STONE DUSTING OR ROCK DUSTING
TO PREVENT COAL-DUST EXPLOSIONS,
AS PRACTICED IN GREAT BRITAIN AND FRANCE

BY

GEORGE S. RICE

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STONE DUSTING OR ROCK DUSTING TO PREVENT COAL-DUST EXPLOSIONS, AS PRACTICED IN GREAT BRITAIN AND FRANCE.

By GEORGE S. RICE.

INTRODUCTION.

The prevention of coal-mine explosions has been one of the chief purposes of the Bureau of Mines. In fact, the first Federal appropriation relating to mining methods, in 1908, authorized the investigation of the causes of mine explosions and the possible methods of preventing them. When that investigation started the mining industry had not determined the real causes of a succession of terrible coal-mine explosions in various countries, culminating in the great disasters at Courrières, France, and Monongah, W. Va. Coal dust as an agent of widespread explosions had been under suspicion, and watering to allay the dust was recommended by some mining engineers but the watering of coal-mine dust was adopted in comparatively few mines of the United States and Great Britain, and had not been introduced widely in any country except Germany.

Rock dusting, another method of preventing explosions of coal dust, was early tested with success by the Bureau of Mines in its first gallery at Pittsburgh and, beginning in 1911, at the experimental mine, Bruceton, Pa. Several of the first publications 1 of the bureau suggested that rock dust be used in gaseous or dusty bituminous mines, and in 1915 Technical Paper 84 2 strongly recommended it. Since that time additional tests in the experimental mine have fully confirmed this first judgment.

FOREIGN INVESTIGATIONS.

Great Britain in 1908, and France in 1907, after the Courrières explosion that killed 1,100 men, began to make coal-dust explosion tests. Investigators in these countries concluded that enough incombustible dust spread through a passageway charged with coal dust prevented the propagation of an explosion by the coal dust.


Long before then, W. N. and J. B. Atkinson, the late William E. Garforth, and other investigators of coal-dust explosions, including the writer, had observed that an explosion would be checked or would not propagate in those parts of a mine where there was a large amount of natural shale dust or other inert dust. Garforth was unquestionably the first to suggest, from his observations at an explosion in his Altofts colliery, England, the systematic application of stone dust throughout a mine to prevent explosions. In 1906 he built a short gallery at Altofts to demonstrate this.

**GREAT BRITAIN.**

In 1907 the Coal Owners Association of Great Britain allotted funds for an investigation of coal-dust explosions and took over and extended the Altofts gallery. The association planned to investigate various means of preventing explosions, and hoped to find some alternative to watering, which had proved to injure many mine roofs. In 1911 the British Government took over these investigations and moved the gallery to Eskmeals, where the work was conducted by the explosions in mines committee, Dr. R. V. Wheeler, chief chemist. In 1912–1914, tests made there showed the stone-dusting method, as the British term it, to be effective. These investigations were interrupted by the World War, but in 1920 Government regulations made stone dusting compulsory in coal mines where the dust was dry and dangerous. Later these regulations were made more stringent. At present stone dusting is practically universal in British collieries, although the efficiency with which the method is applied admittedly varies in different districts and different mines.

**FRANCE.**

In France the Central Committee of Coal Mines (Comité Central des Houillères de France), which is the executive committee of the French coal operators' association for promoting the good of the industry, compiling data, and conducting investigations for increased efficiency in the use of fuels and for safety in mines, built a small coal-dust explosion gallery in 1907 and later a large gallery at Liévin in northern France.

Before the great Courrières disaster of 1906 eminent French physicists believed from laboratory tests that coal dust could not cause an explosion if mines were thoroughly ventilated to prevent fire damp accumulating. This belief was widely accepted by French mining men, but the Courrières disaster, which occurred in a mine then rated as nongaseous, naturally raised grave doubt as to previous conclusions; accordingly the Comité Central built the very complete testing laboratory and gallery at Liévin. J. Taffanel, a mining

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engineer, was placed in charge. He carried on practical and fundamental investigations until the beginning of the World War, when the station was destroyed. His conclusions fully verified those of the British investigators at Eskmeals and those of the Bureau of Mines as to the efficiency of inert dust when the dusting was properly done.

As a result of these investigations, Taffanel issued a series of valuable bulletins on the phenomena of coal-dust explosions and on the rock-dusting preventive method, which he termed "schistification" (literally, shale dusting). During the war the investigations had to be suspended, but from results of Taffanel's experiments the Mines Department of France approved shale dusting as a preventive of coal-dust explosions.

GERMANY.

In Germany investigators at the Derne experimental gallery, Westphalia, where work began later than that in England and the United States, tested various methods, but concluded (1920) in favor of stone-dust barriers similar in action to those developed at the Bureau of Mines experimental mine. According to an article that appeared in Glückauf and was quoted in The Colliery Managers Pocket Book, 1923, page 18, at one colliery in the Ruhr flue dust is distributed in the vicinity of shots to be fired; also along roadways flue dust is distributed every 8 to 10 days, by hand, at the rate of 4½ pounds per linear yard of roadway. Along gate roads (branches or rooms) it is distributed by compressed air. Simple shelf barrages and hanging barrages are placed in each ventilation panel. Nevertheless, watering is still employed at many German mines. In some mines hydraulic stowing of sand has eliminated danger from coal dust because of the thorough wetting and the admixture of silt incident to the use of this method. In Upper Silesia, where the coal-dust problem has been serious in the thick coal beds, disastrous coal-dust explosions have occurred in mines where hydraulic stowing was not used. Ordinary watering methods are now considered of doubtful effectiveness by many, and the director of the Upper Silesia experimental station at Bëuthen told the author (August, 1923) that the operators of that district were considering trial of the rock-dusting method.

PREVENTIVE METHODS IN THE UNITED STATES.

Although the Bureau of Mines has recommended rock dusting, only a few operators in the United States, one in Colorado and several in southern Illinois, have adopted it, and they but to a limited extent. Operators of the mines in southern Illinois that have installed rock-dust barriers state that these have prevented many coal-dust explosions, which were started by local explosions of fire damp or by shot firing, from propagating beyond the barrier in the mouth of
the panel in which the explosion originated. Other operators of mines where disastrous coal-dust explosions have occurred in spite of watering are now considering the adoption of rock dusting.

For three years—1918, 1919, and 1920—the United States was comparatively free from disastrous explosions in bituminous coal and lignite mines. In these three years 41, 81, and 47 men, respectively, died in explosions that killed five or more men, as contrasted with the years 1901–1910, in which an average of 330 men were killed annually. This good record tended to prevent mining men and Bureau of Mines engineers from seriously questioning the effectiveness of watering methods as generally practiced under careful management in naturally dry bituminous and lignite mines. Between January 1, 1918, and December 31, 1923, however, there have been 19 explosions, in 16 of which coal dust was considered to be the propagating or contributing agent; and in these explosions 530 lives were lost. The fact that the watering method was either used or supposed to have been used in these mines has convinced engineers of the bureau that the watering method is not reliable, and that the comparative immunity from disasters during the three years just mentioned was partly due to good luck, since a combination of circumstances is necessary to produce a dust explosion, and partly to better methods of preventing the ignition of gas and coal dust through the adoption of permissible explosives, permissible miners’ lights, and other approved appliances. In other words, the potential danger of coal dust is not eliminated by ordinary watering methods.

When the writer was detailed by the Secretary of the Interior and the director of the Bureau of Mines to investigate mining conditions in Europe, he was especially charged to observe the methods that are now being used to prevent explosions. This report gives the results of his findings.

STONE DUSTING IN GREAT BRITAIN.

Great Britain was the first country to require stone dusting in mines. The tests by the Coal Owners Association of Great Britain at the Altofts gallery in 1908–1909 indicated the correctness of Sir William Garforth’s theory that systematic stone dusting would prevent the propagation of a coal-dust explosion. He introduced the method in the Altofts colliery in 1907, and when the writer visited that colliery in 1911 stone dust had been applied systematically throughout the mine. A number of other progressive collieries in England adopted the method.

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8 The liability compensation for these lives would not be less than $2,000,000 and the property loss, direct and indirect, would probably be equally large.

4 Wood, Lindsay, Garforth, W. E., Pilkington, C., Forgie, J. T., and Hood, W. W., special committee, Record of the first series of the British coal-dust experiments, conducted by the committee appointed by the Mining Association of Great Britain, 1910.
STONE DUSTING IN GREAT BRITAIN.

PROVISIONS OF COAL-MINES ACT OF 1911.

The original British coal-mines act of 1911, which was in effect until 1921, considered the subject of coal-dust explosions under provisions covering five points, which are essentially as follows:

1. As far as practicable coal dust from screens must be prevented from entering the downcast shaft, and to this end no plant for screening or sorting coal at a mine opened after the passing of the act can be situated nearer the downcast shaft than 80 yards.

2. The "tubs" (or mine cars) must be constructed and maintained to prevent the escape of coal dust from the sides, ends, or bottoms.

