on the floor (even if some coal dust be present it will be buried) the mine will be free from the possibility of an explosion of coal dust. The bureau’s work has not gone far enough to permit the determination of the precise amounts of rock dust necessary, but it is believed that there should be at least twice as much rock dust as coal dust. If the amount of rock dust even equals that of coal dust the chance of an explosion starting is very much lessened; but as more coal dust is apt to be present than is supposed, the only safe thing is to put on the rock dust abundantly.

USE OF STONE-DUST OR TAFFANEL BARRIERS.

The bureau has made numerous experiments with the so-called “Taffanel * barriers,” consisting of 10 shelves one-half yard wide and 2 yards apart, placed over the roadway and piled with rock dust as high as possible, thus forming an obstruction of about 15 per cent of the cross section of an ordinary passageway; that is, of one less than 7 feet high. More shelves can be employed if the conditions seem to require it. In tests with such barriers explosions have been checked within a few hundred feet after the explosive wave has encountered them. In one test the pressure recorded was 120 pounds immediately before the barrier and only 12 pounds 300 feet farther out. In the French gallery the experiments were equally successful; but in the Clarence mine disaster in France, in 1912, in certain places where there was a light explosion and consequently little pressure, the explosion passed the barriers without displacing the shale dust. The failure of the explosion to displace the shale dust was somewhat exceptional and should not lead to condemnation of the barriers as a secondary defense. Therefore the use of the barriers is suggested by the engineers of the bureau as suitable, for example, at the entrance of the ventilating splits, particularly in haulage ways, where there is nearly always an accumulation of dust, and at intervals along the main entries, but they should be considered only as supplementing the other means.

LESSENING THE PRODUCTION OF COAL DUST.

As regards means to lessen the danger of explosions, the prime essential is to reduce the production of dust. The excessive use of explosives, particularly in shooting off the solid, causes large quantities of dust to be blown into the gobs and other inaccessible places. Before blasting the coal should be undercut, holes should be properly

* Named after J. Taffanel, director of the experiment station at Liévin, France, who devised this arrangement, although W. E. Garforth, of England, was the first to point out the advantages in the general use of rock dust to prevent coal-dust explosions.
placed and charged, and the explosives used should be permissible explosives.

It is unwise to use broken coal or machine or hand cuttings as ballast for haulage. Even if the coal is in lumps, sooner or later it will be crushed to dust. If an incipient explosion starts, this inflammable material will be thrown into the air and be a source of danger. Use either rock, clay, or cinders for ballast.

**USE OF PERMISSIBLE EXPLOSIVES.**

There has been prejudice against the use of permissible explosives in some parts of the country, but wherever they have been thoroughly tried they have been liked, and they certainly are indispensable to safety in coal mining. The explosives on the permissible list of the bureau, if used under the conditions prescribed, will not ignite coal dust. The recent use of permissible explosives in many mines has undoubtedly prevented many disastrous explosions. The introduction and proper use of such explosives would prevent many that occur in parts of the Southwest, where so-called "cracking" shots are employed. Such shots made by drilling holes 12 to 14 feet straight into the solid and using five or six sticks of dynamite are a menace both to shot firers and to the mine and can not be too strongly condemned.

Permissible explosives of the stronger kinds should also be used in lifting bottom, breaking rock bands, or brushing top. There is often as much danger in using dynamite for this purpose as for shooting coal, as coal dust is liable to be present in dangerous quantities. A number of explosions have been caused during the past few years by this use of dynamite.

**DUST-MAKING FEATURES OF USUAL TYPE OF MINE CAR.**

The second greatest agency in dust making is the mine car. It is often loaded with coal 9 to 18 inches above the sides. The coal on a car so loaded may strike the timbers or roof, or be so jarred that it is dislodged and thrown into the roadway, where it is ground to dust by the car wheels or by men and mules or horses. Again, cars with gates or open joints leak dust.