3. The floor, roof, and sides of mines must be systematically cleared to prevent coal dust accumulating.

4. Systematic effort must be made by watering or otherwise, as may be laid down by the regulations of the specified mine, to prevent explosions of coal dust.

5. The roads must be examined daily and a report on their condition, as to coal dust and the steps taken to mitigate dangers arising therefrom, recorded in a book.

These regulations did not specifically mention stone dusting, but the words "or otherwise" implied that some method other than watering might be used.

REPORT OF EXPLOSIONS IN MINES COMMITTEE, 1914.

As results of the tests at Eskmeals, Cumberland, confirmed the tentative conclusions reached at Altofts as to the efficiency of stone dust in preventing coal-dust explosions, the explosions in mines committee appointed by the home office reported September 23, 1914, as follows:

The experiments which have been carried on at Eskmeals during the past three years, the results of which have been set out in six reports submitted by us, establish, so far as experiments can, that—

(i) The maintenance throughout the roads of such a proportion of incom bustible dust in a state of fine division as would make a mixture yielding on incineration at least 50 per cent of ash; or

(ii) The maintenance of at least 30 per cent of water in a state of intimate mixture with the dust throughout the roads; or

(iii) A combination of the two previous methods, i.e., the treatment of the roads first with incombustible dust and then with water, would prove effective in greatly minimizing—if not preventing, explosions of coal dust.

GENERAL REGULATIONS, 1920.

Investigations were suspended during the World War, but afterwards the matter was again considered officially and the following General Regulations issued June 30, 1920, by the home office, which then had supervision of mining affairs:

Part 1.—Precautions against coal dust (section 62).

1. The following regulations shall apply to all mines in which coal other than anthracite is worked, except mines of which the floor, roof, and sides of the roads are naturally wet throughout.
2. Except in a seam in which anthracite only is worked the floor, roof, and sides of every road or part of a road which is accessible shall, unless the natural conditions as regards presence of combustible dust and moisture are such as to comply with the requirements of the regulation, be treated in one of the following ways, either—

(a) They shall be treated with combustible dust in such manner, and at such intervals, as will insure that the dust on the floor, roof, and sides throughout shall always consist of a mixture containing not more than 50 per cent of combustible matter; or

(b) They shall be treated with water in such manner, and at such intervals, as will insure that the dust on the floor, roof, and sides throughout is always combined with 30 per cent, by weight, of water in intimate mixture; or

(c) They shall be treated in such other manner as the Secretary of State may approve.

Provided that the percentage of incombustible dust required under this regulation may be reduced by an amount equivalent to the percentage of water present in the mixture.

3. The incombustible dust used for the purpose of the preceding regulation shall contain not less than 50 per cent by weight of fine material capable, when dry, of passing a sieve with 200 meshes to the linear inch (40,000 to the square inch).

Provided that if a larger proportion of incombustible dust is used than is required under the foregoing regulation, the percentage of fine material aforesaid contained in the incombustible dust may be reduced proportionately, but shall not fall below 25.

4. For the purposes of testing the composition of the dust mixture in any part of a road, the following procedure shall be adopted:

(a) Representative samples of the dust shall be collected from the floor, roof, and sides over an area of road not less than 50 yards in length.

(b) The samples collected shall be well mixed and a portion of the mixture shall be sieved through a piece of metallic gauze having a mesh of 28 to the linear inch.

(c) A weighed quantity of the dust which has passed through the sieve shall be dried at 212° F. and the weight lost shall be reckoned as moisture. The sample shall be brought to a red heat in an open vessel until it no longer loses weight. The weight so lost by incineration shall be reckoned as combustible matter for the purpose of the test.

Provided that in the case of dust to which the foregoing test would not be applicable, the test shall be such as may be prescribed; if any dispute arises as to the test which should be applied it shall be determined in the manner provided by the act for settling disputes.

Representative tests shall be made by the management at intervals of not less than once a month, and the results shall be posted at the pit head.

5. No dust shall be used for the purposes of complying with these regulations of a kind which may be prohibited by the Secretary of State on the ground that it would be injurious to the health of persons working in the mine. Provided, that if any dispute arises as to whether the dust is injurious, it shall be determined in the manner provided by the act for settling disputes.

6. Paragraph 3 of section 62 of the act shall be amended to read as follows:

The floor of every traveling road shall be cleared of dust at regular intervals of time so as to keep it free from all accumulations of dust. The intervals shall be fixed by agreement between the manager and the workmen employed in the mine, or their representatives, or in default of agreement, by the inspector of the division.
"Traveling road" means a road used by the main body of any shift employed in the mine for traveling to or from their working places, and where the mine is divided into districts, the road used by the main body of men employed in a district.

7. In the foregoing regulations, "road" includes all roads of any description extending from the shaft or outlet to within 10 yards of the coal face, but chutes from the coal face down which coal is thrown, office, stables, engine houses, motor switch and transformer rooms, and pump rooms, shall not be deemed to form part of any road.

8. This part of the regulations shall not come into force until January 1, 1921, provided it is shown to the satisfaction of the inspector of the division in regard to any mine that it has not been practicable by that date to obtain the necessary plant for carrying out the regulations, the inspector may, subject to such conditions as he thinks fit, allow such extension of time as shall appear to him to be reasonably required.

Recently (1923) the Mines Department, which had been transferred from the home office to the board of trade, issued a pamphlet, The Application of Stone Dust in Mines, by Allan Greenwell.⁵

According to this pamphlet additional tests have been prescribed since July 30, 1920, by the board of trade for dust mixtures which contain gypsum (November 2, 1921), for moist dust mixtures, which can not be sieved (February 7, 1921), and for determining the amount of combustible matter in coal-dust mixtures which contain carbonates (February 14, 1921).

The British Government pamphlet cited above states that before the application of stone dust became a subject for legislation, the Government officially recognized and urged its use. Greenwell points out that the subject has been investigated by collieries and by mining societies,⁶ and names the following three systems by which stone dust may be employed to prevent ignition or propagation of a coal-dust explosion:

1. The maintenance throughout all mine roadways of such a proportion of combustible dust as would tend to prevent or minimize explosions of coal dust.

2. The maintenance in the workings of the mine of zones so treated with stone dust as to tend to extinguish a coal-dust explosion or to prevent extension to other parts of the mine.

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3. The provision of stone-dust barrages with the same object as system 2.

Greenwell says that the General Regulations under the coal mines act recognize only the first of the systems named and confines his paper to a discussion of that system. He says that to comply with the requirements of the General Regulations, a colliery must consider the following conditions:

1. The floor, roof, and sides of every road or part of a road which is accessible must be treated with incombustible dust in such a manner and at such intervals as will insure that the dust on the floor, roof, and sides throughout shall always consist of a mixture containing not more than 60 per cent of combustible matter. Although it is not stated in General Regulation 2 (a), General Regulation 4 (c) indicates that the percentage of combustible matter in the mine dust is to be reckoned by weight and not by volume.

2. The incombustible dust used must contain not less than 50 per cent by weight of fine material.

3. The incombustible dust must not be injurious to the health of persons working in the mine.

4. The floor of every traveling road must be cleared of dust at regular intervals of time, so as to keep it free from all accumulations of dust.

5. The regulations do not apply to the face, or to roads, or parts of roads within 10 yards of the face.

Greenwell says that Mr. Lovatt pointed out that there is no uniform method that can be used to carry out those provisions of the act that relate to the treatment of coal dust, since conditions vary at every colliery. Some roadways may have a rock roof and a fire-clay floor and others a coal roof and a coal floor. Moreover, some coals naturally create more dust than others. The dip of the beds, the method of loading the coal and of haulage, and other factors will require differences of treatment.

Anthracite is excepted from the provisions of the act, although at the Altofts gallery the ignition of anthracite dust was reported. The Welsh anthracite dust tested had a higher volatile ratio—10 per cent volatile to 90 per cent fixed carbon—than certain samples of Pennsylvania anthracite. The Bureau of Mines tests at the experimental mine did not find the latter to be capable of propagating explosions.

As Greenwell says, conditions that govern the deposition and nature of the coal dust vary from place to place and time to time, so that the adequacy of any method of treatment can only be judged by periodic examinations both of the quantity and character of the coal-dust and stone-dust mixture found on the roof, sides, and floor of the passageways. He discusses the application of stone dust.
to conform to the requirements under six heads. Abstracts of his discussion, with comments by the writer, follow:

METHODS OF DISTRIBUTING STONE DUST.

The management of a colliery can use and vary from time to time any methods that it chooses for the distribution of stone dust "provided that representative tests of representative samples" of the coal dust are made by the management at intervals of not less than once a month so that the dust on the floor, roof, and sides throughout will always consist of a mixture containing not more than 50 per cent of combustible material. Greenwell then discusses several methods which have been proposed from time to time.

DISTRIBUTION BY hand.

The stone dust is scattered from bags or mine cars, sometimes with a small shovel or scoop, over the surfaces of the passageway, or is thrown with enough force to dislodge accumulations of coal dust on timbers, ledges, and cavities.

DISTRIBUTION BY THE VENTILATING CURRENT

AUTOMATIC DISTRIBUTION.

Halbaum, in a paper published by the Institution of Mining Engineers in 1914, proposed that shallow trays of dust be placed on top of full mine cars. He contended that the stone dust would be shaken and carried away by the air currents and deposited along the passageway as coal dust is deposited.

UTILIZATION OF THE HIGH VELOCITY OF THE AIR PASSING THROUGH THE REGULATORS.

Utilization of the velocity of the air passing through regulators was tried at the Birchenwood collieries, North Staffordshire, and was claimed to be effective where the velocity of the current was high. Handfuls of dust are held where the velocity is greatest and the dust is carried away by the air current. In this way 2 hundredweight (224 pounds) of dust was distributed in five minutes.

PLACING SMALL TRAP DOORS (1 FOOT SQUARE) IN MAIN SEPARATION DOORS.

In this method, which is a modification of the preceding one, a small trap door is placed in the ventilation door of the district; when this small trap door is opened stone dust is applied, as described above.

PIPE THROUGH AIR CROSSING.

The use of pipe through an air crossing or overcast is a modification of the two methods just mentioned. A 2-inch pipe that has a valve in the intake end leads from the intake to the return side.

To apply the dust the valve is opened and the stone dust held at the mouth of the pipe. If there is enough difference of pressure, the dust is carried in a cloud along the returns.

APPLICATION OF METHODS.

These last three methods were tested at the Birchenwood collieries, but it was found that the deposit of stone dust decreased rapidly with the distance from the point of discharge, hence portable appliances were used instead.

In 1910 at the Altofts colliery, the shale-dust pulverizing machinery was installed at the bottom of the downcast shaft and by a mechanical arrangement it threw the dust into the ventilating current. The heavier dust settled on top of the coal loaded on the mine cars and on the rails, interfering with the traffic; and although the fine dust was carried a long distance the coating deposited along the passageway was too thin to be effective. Accordingly this method was abandoned and preference given to hand distribution.

The writer observed a similar arrangement of the shale-dust pulverizing machinery at the Yorkshire main colliery, which was experimenting at the time with the carrying away of floating shale dust in the air of the chamber, at times when the pulverizer was in operation, by means of large pipes opening into the strong intake current. The experiment had not proceeded long enough to determine its effectiveness. At present, in this mine, the rock dust is distributed by hand from bags.

DISTRIBUTION BY MECHANICAL MEANS.

STATIONARY APPLIANCES.

Greenwell says that “compressed-air stone-dust sprayers worked from stone-dust stations were tried at Birchenwood collieries, but they were found to be unsatisfactory” for the reason given under “Distribution by the ventilating current.”

A mechanical appliance for the distribution of stone dust by the passage of mine cars was designed by the late George Hann, Powell Duffryn collieries, South Wales. It consisted of a hopper fixed in the upper part of the haulageway, with levers attached to a sluice gate in the hopper; when a lever was pressed outward by the wheels of a passing car a fixed quantity of dust was released into the air current. Objection was raised to appliances of this character because they make dust clouds when men and horses may be passing.

SEMIPORTABLE APPLIANCES.

Semiportable appliances include the ejector type which must be coupled by a hose to a compressed-air main and draws its supply of stone dust from a car through a pipe or hose. Greenwell says that the field of action of this type depends upon the frequency of the
available coupling points and the lengths of hose found convenient. A record of work done by such an ejector, which can be used for cleaning coal dust as well as for applying stone dust, is described by Budge.\textsuperscript{10} Compressed air is very generally used in European coal mines for various purposes, such as driving coal cutters and incline hoists, and therefore is available and convenient for rock-dust distribution.

Greenwell refers to a report made in December, 1913, concerning a method of distributing stone dust at Atherton colliery, Lancashire, by compressed air. An ejector pipe was connected to the compressed-air line and one leg of the ejector put in a car of stone dust. "It was stated that very distinct traces of stone dust had been found in working places three-quarters of a mile from the point of distribution." Lovatt describes compressed-air distribution of rock dust in use at the Birchenwood collieries, which employs a line of 1-inch or 2-inch compressed-air pipes with taps every 50 yards. A 25-yard length of 1-inch flexible hose is coupled to a blower. Bags of stone dust are deposited at intervals along the roadway; then in the noncoal-hoisting shift, the stone-dust men start at the outby end of the roadway with a bag or two in a mine car and with the blower coupled to the nearest compressed-air tap dust the roof, sides, and floor as the car travels along. When they have gone as far as the flexible hose will extend, they couple to the next tap.

A similar blower is used in the Sneyd collieries, North Staffordshire,\textsuperscript{11} but instead of suction drawing up the stone dust out of the car, a funnel is fixed to the ejector and the dust falls down by gravity. The blower has two parts, the ejector and the funnel attached, is mounted on a light collapsible frame, and is capable of distributing 12 hundredweight of shale dust per hour.

\textbf{TRAVELING DUST DISTRIBUTOR.}

Greenwell lists under this head the Oldham patent stone-dust distributor. "The appliance is mounted on an ordinary mine-car truck and distributes the dust by an air blower with special blades as it is hauled along the roadway by endless rope, pony, or by hand." The stone dust is carried on the truck in a hopper that has sloping sides and a bottom outlet with a mechanical agitator to assist the dust to flow through the curved rectangular outlet-nozzle where it joins the air blast from the fan. The fan is driven from the car axles by a chain and gears. By means of a gear shift the fan may be also driven by a hand lever when the truck is stationary.

The writer of this paper observed some years ago the successful operation of a somewhat similar appliance which was developed by


the Victor-American Co. at its Delagua mine, Colorado, for the distribution of adobe dust, except that the fan was driven by an electric motor taking current from a trolley wire and the truck was hauled by an electric trolley locomotive.12

Another rock-dust distributor13 was independently designed by the writer and his associates and constructed with materials at hand at the experimental mine at Bruketon, Pa. Like the Delagua machine it made an excellent inert dust cloud.

In Bureau of Mines Bulletin 16714 it is proposed that when electricity is not available the blower fan should be driven by gear or belt from the car wheels so that the machine would operate when hauled by mule or rope. A permissible electric storage-battery locomotive or compressed-air locomotive could be used for hauling the machine in gaseous mines.

The latter two dust distributors ejected the dust through a large flexible hose so that the stream could be directed toward the roof, timbers, or sides of passageways with the effect of a sand blast, enabling accumulations of coal dust to be dislodged and crevices and cavities filled with rock dust, as pointed out in Bulletin 167. As a pile of rock dust has a steeper angle of repose than a pile of coal dust, any coal dust subsequently produced by the haulage of coal cars will tend to roll off to the floor and thus attain one of the objects of applying dust by hand, a method which on this account is considered preferable by many British mining men. The use of a flexible hose for ejecting the dust has the further advantage, named in Bulletin 167, that the hose can be put through valves in stoppages to blow dust into a parallel entry, such as a traveling way, that may have no track. To apply dust thus, arrangements must be made for driving the fan when the dusting machine is stationary. This may be done by obtaining current from power lines or from the storage battery of a “permissible” locomotive.

Nevertheless there are many places in the interior of a mine where there are no tracks or where it would be difficult to move a truck because of the normal haulage blocking the tracks; for these, taking in rock dust in bags and applying it by hand or scoop is the logical method.

BRITISH METHODS OF SAMPLING MINE-ROAD DUST.

“For the purpose of testing the composition of the dust mixture in any part of a road,” the General Regulations require that “representative samples of the dust shall be collected from the floor, roof,

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and sides over an area of road not less than 50 yards in length," and that "the samples collected shall be well mixed and a portion of the mixture sieved through a piece of metallic gauze having a mesh of 28 to the linear inch."

The manner of testing these samples is prescribed by the General Regulations and "representative tests shall be made by the management at intervals of not less than once a month and the results posted at the pit head."

The chief inspector of mines also requires that copies of the analyses be sent to the district inspector, who notes them, sends comments to the mine owner or agent if the analyses show too high a percentage of combustible, and then forwards the report to the office of the chief inspector of mines at London for review and recording.

When a Government inspector examines a colliery, he takes samples of roadway dust from floor, sides, and timbers in places where he is suspicious of the combustible content of the dust and sends the samples to the Eskmeals laboratory for analysis. If the combustible content is too high the mine management is required to stone dust that area freshly.

Greenwell comments that the regulation implies a definition of dimensions of mixed dust as material, the particles of which will pass through a 28-mesh screen (the fineness required for safety-lamp gauzes); that is, particles that do not exceed roughly one-fiftieth inch in diameter. The Bureau of Mines tests have indicated that coal dust from the Pittsburgh bed through a 20-mesh and over a 40-mesh screen is explosive when strongly ignited; hence it has adopted 20 mesh as the dividing size between coal particles and what is termed dust. The coarsest grains of dust would then roughly have a diameter of one-fortieth inch.