The remedy is drastic, but should be followed. Tight cars should be used, and wherever possible cars without gates should be used. Gateless cars require the employment of a revolving tipple. In Europe, except in Wales and Scotland, tight cars without gates are universally used in coal mines. Side-revolving tipples are employed for dumping the cars, and by proper arrangement the coal is dumped with little breakage. In building or buying mine cars the endeavor

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*Hall, Clarence, Permissible explosives tested prior to January 1, 1912, and precautions to be taken in their use: Miners' Circular 6, Bureau of Mines, 1913. 20 pp.*
PREVENTING AND CHECKING EXPLOSIONS.

should be to get a car that is as tight as possible, and enough cars should be supplied so that the miners will not be compelled to pile the coal up above the sides. In addition to tight cars, automatic sprinklers adjacent to the gathering places and sidings should be used so that the cars may be drenched as they pass under a spray. The automatic spray system, operated by a lever depressed or moved by the passing car, is effectively used in a few mines in this country and in many abroad. If well arranged it washes the dust from the top and prevents the dust from being dropped or blown off by the air currents along the roadway. The rapidity with which dust will accumulate along the roadway is astonishing, but as long as coal is constantly falling off the cars and being ground to dust by the wheels of passing cars (which make a too efficient grinding device and render increasingly difficult the task of rendering coal dust inert) it is easy to see why there is often a large quantity of coal dust ready-made for an explosion.

COLLECTION OF DUST FROM SCREENS.

If hoisting is done in a downcast shaft the shaking screens should not be placed immediately adjacent to the shaft, and if they are near the shaft, vacuum dust collectors should be installed over the screens and chutes. Otherwise, a large quantity of dust may be drawn down the shaft. In a certain mine in England in which rock dust was used to counteract the danger of coal dust the writer observed a thick film of coal dust on top of the rock dust, the deposit extending for a distance of 500 or 600 feet from the shaft. Had it not been for the light-colored rock dust the deposit could not have been seen. It had been collecting for only two months subsequent to the time when the rock dust had last been laid. This mine has since put in vacuum dust collectors over its screens. In many of the recently built European plants it is the practice to place the screening plant 100 to 200 feet distant from the downcast shaft.

PREVENTIVE METHODS.

It should always be borne in mind that, except in anthracite mines, coal dust is the agency that causes an explosion to sweep through a mine, leaving a trail of wreckage and death. Certain means of prevention have already been indicated, but are reviewed below. Apart from lessening the production of dust, there are two principal ways of fighting the coal-dust danger—first, wetting the dust by various means, such as humidifying the air current or washing down the dust with hose or with pump water cars; second, spreading rock dust over it.
THE PREVENTION OF DUST AND GAS EXPLOSION.

HUMIDIFYING THE AIR CURRENT.

With the humidifying system the intake air current is so saturated or supersaturated as to carry the moisture into the mine in minute but constant quantities every minute of the day. Details of the system are given in Bureau of Mines Bulletin 20, and in many articles in current journals.

PREHEATING THE VENTILATING CURRENT.

Some operators have placed steam heating coils at the intake entrances of their mines in order to heat the entering air current in cold weather to the temperature of the workings. This permits the immediate saturation of the ventilating current by steam jets, without serious fogging of the air by particles of condensed moisture from the steam jets being carried in suspension until the air receives heat enough from the mine walls to absorb them.

Preheating the air, if done with careful regulation, has the further merit that the temperature of the roof and walls of the airway near the entrance is, or may be, kept more nearly uniform, summer and winter. This prevents the constant expansion and contraction of the roof, which otherwise takes place and probably tends to increase roof falls.

From inquiries received by the Bureau of Mines, it is evident that there has been misapprehension regarding the purpose of preheating; some persons have thought that merely heating the air to a summer temperature would suffice to produce humid conditions underground. This is not the case, as the mere heating of the air does not increase the amount of moisture it carries. On the other hand, the amount carried being the same at the higher mine temperature, the percentage of relative humidity is decreased; hence the necessity of introducing artificial moistening by fine sprays of water, or, more easily, by jets of exhaust or live steam.

Inquiries have been received as to the size of the steam coils necessary for heating. To determine the size it is necessary to know (1) the volume of the ventilating current, (2) the temperature of the mine workings, and (3) the lowest outside temperature at the mine in winter. It does not seem necessary to take the temperature of an extremely cold day, but the average during a single cold wave. If the ventilating current is 100,000 cubic feet of air per minute, if the temperature of the mine workings is 65° F., and if the average temperature of the coldest cold wave is zero F., then the temperature of 100,000 cubic feet of air must be raised 65° F. every minute. Knowing the steam pressure available, it becomes an ordinary steam-heating problem to determine the size of the coils, the amount of steam, and

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*Rice, G. S., and others, The explosibility of coal dust, 1913, pp. 89, 168.*
the coal consumption required to heat the entering air to mine temperature.

A word of caution about humidifying seems necessary. As already mentioned, tests at the bureau’s experimental mine show that accumulations of dry coal dust do not take up moisture enough to prevent their spreading an explosion. Therefore, whenever dry dust accumulates, the accumulations must be promptly removed as cleanly as possible and the area thoroughly wet. Evidently, in most mines, supplementary treatment with hose or with water cars is necessary, for, regardless of whether the air current is saturated, the dust must be wet.

**Sprinkling with water hose.**

Water hose is proving a good means of washing down the coal dust, not only in Utah mines, where the use of such hose is compulsory, but in some mines in other parts of the country. If the water-pipe system goes throughout all the entries of the mine not only does it have the merit of giving fire protection, but a stream of water can be used to sweep dust from any projection of the ribs or from timbers.

**Sprinkling with water cars.**

Efficient pump cars giving a strong spray that sweeps throughout the whole area of an entry have been installed in some coal mines. If used regularly, they furnish an admirable means of washing down the dust from the ribs and timbers and wetting that on the floor. Parts of the mine not reached by the cars will require treatment by water hose or other efficient means.

**Use of fixed water sprinklers.**

It must be admitted that experience in a number of mines has indicated that fixed water sprinklers are not sufficient in themselves unless they be placed so close together that their cost becomes almost prohibitive. Comparatively, the range of the sprinklers is limited and they easily get out of order. It has been observed that from a point 25 feet or so beyond a sprinkler the dust may be dry as far as the next sprinkler. In one mine dry dust was observed less than 10 feet beyond the sprinklers in the direction of the air current and within a few feet on the intake side. Therefore fixed sprinklers must usually be supplemented by water cars or hose.

**Use of calcium chloride.**

Calcium chloride is being used with good results in mines in some parts of West Virginia, and in a few other places. As ordinarily applied it is not sufficient for all needs, but is useful for keeping the floor damp along roadways, and is particularly efficacious in keeping
geoave surfaces moist. If supplemented by sprinkling or washing down the ribs and timbers, the use of calcium chloride is satisfactory.

**SCATTERING ROCK DUST.**

The merits of rock-dust treatment can be more definitely stated now than was possible a few years ago, for tests by the bureau and by foreign experiment stations have shown its success in preventing or checking experimental explosions. As regards checking explosions under headway, rock dust is certainly more effectual than either a so-called dustless or even a damp zone of several hundred feet. Its use can not be said to have made much progress in this country, the writer having knowledge of only one coal mine, a mine in Colorado, in which rock dust is used. In that mine the system is used on some of the trolley roads: for the present, adobe dust, which is equivalent to rock dust, is being applied by means of a motor-driven fan having a flexible outlet. In France, however, the rock-dust system has been adopted by an association of mine operators (Comité Central des Houillères de France) that includes practically all the coal mines in that country.

There are two methods of using rock dust—continuously throughout the mine and, as first advocated by W. E. Garforth and later by the committee that carried on the coal-dust experiments at Altofts, England, on barriers as a secondary means of arresting an explosion already started. The writer recommends that these secondary safeguards be placed in or near the entrances of each split of air and that as many more be used as seem to be needed. If rock dust of sufficient fineness (say, 95 per cent through a 20-mesh sieve) be not available, fine dust or screened ashes not containing too much carbonaceous matter (less than 10 per cent) can be used. As previously stated, such barriers, however, should not be used alone, but should be considered only as supplementary safeguards.

As it has been found that dust explosions have originated in the last few years from causes other than the use of explosives and ignition of pockets of fire damp, as from electric arcs and open lamps surrounded by a cloud of dust, it is necessary to have protection throughout the whole mine, as no one can say where an explosion may originate. For example, a couple of years ago in a Rocky Mountain coal mine, in which an explosion occurred, the evidence was thought to show conclusively that the explosion originated within a few hundred feet of the intaking drift entrance of the mine through the breaking in two and derailment of a trolley trip, resulting in the knocking down of timbers, stirring up of coal

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*Inman, Samuel, Prevention of coal-dust explosions; Coal Age, vol. 2, Nov. 30, 1912.*

*Such an accident in a surface coal-crushing plant in Pennsylvania killed four men.*
Preventing and Checking Explosions

Dust, and resultant arcing of the trolley wires. This explosion traveled for a couple of miles into, or toward the face of, the mine.