The British General Regulations also prescribe that at least 50 per cent by weight of the incombustible dust used (25 per cent where the dust is applied in sufficient excess) must be fine enough to pass through a 200-mesh screen, the dimensions of the particles forming the balance remaining unspecified. The regulations seem to intend that the bulk of the incombustible material used for treating the roads must pass through a 28-mesh sieve, inasmuch as the samples taken for the prescribed test to determine the proportion of combustible matter in the mine dust exclude particles larger than 28 mesh.

Greenwell discusses screen sizing, for which there is no one standard. He finds that the maximum diameter of particles that can pass through a 28-mesh safety-lamp gauze with S. W. G. wire corresponds to that for 24-mesh Institution of Mining and Metallurgy standard and 32-mesh cement manufacturers' standard. Greenwell suggests the advisability of fixing on a standard screen for the purpose.
INSTRUCTIONS IN BRITISH GENERAL REGULATIONS.

Instructions of the General Regulations regarding the collection of samples in the mine, by the mine owner or his representative, give the following requirements for the samples:

1. They are to be representative.
2. They are to be collected from the floor, roof, and sides over an area of road not less than 50 yards long.
3. The samples collected shall be well mixed. Greenwell says:

The word "representative" is truly ambiguous, **taken literally these instructions seem to imply that the final result arrived at would correspond with that which would be obtained by collecting the whole of the dust from the floor, roof, and sides of the road for a length of 50 yards, thoroughly mixing it, and taking a portion of the mixture for sieving.

From observation and inquiry, at mines visited and at the mines department, the writer concludes that the sample is usually taken as follows: Small samples are gathered in as uniform amounts as possible at regular intervals along the passageway in a 50-yard stretch, from the floor and sides and over timbers, brushed on to a sheet of paper, and screened; the part that has passed through the screen is mixed well and a portion is put in a small bottle marked with the location of the place of collection.

The sampling is sometimes done by a chemist of the colliery or his assistant, as observed at the large Bentley colliery in Yorkshire. The accuracy of the ordinary collection of small individual samples at intervals to make up the representative sample for the 50-yard length of roadway was recently tested at this colliery by collecting all the dust in a specified length and screening it. When the combustible percentage of the mixed sample was compared with that of the gross sample of all the dust, results checked surprisingly well, within a few per cent.

NEW REQUIREMENTS IN SAMPLING.

The mines department has recently issued an order requiring the submission of separate samples of the dust that adheres to the roof, timbers, and ribs—potentially the most dangerous float dust—and of the dust along the floor, for 50 yards. This distinction in the samples as between "top" and "bottom" dust instead of a composite of the two should cause quantitative sampling, otherwise a mere pinch of nearly pure coal dust may out balance a large quantity of inc combustible dust on the floor.

RESULTS OF APPLICATION OF STONE DUST AS SHOWN BY SAMPLING.

Greenwell says that records of results of stone dusting under working conditions in various mines have been too meager to furnish more than generalized conclusions applicable to a particular mine.
Requirements of the General Regulations relating to stone dusting are restricted to every road or part of a road that is accessible, and no provision is made for the dilution of coal dust that has accumulated in cavities above the roadway.

RESULTS AT BENTLEY COLLIERY.

The Bentley colliery, Yorkshire, one of the first collieries to apply stone dust systematically, took a number of samples in different parts of the mine and a year later again sampled, this time very thoroughly. A complete report of the sampling results is given in a paper by Robert Clive.\(^5\) The results for 1912 were as follows:

**Results of sampling before stone dusting in Bentley colliery, 1912.**

<table>
<thead>
<tr>
<th>Description of road</th>
<th>Number of samples</th>
<th>Average ash, per cent.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main endless-rope haulage roads</td>
<td>4</td>
<td>46.7</td>
</tr>
<tr>
<td>Traveling roads</td>
<td>4</td>
<td>51.7</td>
</tr>
<tr>
<td>Main return</td>
<td>8</td>
<td>43.1</td>
</tr>
<tr>
<td>Cross gates (very little dust)</td>
<td>3</td>
<td>38.7</td>
</tr>
<tr>
<td>Face</td>
<td>10</td>
<td>43.7</td>
</tr>
<tr>
<td></td>
<td><strong>29</strong></td>
<td><strong>44.8</strong></td>
</tr>
</tbody>
</table>

Results of the 1913 analyses are as follows:

**Results of sampling after stone dusting at Bentley colliery.\(^6\)**

<table>
<thead>
<tr>
<th>Description of road</th>
<th>Number of samples</th>
<th>Ash in samples.</th>
<th>General average of floor, sides, and roof.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Floor Sides Roof</td>
<td>Limits of variation</td>
<td>Average.</td>
<td></td>
</tr>
<tr>
<td>Floor Sides Roof</td>
<td>Per cent.</td>
<td>Per cent.</td>
<td>Per cent.</td>
</tr>
<tr>
<td>Floor</td>
<td>Sides</td>
<td>Roof</td>
<td>Floor</td>
</tr>
<tr>
<td>Endless-rope haulage... 15 15 3 58.4-91.6 54.4-90.0</td>
<td>57.3-78.7 55.2</td>
<td>72.9</td>
<td>Other haulage 8 8 2 40.8-81.5 54.4-90.3</td>
</tr>
<tr>
<td>Total and average... 77 75 20 36.3-91.6 49.3-91.1</td>
<td>42.1-89.2 65.8</td>
<td>77.8 69.6</td>
<td>71.8</td>
</tr>
</tbody>
</table>

\(^5\) Clive, Robert, Stone dusting at Bentley colliery, compiled from Tables III to VII, omitting samples from roads which had not been stone dusted. The percentages of ash were calculated from dust passing through a 90-mesh sieve.

**RESULTS AT SOUTH YORKSHIRE COLLIERY.**

Prof. J. Ivon Graham, of Birmingham University, in a discussion following a paper by R. C. Smart,\(^6\) gave the results of analyses of samples taken on main roads, with endless haulage traveling about 2½ miles an hour, in an "up-to-date" South Yorkshire pit where


stone dusting had been practiced for eight years. The figures given for the average ash content cover samples from the roof, sides, and floor that passed a 30-mesh sieve. The range of ash content for the roof samples is 53 to 82 per cent and for the floor samples 54 to 75 per cent.

**Disadvantages of Grab-Sample Analyses.**

Most of the reports on stone dusting that the writer of this paper has seen are open to the criticism that analyses of grab samples of combined floor dust, side dust, and dust from roof and timbers do not show whether or not the dust was in such quantity that an explosion would propagate through the area sampled. To obtain this information, all uncompacted dust, that is, dust that a strong blast of air would not raise, found in a belt 1, 2, or more feet wide around the periphery of the passageway should be collected and the part fine enough to pass a sieve that will pass the maximum explosive size (28 mesh in Great Britain, 20 mesh in the United States) should be weighed. This gross sample should then be screened through a finer standard screen or set of screens to determine the proportions by weight of the fine dust, which is most important in propagating an explosion. The Bureau of Mines has selected a 200-mesh screen to measure the amount of finest dust in the samples. When a sample is gathered in a mine, it is screened through a 20-mesh screen; the oversize is rejected, but the undersize is quartered down to permit putting it in a container for shipment to the laboratory. There the percentage of 200-mesh dust in the dust that passes through a 20-mesh sieve is determined. This percentage is then regarded as the characteristic size factor of the particular sample of roadway dust.

The results of course apply only to the narrow belt or zone sampled, but by taking similar samples at regular intervals the condition of the mine roadway as to the liability of an explosion originating in or being propagated through the zone sampled can be determined within the limit of error for such sampling.

On the other hand, grab samples, especially those gathered by the fingers or hand, are not truly representative. The finer dust, especially on timbers or projections, which may contain much pure coal dust, may be too fine for accurate collection in this way and the proportion of coarser dust or that too high in ash may consequently be disproportionately large in the gross sample.

**Quantity of Stone Dust Applied.**

Greenwell says that the quantity of stone dust used in the British mines has been reported as ranging from 1 to 10 pounds per ton of coal output, but points out that "for purposes of comparison, statements made upon this basis are very likely to be misleading unless they are always accompanied by particulars of the character, length, and average sections of the roads, and the average percentage of ash
maintained in the roads." He also notes that "natural conditions, as regards the presence of incombustible dust and moisture" affect the quantity.

The writer of this paper suggests that other important factors are those that relate to daily production or distribution of coal dust, as follows: (1) The friability or dust-making tendency of the coal being mined; (2) the system of mining used, whether longwall or room and pillar, and, if the latter, whether coal spalls off the coal ribs; (3) the influence of the roof and floor upon the natural mixing of shale or clay with coal dust; (4) the speed of haulage, with reference to the liability of coal dust being blown or shaken from cars; (5) the loading of mine cars, whether miners are permitted or required to "top the cars," that is, to build the coal higher than the sides, a practice which leads to much spilling of coal on the roadways and rapid making of dust; (6) the condition of tracks with respect to the liability of coal being shaken off; (7) the type of car used, that is, whether "tight end," without doors or gates.

Greenwell quotes figures from the Powell Duffryn collieries of South Wales that refer to four classes of haulage roads and illustrate how the amount of stone dusting required may vary according to conditions:

**Application of stone dust.**

<table>
<thead>
<tr>
<th>Road</th>
<th>Quantity of stone dust per annum per linear yard or road.</th>
<th>Place in roadway.</th>
<th>Number of applications per annum.</th>
<th>Quantity of stone dust per linear yard at each application.</th>
<th>Ash content maintained.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>180 Pounds.</td>
<td>Roof, sides, and floor</td>
<td>12</td>
<td>7 lbs.</td>
<td>55-65 Per cent. 50</td>
</tr>
<tr>
<td>2</td>
<td>90 Pounds.</td>
<td>Floor</td>
<td>36</td>
<td>2 lbs.</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>120 Pounds.</td>
<td>Roof, sides, and floor</td>
<td>12</td>
<td>15 lbs.</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>70 Pounds.</td>
<td>do</td>
<td>2</td>
<td>35 lbs.</td>
<td></td>
</tr>
</tbody>
</table>

*Area of road 1, 55 square feet; area of roads 2, 3, and 4 not stated.*

As the table shows, on the haulage roads alone of one colliery the quantity of stone dust required ranged from 70 to 180 pounds per annum per linear yard of roadway, and the frequency of application ranged from three times a month to twice a year.

**Preparation of stone dust.**

British General Regulation 3 requires that the incombustible dust used for stone dusting—

Shall contain not less than 50 per cent by weight of fine material capable, when dry, of passing a sieve with 200 meshes to the linear inch. Provided, that if a larger proportion of incombustible dust is used than is required under Regulation 2, the percentage of fine material contained in the incombustible dust, may be reduced proportionately but shall not fall below 25.
This requirement was based, Greenwell says, on the report of the explosions in mines committee, as follows: 17

We have already explained in our fifth report that samples of mixed dust collected from the roadways for the determination of the ash content should be sieved through a safety-lamp gauze to exclude large particles. Any incombustible dust used in order artificially to raise the ash content of the dust on the roadways, therefore, should consist as far as possible of particles capable of passing through a safety-lamp gauze.

Shales, limestones, and similar substances, which have been ground so as to pass through a safety-lamp gauze, normally contain a large proportion of much finer dust, the inclusion of which is of importance. For our experiments have shown that unless there be present not much less than 50 per cent by weight of particles capable of passing through a 200 by 200 sieve, more than one part of incombustible dust to one part of coal dust is required to prevent the ignition of the mixture by a cannon shot.

Greenwell says: 18

From this it appears that the explosions in mines committee were, broadly, of opinion—

(a) That that portion of any incombustible dust, used in order artificially to raise the ash content of the dust on the roadways, which consists of particles capable of passing through a 28-mesh gauze, is of chief importance.

(b) That in order to prevent the ignition of a mixture of combustible and incombustible dust, 50 per cent of the incombustible dust used should pass through a 200-mesh sieve; or, if the incombustible dust contains less than 50 per cent—say $x$ per cent, where $x$ is less than 50—of material which will pass through a 200-mesh gauze, then the total quantity of the incombustible dust used must be increased in the proportion of $1 + \frac{50}{x}$, for example, the quantities of incombustible dust used containing 50 per cent and 40 per cent, respectively, of material passing through a 200-mesh gauze, would have to be in the proportion of $1 : \frac{50}{40}$ or 1 to $\frac{5}{4}$.

General Regulation 3 has adopted the percentage of combustible matter in the mine dust as standard, whereas the explosions in mines committee employed the percentage of incombustible as the criterion.

The General Regulations base compliance upon two tests: (1) The percentage of incombustible that passes through a 200-mesh sieve; and (2) the percentage of combustible material in that portion of the mixed dust found in the roadways of the mine which passes through a 28-mesh sieve.

Greenwell's interpretation of these requirements is:

That if more incombustible dust is used than is required to prevent the percentage of combustible matter in the mine dust exceeding 50, or in other words, if the percentage of combustible in the mine dust is maintained at a figure below 50, then the percentage of fine material contained in the incombustible dust used may be reduced proportionately (but not below 25) * * * Thus the

17 Explosions in mines committee, Sixth report, 1914, p. 13.
explosions in mines committee approached the question from the quantitative side and advocated the presence of an excess of coarser particles of stone dust, provided the excess is in addition to the necessary quantity of fine dust; while the General Regulations approach it, rather, from the qualitative side, and permit a limited reduction of the percentage of fine particles in the stone dust provided that the prescribed tests show a proportionate reduction of the percentage of combustible matter in the samples of mine dust.

**STONE-DUST TESTING AT THE EXPERIMENTAL MINE.**

In the explosion investigations of the Bureau of Mines the effect on explosion limitation of different sizing of the stone or rock dust used was studied.\(^\text{19}\)

Pulverized shale-dust, 90 to 95 per cent or more of which passed through a 200-mesh screen, was used in nearly all the tests to determine the relative explosibility of coal dust from different seams, but a series of tests was made with coarser shale dust, 95 per cent of which passed through a 20-mesh screen and only 27 to 30 per cent of this amount a 200-mesh screen. In only one of these tests did the coarse shale dust fail to prevent propagation through a mixture that would not sustain an initiatory explosion when the fine or pulverized shale dust in the same percentage of the mixture was used. The British official specifications for incombustible dust, which require that not less than 50 per cent passes a 200-mesh screen, are on the safe side, but it is a mooted question in Great Britain whether it is best to use only the finest pulverized dust or a larger quantity of coarser stone dust containing not less than the required 50 per cent of fine incombustible dust.

If the dust is distributed by a blower there is a distinct advantage in using the finest size, which can be distributed more evenly; but for other methods of distribution larger quantities of the coarser, more cheaply ground, dust are advantageous. It is thrown more easily by hand and scoop to displace coal dust and to fill cavities, does not pack down so tightly, and takes a more uniform angle of repose; in consequence it may be more easily raised by the air turbulence of a concussion than a finer lighter dust that may tend to stick together and pack down.

Selection of one dust that can be used under all conditions is impossible. The kind of dust, the cost of fine grinding, and the method of distribution must be considered. Weight for weight when in the air fine particles quench the flame of an explosion more effectively; but if the fine particles tend to stick together after long standing in the mine, coarser particles may be more effective, provided that practically all the dust passes through a 20-mesh sieve and at least 30 per cent, preferably 50 per cent, a 200-mesh sieve.

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\(^{19}\) Rice, G. S., and others, Coal-dust explosion tests in the experimental mine, 1913 to 1918, inclusive: Bull. 107, Bureau of Mines, 1922, p. 36.
CLASSIFICATION OF GRINDING MACHINES USED IN GREAT BRITAIN.

Greenwell says: 20

The machinery for preparing stone dust for use in coal mines may be arranged under two principal heads, with subdivisions:
1. Impact, or percussion action with or without grinding:
   a. Beaters or hammers which strike the material in suspension and beat or grind it against the lining plates.
2. Grinding action:
   a. Pestle and mortar.
   b. Balls working in a revolving drum lined with stepped plates. The balls fall from plate to plate and crush the material. There is also a grinding action between the balls and the plate.
   c. Balls and ring.
   d. Disks and projecting pins.
   e. Roll and ring.
   f. End runners.

Greenwell describes machines of each class. Most of the types of machines he lists are manufactured in the United States. This is especially true of those most used, such as the impact machine, hammer crusher, the pestle-and-mortar, balls working in a revolving drum, and balls and ring. In Great Britain more pestle-and-mortar grinders are now used for “stone-dust” grinding than any other type. The following table, abstracted from a table in Greenwell’s pamphlet, 21 names and gives specifications for machines of American design most used in British mines.

List of machines of American type for the manufacture of stone dust in use in British coal mines.

<table>
<thead>
<tr>
<th>Maker of machine</th>
<th>Name and size of machine</th>
<th>Type</th>
<th>Feed (size)</th>
<th>Output per hour</th>
<th>Power required</th>
<th>Fineness, per cent through 200 mesh</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Bradley Pulverizing Co.</td>
<td>Griffin 30-inch</td>
<td>Pestle and mortar</td>
<td>Up to 1-inch cube; moisture up to 2 per cent</td>
<td>25-30</td>
<td>23</td>
<td>80-90</td>
<td></td>
</tr>
<tr>
<td>2 Fuller Engineering Co.</td>
<td>Fullert-Lehigh pulverizer, 24-inch</td>
<td>Ball</td>
<td>Up to 4-inch ring; moisture up to 6 per cent</td>
<td>9-11</td>
<td>10-12</td>
<td>50</td>
<td>Three larger sizes also made.</td>
</tr>
<tr>
<td>3 Jeffrey Manufacturing Co.</td>
<td>Jeffrey lime mill, pulverizer, No. 2</td>
<td>Impact, combined jaw-breaker and pulverizer</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 Hardinge Co.</td>
<td>Hardinge conical mill, 3-foot</td>
<td>Ball</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Three larger sizes also made.</td>
</tr>
</tbody>
</table>

* The particulars given in columns 4 to 7 refer to the size of machine stated in column 3. Also as shaler the material most commonly used for the manufacture of stone dust for use in mines, the particulars given refer to shale, unless otherwise stated.
  a Column 3. Name of machine.
  b Column 4. Type of machine.
  c Column 5. Feed size.
  d Column 6. Output per hour.
  e Column 7. Power required to drive the machine, so as to give continuously the output stated in column 6.
  f Column 8. Fineness of the material.
  g Column 9. Remarks.