The best method of using rock dust is, after cleaning the passageways, to place it continuously throughout the mine—on the floor and on all projections on the sides, roof, and timbers—so as to cover any coal dust that could not be removed, and if the ribs are bare and smooth it is desirable to place shelves at intervals on the sides or over the roadway to provide a place of lodgment for some of the rock dust. Tests of the use of rock dust are being continued at the bureau’s experimental mine, but definite conclusions have not been reached regarding the quantity necessary for preventing propagation of an explosion started by an ignition of fire damp. However, it may be stated tentatively that the rock dust should be placed along the entries at the rate of at least 4 pounds per linear foot. Such placing would require 1 ton for about 500 feet of entry. Later treatments would not require so much, although from time to time, when too much coal dust becomes mixed with rock dust, the dust should be removed and fresh rock dust substituted. The rock dust should not contain much free silica or flint particles, which would be bad for the lungs of the miners traveling the roadways, but should be made preferably from shale from the roof, if this shale is not too carbonaceous; that is, if it does not contain more than 5 or, at most, 10 per cent of bituminous matter. Shale dust seemingly is not harmful to the lungs. Limestone also would not be harmful and would make one of the best materials that could be used. All the machinery required for producing the dust is a classifier or grinder that will reduce the dust so fine that about 95 per cent will pass through a 20-mesh sieve.

One of the great merits in the use of rock dust is that it whitens the roadways and makes them easily lighted, so that accumulations of coal dust can be readily noted. The whitewashing of the walls of passageways is also a great protection, as the lodgment of coal dust on the white surfaces is readily seen, and the whitewash also acts somewhat like a thin coat of rock dust. It is extensively used in some coal mines and makes the roadways lighter and therefore safer.

Fire-Damp Explosions.

Inflammable gas can not be prevented from entering a mine; hence in gaseous districts every precaution should be taken to minimize the risk from such gas. Many precautions are undoubtedly taken in almost all of the very gaseous mines, as explosions are seldom reported from those mines. It is chiefly in the slightly gaseous or so-called “nongaseous” mines that gas explosions have occurred.
One of the principal causes of danger is the use of "mixed lights"; that is, of safety lamps in some parts and of open lights in other parts of the mine. It may be possible in some mines to separate districts so completely that there is little danger of open lights being carried into the gaseous districts, but experience has shown that such a separation is very difficult. If, however, mixed lights are used, the entrance to the gaseous district should at all times be guarded by a mine official with sufficient authority to absolutely prevent even the higher officials of the company from entering with naked lamps. Safety lamps are an effective measure of precaution. Statistics on the point have not been gathered in this country, but in England, where they have been gathered and cover mines using safety lamps and those using open lights, it has been found, in districts in which the mines using locked safety lamps about equal in number those using open lights, that 90 per cent of the explosions of fire damp, large and small, have occurred in mines in which the open lights are used, and that the ignitions were due to the open lights.

The bureau strongly urges that safety lamps be used throughout all mines in which fire damp has been found on several occasions or in which the returns of any district show as much as one-half of 1 per cent of gas (methane) by analysis. The percentage seems small, but in England the use of safety lamps is now obligatory where this percentage is found in the return air currents. More than one-half of 1 per cent of methane in the return, at times when there is a stoppage at the face, is apt to mean that a dangerous accumulation of gas will result.

Safety would be enormously increased by the general use of safety lamps. Now that there are on the market portable electric lamps, a number of which have been tested by the Bureau of Mines and pronounced safe for use in gaseous mines, the adoption of such lamps is urged when the safety lamp is considered unsatisfactory because it encumbers the wearer or gives poor light. Electric lamps have by no means reached perfection and are being constantly improved by the manufacturers. However, in mines where electric lights are extensively employed it is necessary to maintain constant supervision of the working places by a face boss or foreman with a safety lamp to test for gas. In other words, if the mine makes any fire damp, do not rely entirely on the early morning inspection, for after this inspection the miners may strike a fault or a clay slip or there may be a roof fall, resulting in an outflow of gas.

Explosives.

Next to open lamps, explosives are the most prolific cause of ignitions of fire damp. The use of permissible explosives will largely
prevent such ignitions, provided that proper precautions be taken and the permissible explosive be used in accordance with the instructions of the Bureau of Mines.

TROLLEY LOCOMOTIVES.

A number of great explosions in mines are thought to have been due to the open trolley. It is well known how easily an open trolley may ignite fire damp. If a mine is not gaseous (and this rating might be on the English basis of a methane content less than 0.5 per cent in the return from any district) it does not seem necessary to prohibit the use of trolley locomotives if they be kept on the intake road, provided the mine is not subject to sudden outbursts of methane (which are rare in this country) and provided the coal dust along the road is rendered inert. To allow a trolley locomotive to operate in the return of any gaseous mine is a reprehensible practice. Samples of air taken by an engineer of the bureau in a return in which a trolley locomotive was being used showed that on one occasion the air of that return contained 1 per cent of methane. It is easy to see that if there were any sudden stoppage of ventilation a dangerous proportion of gas would soon be reached.