  Work cited, p. 28.
  h Work cited, pp. 50-51.
Undoubtedly many other American grinders or pulverizers capable of doing good work are not in use in Great Britain or are not listed in Greenwell’s report. The Bureau of Mines installed at its experimental mine in 1912 a small-capacity Raymond pulverizer with a closed air-circuit system. The pulverizer itself, of the impact or beater type, was primarily installed for making coal dust, but is also used for pulverizing shale.

**EFFECT OF VARIOUS STONE DUSTS ON HEALTH AND EFFICIENCY.**

The British General Regulations say:

No dust shall be used for the purpose of complying with these regulations of a kind that may be prohibited by the Secretary of State on the ground that it would be injurious to the health of persons working in the mine; provided, that if any dispute arises whether the dust is injurious, it shall be determined in the manner provided by the act for settling disputes.

Greenwell says that when any question arises as to the suitability of a particular dust, the initiative rests with the government and unless the conclusion is obvious a decision is difficult because expert opinion is seldom unanimous.

A circular to accompany the issue of the General Regulations for August, 1920, contains an opinion by the celebrated physiologist, Dr. J. S. Haldane, of Oxford, quoted from the seventh report of the explosions in mines committee, on the effect of different kinds of dust when breathed. This report states:

That shale dust may be used quite safely and that powdered clay or chalk (free from flint or grit) is also practically harmless. On the other hand there are two kinds of dust, the use of which may be injurious to health, namely (a) dust from stones such as ganister or sandstone, which contain a large proportion of free crystalline silica, and are liable to break up into fine sharp-edged particles (such dust may cause serious risk of phthisis), and (b) dusts of a gritty nature, such as powdered slag, clinker, or flue dust, which, though possibly not injurious to the lungs when mixed with coal dust, may produce considerable irritation to the eyes and throat and predispose to bronchial ailments.

**CHARACTER OF DUST AS AFFECTING EFFICIENCY IN EXPLOSION PREVENTION.**

Several kinds of dust were tested at Eskmeals under the direction of Dr. R. V. Wheeler. From these tests the explosions in mines committee concluded “that the fineness of an incombustible dust rather than its chemical composition affords a measure of its probable effectiveness in preventing the ignition of coal dust with which it may be mixed.”

The writer infers the committee made the assumption that the condition and character of the dust when applied were such that the dust would not adsorb moisture enough from the air to cause it to stick

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24 Greenwell, Allan, work cited, p. 32.
25 Work cited, p. 34.
together, and it would not be so unstable chemically that its physical characteristics would be changed. In other words, the committee seems to have assumed that the dust would always be in such condition that it would be raised into the atmosphere by a concussion or the blast of air that precedes an explosion.

The committee tested fuller’s earth, fuller’s earth substitute, shale dust pulverized in a disintegrator, extra superfine dolomite dust, oölite stone dust (containing 97 per cent of calcium carbonate), and “Chance’s mud.”

In each case the whole of the dust would pass through a safety lamp gauze (28 by 28 sieve) and between 80 and 90 per cent by weight could pass through a 200 by 200 sieve.

Other materials experimented with include sand, Altofts shale, flue dust, and gypsum.

All of these materials but sand successfully prevented propagation. Sand, of which only 4 per cent passed through a 200-mesh sieve, was unsuccessful, even in proportions of three to one of coal dust.

The British Mines Department, in a memorandum of February, 1921, refers to “Chance’s mud” as follows:

Among the materials suitable for stone dusting mine roads, attention has recently been drawn to “Chance’s mud,” a carbonate of lime product which, when dried, forms a very fine powder. The Secretary for Mines is advised that this material appears to be generally suitable provided that it does not contain more than a trace of free sulphide. He desires to warn mine owners and managers, however, there is danger of the emission of sulphured hydrogen (as by chemical reaction with acid waters), and such material should therefore be tested periodically for free sulphides before it is used.

POSSIBLE DANGER TO HEALTH.

Referring to experiments by Doctor Haldane, Sir Henry Cunynghame, chairman of the explosions in mines committee, said in his introduction to the seventh report (July 23, 1915) of that committee: “His investigation has shown that dust of argillaceous shale such as is found interstratified in the coal measures in most mines of the United Kingdom is being extensively used for stone dusting; although it contains silica, it is not in the least likely to prove a danger to health.”

The writer of this paper had the opportunity in 1923 of discussing this question with Doctor Haldane, who said he was of the same opinion as in 1915, although he is continuing his physiological experiments on the effect of various dusts on animals. Doctor Haldane also pointed out that even when there was some free silica in the shale, the percentage in the aggregate road dust was lessened by the coal dust present, and furthermore coal dust seemed to have a neutralizing effect physiologically.

* Work cited, p. 34.
STONE DUSTING IN GREAT BRITAIN.

No reports of serious effects on health from stone dusting have been received from collieries that have used it 8 or 10 years, or from Altofts colliery, where it has been used 16 years.

LABORATORY METHODS.

The determination of whether a mine-dust sample, apart from being within the sizing requirement of the British regulations, meets its specifications of not having more than 50 per cent of combustible matter, is not always as simple as it seems. The procedure for analyzing samples collected by Government inspectors is defined by General Regulation 4(c) as follows.\(^\text{28}\)

A weighted quantity of the dust which has passed through the sieve shall be dried at 212° F. and the weight lost shall be reckoned as moisture. The sample shall then be brought to a red heat in an open vessel until it no longer loses weight. The weight so lost by incineration shall be reckoned as combustible matter for the purpose of the test; providing that in the case of dusts to which the foregoing tests would not be applicable, the test shall be such as may be prescribed; if any dispute arises as to the test which shall be applied it shall be determined in the manner provided by the act for settling disputes.

British General Regulation 2 provides "that the percentage of incombustible dust required under this regulation may be reduced by an amount equivalent to the percentage of water present in the moisture." For example, if moisture of the road dust as finally treated was 6 per cent (including, in accordance with the regulations, all moisture indicated by drying at 212° F.), only 44 per cent of dry stone dust would be required in the treated road dust, provided the stone dust was free from combustible matter.

Greenwell suggests that, under the provisions in the regulations named above,\(^\text{26}\)

The estimation of the combustible matter after the dust has been dried at 212° F. discriminates between the total of the moisture removable by "air drying" and the "hygroscopic" moisture, on the one hand, and the "combined water" or "water of hydration" on the other hand, the former being counted as "incombustible matter" and the latter being included in the "combustible matter." This is on the safe side in making the combustible percentage really less than the 50 per cent allowed.

A special test has been prescribed by the Board of Trade for dust mixtures that contain gypsum, the object being the inclusion of the "water of hydration" (which is considerable) under the head of moisture, as computed by General Regulations 4(c). * * *

An alternative procedure has been prescribed by the Board of Trade (February 7, 1921) for the purpose of testing the composition of samples of dust mixture which contain such a high percentage of moisture that the mixture cannot be sieved in the manner prescribed by the General Regulations.

This alternative procedure is merely to dry the dust before, instead of after, sieving, and seems to assume that the loss in weight of the part that passed the screen had the same percentage of loss as the gross sample. Such an assumption is only approximately correct, as fine dust entrains more moisture than the oversize rejected. However, the procedure gives a small additional factor of safety.

\(^*\) Work cited, p. 35.
METHODS OF ANALYZING STONE DUST OTHER THAN SHALE DUST.

When the stone dust consists of or contains carbonate of lime or other carbonates, part of the loss in weight through incineration of the dust mixture is due to the loss of carbon dioxide from the carbonates and should not be included in the percentage of combustible. The board of trade prescribed (February 14, 1921) the following procedure "for determining the amount of combustible matter in dust mixtures which contain carbonates."

1. A weighed quantity of the dry dust shall be heated to insure complete decomposition of the carbonates in an open vessel, until it no longer loses weight, and the percentage loss of weight shall be determined.

2. A weighed quantity of the dried dust shall be treated with dilute acid in a suitable apparatus and the percentage loss of weight due to the evolution of carbonic acid gas shall be determined.

3. The difference between the two percentage losses of weight, so determined, shall be reckoned as the percentage of combustible matter for the purposes of the test.

The board of trade, on November 2, 1921, prescribed a special procedure for testing the composition of samples of dust mixture that contain gypsum. This calls for drying of the mixed dust at 275° F. instead of 212° F., "in order that the moisture content may include the considerable quantity of 'water of hydration' contained in the gypsum in the mixture."

The foregoing paragraphs quoting regulations and orders of the British Board of Trade and prescribing analytical procedure in the analysis of dust samples from mines refer primarily to samples gathered by inspectors in the course of their work but are not mandatory with respect to the sampling and analysis methods used by mine owners.