ELECTRIC SIGNAL WIRES AND TELEPHONES.

It is a common belief that gas can not be ignited by electric signal wires or telephone wires, but if inductive apparatus is employed, the high voltage momentarily built up when the circuit is opened may cause ignition although the nominal voltage is very low. Two well-authenticated cases of ignition of pockets of fire damp by electric signal wires occurred in 1912 in South Wales.

ELECTRIC MINING MACHINES.

Electric mining machines have been under suspicion as causing explosions that have occurred in gaseous or partly gaseous mines. There is always the potential danger; therefore it would be safer in gaseous mines if the power wires were covered with a good insulating covering, if the motors were explosion proof, and if switches at the end of feed wires were also explosion proof. These are the requirements in a number of coal-mining countries. The new laws of Pennsylvania relating to electric mining machinery, which also require explosion-proof motors, represent a great step in advance.

Where electric mining machines are used in a gaseous or dusty mine the cable should not be dragged along the ground any more than can be avoided, and in such a mine no cable with badly worn insulation should be used. It was suspected that one disastrous ex-

plosion might have been due to a machine rapidly moved on a down
grade on a dusty roadway, the cable furnishing the power dragging
in a loop behind. If such a cable has the insulation worn bare in
places and such a place comes in contact with the steel tracking, a
grounding may occur accompanied by a flash that may ignite the
dust raised by the moving machine. It is better that the cable be
put on a reel in moving from one working place to another.

**IMPORTANCE OF ADEQUATE VENTILATION.**

After all, the greatest remedy for inflammable gas is an adequate
ventilating current, not only in the main roads, but also at the faces
and in goaves where fire damp is likely to be found. The mine
should be provided with a number of splits, not enough to make the
velocity of the air too slow, but as far as possible there should be a
separate ventilating split for every pair of entries in which gas
occurs, and the return of the split should go straight to the return
airway. It is advised that hereafter, in opening a mine in any coal
basin or field in which gas has been encountered in neighboring mines,
or, from the nature of the geologic formation, is likely to be en-
countered, the haulage roads and traveling ways be not made the
return airways.

**CONTROL OF VENTILATION BY ANALYSIS.**

By the ordinary hurried manner of testing for gas with safety
lamps only 2 per cent of gas is detected, and even with care only 1
per cent. It is advisable to know more exactly the amount of
methane being produced in a given district. This information can
be obtained only by analysis. Attention has been directed by the
bureau to the advantage of frequent, if not daily, analyses of the
ventilating currents of different parts of a gaseous mine. Such
analyses are made at a number of large mines, and with the informa-
tion thus obtained the ventilation is so adjusted that the percentage
in every split of air is kept below what is considered the danger
point under the conditions that prevail.

**NEED OF TIGHT STOPPINGS AND DOORS.**

One of the defects that has been repeatedly found by engineers of
the bureau has been a leakage of the ventilating current so great
that only a small proportion of the current that enters the air shaft
reaches the inner workings. This leakage is due to defective stop-
pings and doors. Air easily passes through dirt stoppings in which
there is no facing of lime or cement plaster. Wood stoppings also

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BAROMETRIC WARNINGS.

are inefficient and constitute a fire risk. Whatever kind of stop-
pings be employed it is always desirable to have them plastered with
a rich mixture of lime or cement.

It is a mooted question whether it is best to put in very strong
stoppings and overcasts or to have them relatively frail, so that they
will be easily blown down in case of an explosion. Many persons be-
lieve that an explosion may be checked if the stoppings or overcasts
are thrown down; on the other hand, the argument may be made that
if a stopping is blown down much coal dust may be dislodged from
the break-through; also, that in nearly all the great disasters in this
country the stoppings and overcasts throughout the mine have been
thrown down, and yet the explosion has not been checked. The merit
in having them strong is that if they are not blown down the ventila-
tion is quickly renewable. At the bureau's experimental mine a solid
brick stopping 18 inches thick was blown down by an explosion of
low pressure. In this experiment and in previous ones when stop-
pings were blown down there was no appreciable check of the move-
ment of the explosion. On the other hand, 18-inch concrete stop-
pings (placed in the middle of the cut-through or crosscut), rein-
forced horizontally with steel bars and keyed into the rib on either
side, have resisted repeated explosions, except that once a stopping
calculated to be able to withstand a pressure of 48 pounds per square
inch was cracked by an explosion that registered the unusually high
pressure of 120 pounds per square inch a short distance outby in the
entry. A stopping built for the purpose of resisting an explosion
must have great strength; otherwise it will not be worth while to pay
for the added cost over that of an ordinary fireproof stopping. The
writer, giving his own personal views, believes it is better to make
stoppings, at least those along the main entries, strong enough to
resist a pressure of about 100 pounds per square inch.

USE OF DUPLICATE OR TRIPlicate DOORS.

Too often the main splits have only single doors. A single door
permits great waste through leakage, and whenever the door is
opened the ventilation is almost suspended. Doors in the main splits
should always be in duplicate, and preferably in triplicate. It is,
of course, still better to have the currents so split and handled by
overcasts that there are few doors in a mine. If the overcasts or
undercasts can be made in the solid strata, so much the better, for in
the case of an explosion they will probably remain intact.

BAROMETRIC WARNINGS.

In many well-equipped mines, especially in the anthracite field of
Pennsylvania, recording barometers are installed at each of the
mines. However, in a mine where open lights are used, whether
throughout the mine or in certain districts, conditions may become serious before the management is aware of the danger. Methane is held in the coal and rock, usually at high pressure, so that in new workings changes in the barometric pressure are not likely to affect the issuance of gas; but in old mines, especially those having extensive goaves or many abandoned rooms, gas may accumulate in unventilated and even inaccessible places, and when the barometric pressure lowers the gas may come out. Hence the indication of falling barometric pressure is of value to the mine official, as he may warn fire bosses and others of the increasing danger; but it must be borne in mind that outbursts of gas under high pressure may be released by a fall of roof or a large blower may be opened in a heading or entry when the barometer is high; therefore, vigilance should not be relaxed.  

**MISCELLANEOUS PRECAUTIONS.**

A few miscellaneous precautions are presented below, as follows:

Don't forget that even in summer there may be a dangerous amount of dry coal dust in a mine, and that an explosion may occur then as well as in the winter if the dust be ignited.

Don't neglect the smallest pockets of gas. Instruct your fire bosses to have such places ventilated, even if a long line of brattice be required.

Have the return air from the different splits analyzed frequently. It will be of the greatest assistance to you in controlling the ventilation and in preventing dangerous conditions from developing.

If you use water cars and hose, don't forget that they must be used daily in all parts of the mine. When an entry is dry, it is likely to be in a most dangerous condition, as the fine, pure coal dust is apt to be lying over all the surfaces.

Don't forget that it is almost impossible to wet a mass of dry coal dust, and that it is necessary to keep surrounding surfaces thoroughly damp in order to prevent accumulations of dry dust.

Remember that humidifying the air current is a good way to dampen the mine, but the means used must be constantly kept under control to insure humidity near the point of saturation when the weather is very cold. In using any system of wetting the coal dust, be sure that the dust throughout the roadways is kept wet all the time.

Test the moistened coal dust to ascertain whether it will pack in the hand into a compact ball, for if the dust will not pack compactly there is not enough water present to render it safe.

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*a* On account of the fear of mining men coming to feel a false sense of security at times when reports of dangerous barometric conditions are not published, the Bureau of Mines has been reluctant to advocate the use of general public warnings issued through the newspapers that may not be received until the specific danger is past. The installation of recording barometers at the gaseous mines is, on the other hand, to be commended, as there is no delay in obtaining the information of a falling barometer.
PUBLICATIONS ON MINE ACCIDENTS AND METHODS OF MINING.

The following Bureau of Mines publications may be obtained free by applying to the Director, Bureau of Mines, Washington, D. C.:

**Bulletin 10**, The use of permissible explosives, by J. J. Rutledge and Clarence Hall. 1912. 34 pp., 5 pls., 4 figs.


**Bulletin 48**, The selection of explosives used in engineering and mining operations, by Clarence Hall and S. P. Howell. 1912. 50 pp., 3 pls., 7 figs.


**Bulletin 52**, Ignition of mine gases by the filaments of incandescent electric lamps, by H. H. Clark and L. C. Usley. 1913. 31 pp., 6 pls., 2 figs.


**Bulletin 65**, Oil and gas wells through workable coal beds; papers and discussions, by G. S. Rice, O. P. Hood, and others, 1913. 101 pp., 1 pl., 11 figs.


**Technical Paper 13**, Gas analysis as an aid in fighting mine fires, by G. A. Burrell and F. M. Seibert. 1913. 16 pp., 1 fig.


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