Regulation 4 requires that "representative tests shall be made by the management at intervals of not less than once a month, and the results shall be posted at the pit head."

Greenwell says:

The procedure is governed only by the general provisions in the regulations and the methods employed at the different collieries vary both as regards the collection of the samples, manner of transmission, and subsequent examination.

Until the method of taking mine samples is made uniform and based on scientific principles the element of error at that stage is so preponderant as to make the results of subsequent laboratory examination of little value as an indication of the safety of the mine in question, so far as the absence of coal dust in dangerous quantity is concerned.

Greenwell then quotes reports on other methods of analysis or determination, describing at length the volumeter designed by Taffanel.
which is much used by the French. A description of these methods would be too long for inclusion in this paper. The volumeter has been described in Technical Paper 144,\(^2\) Bureau of Mines, with modifications proposed by the authors of that paper.

A consideration of the relative accuracy of different chemical and physical methods of determining combustible matter in the dust is beyond the scope of this report. For the present the usual simpler laboratory methods seem best adapted for American mines that are taking up stone dusting or rock dusting for the first time.

When stone or rock dusting is first begun the service of a chemist is important. After the use of a certain type of incombustible dust has been well started, however, and various trial analyses have been made, the procedure can be so simplified that any person of good intelligence can be trained to sample, weigh, screen, dry, and incinerate that same kind of incombustible dust so long as it is used, if occasional duplicate samples are sent to a chemist for checking. Undoubtedly, as Greenwell points out, the standardization of sampling methods is most important. There is a greater chance for error in sampling than in laboratory work, especially if the sampling is done by an untrained man.

STONE-DUSTING OR ROCK-DUSTING METHODS OBSERVED IN BRITISH, FRENCH, GERMAN, AND BELGIAN MINES.

In the preceding section the writer reviewed the mines department stone-dusting regulations and orders and the interpretations thereof, by Allan Greenwell. Some notes on the writer's observations in the course of visits to British, French, and German mines follow.

GREAT BRITAIN.

Stone dusting seems now to be thoroughly accepted in principle in Great Britain. From the writer's observations in 1908 and 1911, wetting coal dust by watering or humidifying mines to combat danger from coal dust, the only method recognized prior to the introduction of stone dusting, was never fully accepted or thoroughly carried out by mine managements.

Most British mining engineers and practical mining men believed that watering would cause a great deal of trouble in deep dry mines from the slacking of the roof and ribs and the heaving of the bottom, and hence would cause loss of life from numberless small accidents due to roof falls that would exceed the loss due to occasional disastrous coal-dust explosions. Tests made in some British mines tended to verify estimates of the damage caused by watering.

As soon as favorable reports on the efficacy of stone dusting were received following the Altofts and Eskmeals explosion tests and stone dusting was officially sanctioned by the Government, many important mines, particularly those in the extensive Yorkshire field, began to apply stone dust as an explosion preventive. A number of disastrous explosions in various parts of Great Britain hastened that action.

The World War interrupted investigations and new installations, but after the war the mines department resumed research vigorously and the regulations quoted in previous sections were promulgated. The mine owners in most districts where the mines were naturally dry throughout complied with the regulations willingly, although opinions differed as to the manner and extensiveness of application needed for each mine.

DIFFICULTIES IN SOUTH WALES AND SCOTLAND.

There were particular difficulties in applying stone dust adequately in some mines of two important districts, South Wales and Scotland. Operators of some mines in South Wales contended that it was not practicable to keep the roadways stone dusted, because poor roof conditions necessitated constant repairs and changes in the roadway. They also asserted that stone dusting was not always necessary because natural spalling of the shale roof and pack walls made enough stone dust to neutralize the coal dust.

In Scotland many mines are wet or damp or have damp places. Some of the operators of such mines contended that under the terms of the law stone dusting was not required in their mines; moreover, that it was not needed because dry coal dust was generally absent.

Numerous disastrous explosions that involved propagation by coal dust have occurred in the last few years in mines in various parts of Great Britain where some places were so damp that stone dusting was not thought necessary or was done inadequately, and these have largely changed the attitude of most mining men. There is now no open contention that mere dampness is an adequate preventive.

On the other hand, no coal-dust explosions have occurred in mines that were thoroughly stone dusted. Although enough time has not yet elapsed to make this convincing, the immunity so far experienced is most favorable. As stated before, the method is now fully accepted in Great Britain as an efficient preventive.

COMBINATION OF WATERING AND STONE DUSTING.

Some competent persons who concede that stone dusting is effective think there should be some less cumbersome means of protecting a mine against explosions. Others favor a combination of stone dusting and watering, since less water (30 per cent) than stone dust
(50 per cent plus) is needed to be effective. For example, the district inspector of mines for South Wales, in his annual report for 1922, says:

The inspector calls attention to the advisability of continuing the watering of main roadways instead of relying entirely upon stone dusting, and especially to the watering of journeys (trips of mine cars) as they leave the double partings. This combination of watering and stone dusting, especially where the latter is carried out with circumspection and common sense, will go far to eliminate the danger of an explosion spreading throughout a mine.

Unquestionably, the use of strong sprays to wash down the dust as the loads pass under will help to keep coal dust from blowing off and contaminating the roadway, but the author doubts the wisdom of attempting to water roadways where stone dusting is systematically done, for that would destroy the effectiveness of stone dusting. Bureau of Mines tests at the experimental mine indicate that if stone dusting is merely used as an aid to watering it will tend to retard the drying of the road. In general, however, it does not seem best to combine the two systems, except for washing down dust into the body of the mine car, as mentioned above.

STONE DUSTING IN MINES VISITED.

The writer visited typical mines in all the chief coal fields. Stone dusting was employed in these with varying degrees of thoroughness except in Welsh anthracite mines. Dust protection is not required in anthracite mines. In the United States also anthracite dust has not been found dangerous.

YORKSHIRE.

Practically perfect application of stone dust was found in several large modern collieries in South Yorkshire, where every passageway, whether traveling road, air course, or haulageway, was stone-dusted from the shaft bottom up to near the face. In one of these mines there was noted a slight amount of coal dust that had been jarred off cars in switching and bumping loads on the bricked floor and trackways at the shaft bottom, but the hazard therefrom seemed negligible in a mine that does not use trolley locomotives nor open lights and has concrete or brick walls along the shaft bottoms and main roadways.

In an older mine, where the tipple and screening building was close to the shaft—an arrangement not permitted in new mines—a film of coal dust was observed which had been carried by the intake air current down the shaft and through the shaft bottom.

Practically no coal dust was observed in by the shaft bottoms in these Yorkshire mines until the longwall face was reached. Stone dusting is carried to within about 10 yards of the face. Stone dusting of the face itself is not required and is deemed impracticable and unnecessary.
In these mines the stone dust was largely distributed by hand, that is, thrown forcibly by handfuls upon the timbers and sides of the passageway and strewn on the bottom. These mines were using shale dust that was grayish, so that where considerable coal dust was present it darkened or blackened the shale dust, and the officials stated that they could judge by the color when the road should be cleaned and new dust laid. One official claimed that he could judge within 10 per cent of the combustible content. In general, these mines tried to keep the average content of incombustible higher than 70 per cent.

Throughout Yorkshire each colliery generally has its own grinding plant. Some colliery companies have one grinding plant for supplying several of their mines. For making dust Yorkshire collieries generally use roof shale that has been brushed from roadways to obtain enough height. This shale is hoisted to the surface and sent to the grinding plant; the ground shale dust is returned in tubs (mine cars). At some mines the dust is sacked so that it can be carried to places where there are no tracks or where it is inconvenient to haul the dust in mine cars. At two mines the crushing plant was underground, but that arrangement was exceptional. The operators thought that by installing it underground they would have the advantage of some natural distribution of the stone dust by means of a ventilating current through the grinding room. Moreover, the shale did not have to be hoisted to the surface and then sent back when powdered. However, most engineers considered that this arrangement was not so satisfactory because of the cramped quarters for the crushing machinery.

Another mine in South Yorkshire used gypsum purchased in dust form, which made a very satisfactory coating and decidedly improved the illumination in the mine. In general, stone dusting is thoroughly done in Yorkshire.

LANCASHIRE.

In one Lancashire mine visited the roadways were thoroughly stone dusted with shale dust. At one time this mine tried a calcium carbonate residue from chemical works, but had some trouble from the caustic soda in it. The wetness of the material when first distributed was another disadvantage. In the shaft bottom of this mine much coal dust was observable on the floor, and in the roadways near the faces the blackness or darkness of the dust indicated that the combustible content had reached the permissible limit.

SCOTLAND.

Various practices were observed in several Scottish mines. One of the mines was well stone dusted with shale dust that was ground locally. Some parts of other mines were naturally wet and there
seemed to be no danger from coal dust—that is, no coal dust was seen on timbers or floor. On the other hand, at other places in the same mines reliance seemed to be placed on slight dampness and a certain amount of admixture with clay from the floor or the roof. In these places the coal-dust hazard seemed distinct, especially in mines where there was gas. Undoubtedly great improvement can be made in mines of this type, especially where much blasting is done in the coal. In spite of the fact that in Great Britain when blasting is done in coal a small charge of properly stemmed permitted explosive is supposed to be used always, it was officially reported that miners have been guilty of using fine coal for stemming—a contributing factor in a recent explosion.

SOUTH WALES.

In the important steam-coal district of South Wales some of the mines visited were thoroughly stone dusted, in others the dusting seemed imperfect, but in certain of those mines not much coal dust was observable. Probably it was more or less buried by dribblings from the roof, but coal dust was seen near the face and on the sidings and shaft bottom. The writer's impression was that there was a distinct hazard from coal dust in these mines in comparison with the thoroughly stone-dusted mines. The shale dust used was sometimes so dark that it was difficult to decide whether or not the mixed dust was contaminated with coal dust. This is a distinct disadvantage, as compared to the use of light colored dust.

BRITISH INSPECTION METHODS.

In one of the northwest districts of England the writer visited an extensive pillar-and-stall mine where an explosion had occurred. Watering had been practiced in this mine, but its inadequacy had been plainly indicated by the explosion. At the time of the author's visit stone dusting had been introduced, but had not been done thoroughly enough to satisfy the Government inspector. The members of the British inspection service, from the chief inspector of mines, Mr. Mottram, to the subordinate inspectors, are fully alive to the importance of adequate stone dusting, and their alertness should be an inspiration and example to the mine-inspection forces of other countries, including the United States. On their regular inspection rounds they gather samples of road dust which they send to the Eskmeals laboratory for analysis. From 15 to 40 samples are usually sent in monthly from each district. These are check samples from areas that are considered from visual inspection to be most dangerous. They are taken to determine whether a colliery is keeping the combustible content of the dust below 50 per cent and incidentally to check the dust sampling and the analytical reports thereon required monthly from each colliery. Most of these inspectors' sam-
amples, however, show a high enough, or just high enough, degree of protection under the law; that is, they have less than 50 per cent of combustible content. Should they show more, orders are immediately given to the mine to redesul the area sampled.

MATERIALS USED FOR STONE DUSTING.

Most of the collieries use shale dust, made by grinding roof shale from the mine or from some neighboring mine. In some South Yorkshire mines this roof shale is light colored and is not injurious to the health of miners. Other collieries do not have a shale so suitable for making dust; it has either too large a proportion of sharp quartz particles or contains too much carbonaceous matter. These collieries buy stone dust. If any dust is questionable, samples are sent to the health authorities for determination.

Limestone dust is used to some extent, especially in Scotland, and a few collieries buy gypsum dust. Both of these dusts have the great merit of whiteness. Where dust is purchased, however, there seems to be a tendency to use it less freely than where it is provided by the colliery grinding plant.

Considerable flue dust was used when stone dusting was started, but miners complained that it affected their breathing. The medical board found that it was injurious to health, hence it is only used now occasionally to supplement other kinds of dust.

EFFECT OF STONE DUSTING ON HEALTH.

When stone dusting was first introduced in British mines its possible effect on the health of miners aroused misgivings. Operators remembered that dust had been injurious to the lungs of workers in Cornish tin mines, in the ganister mines of England, and in gold mines of the Rand in South Africa. While siliceous quartz dust was known to cause high mortality, it was not definitely known at the time whether dust from shale and other proposed materials that contained free silica, sometimes in large proportions, would injure coal-mine workers. Coal dust itself does not appear to be unhealthful to breathe in the quantities usually encountered in mine air.

Coal miners are less liable to inhale artificially ground stone dust than metal miners are to inhale siliceous dust, due to the difference in working conditions. In metal mines the bulk of the siliceous dust is made by drilling and blasting at the face where most of the men are working. In coal mines most of the workers are also at the face, but stone dusting is expected to be done only in the roads and passageways back from the face.

In mine explosions, the propagation of flame by the fine coal dust along roadways has developed explosion waves of great violence, and some explosions have carried these waves to all parts of a mine.
Investigations made at disasters and in experimental tests afforded ground for the belief that an explosion would not propagate along long-wall faces when coal dust was fresh, and most of it coarse and admixed with particles of shale from the roof and partings or with clay débris; moreover, in mines worked by the pillar-and-stall or room-and-pillar system the face workings would be separated by stretches of stone-dusted roadway; hence it does not seem to be essential to stone dust at or along the coal face.

However, it must be conceded that men engaged in transport and road-repair work on haulageways and all men traveling between the shaft and their working places are forced to breathe dust distributed along manway roads.

The question has been studied by Dr. J. S. Haldane and his associates, and an abstract of his preliminary report has already been given (p. 21).

While visiting British mines the writer noted that when he walked along roadways thoroughly stone dusted inappreciable amounts of stone dust rose high enough in the air to be breathed; even the maximum amount of dust rising in the air was less than that in dust clouds often met during travel over an unpaved country road. Tubs in British mines move slowly and do not stir up dust. In most of the mines the main haulage is by endless rope, with a traveling speed of only 2½ to 3 miles per hour, and the secondary haulage is by tail rope at not more than 4 miles per hour. In some mines the gathering is by ponies or horses. The tramp of their hoofs stirs up stone dust more than does rope haulage.

The only serious complaint heard was not of possible injury to men but to horses. In one colliery visited in South Wales the under manager said he had found that some of the mine horses that worked on stone-dusted steep grades became short-winded. A horse pulling hard on such an up grade lowers his head for balance, so that his nostrils are close to the stone-dusted ground. This was, however, the only direct complaint heard in visits to a large number of stone-dusted mines.

Miners were asked how stone dust affected them. They said that it dried their throats and made them thirsty, but face workers encounter dust in the air stirred up by the travel of many men only when going in and coming out of the mine on the traveling way. The men who work on the haulage roads, especially horse or pony drivers, are more exposed, but the writer heard no complaint, nor had the high officials of miners' organizations whom he saw, and they are always conversant with any complaints of constituents reporting serious trouble.

The attitude of miners was well shown by witnesses at the inquiry into the Maltby colliery mine fire and explosion, who said that when
certain roadways had been especially stone dusted during fire fighting as a precaution against an explosion, workers liked it because it made them feel safer. This stone dusting did prevent propagation of a mine-fire gas explosion and thus saved men working at a distance from the fire area.

The most important indirect evidence is that no claims for compensation have been made to the compensation board on account of lung troubles caused by stone dusting, although there has been a constant increase in individual demands for compensation for various occupational ailments, real and fancied.

Judged from experience at many large British mines for over 10 years, it would therefore appear that stone dusting does not endanger health if care is exercised to use a suitable material.

**COMMENTS ON BRITISH COAL-DUST STANDARD OF REQUIREMENTS.**

The maximum proportion of combustible material fixed by the British authorities, 50 per cent, which must not be exceeded in the dust found in the mine, seems very low as compared with the standards determined by the tests at the experimental mine of the Bureau of Mines, especially as the British standard ignores any fire damp that may be present in amounts below the explosive limit. The bureau's tests indicated that each per cent of methane in the air required 2 to 5 per cent more of stone dust to offset it. The Colliery Guardian of October 5, 1923, reports that in recent tests at Eskmeals with dust from the Ayr-Hard seam of Scotland a mixture containing 50 per cent of incombustible dust (fuller's earth) was ignited from a blown-out shot. If 6 per cent be allowed for the ash plus moisture content of the coal, ignition in the above tests took place with about 47 per cent combustible. \[ \frac{5}{100} - \left( \frac{6}{100} \times \frac{1}{4} \right) = 47 \text{ per cent.} \]

Furthermore, the British standard deals with preventing the ignition of dust rather than preventing the propagation of an incipient explosion. For the most explosive (pulverized) American coal dust the combustible content of road-dust mixture must not exceed 40 per cent to prevent ignition and 30 per cent to prevent propagation. As the British use the ignition standard, the Bureau of Mines standard seems to require about 10 per cent more stone dusting than the British for the same purpose. However, these limits were determined for pulverized dust, and the limits of coarser dusts, such as are usually found in mines, are, say, 10 per cent lower (that is, require less incombustible to neutralize the coal dust). Furthermore, the British regulations set 50 per cent as the *maximum* allowable; whereas it is found that the majority of samples taken in British mines show *less* than 40 per cent combustible. The British minimum requirement therefore seems to be safe for all but the most inflammable
coal dusts, or the less inflammable dusts when there is liable to be more than 0.5 per cent of methane in the air. Under either of these conditions it will be wise under American conditions to keep the combustible content in the road dusts less than 40 and in gaseous mines less than 30 per cent. Tests of the relative explosibility of coal dust of a typical mine in each coal bed in every mining field are desirable to determine the proportion of rock dust that must be added to make the dusts nonexplosive in roadways of the coal beds concerned.

QUANTITY OF STONE DUST USED AND COST OF APPLICATION IN BRITISH MINES.

As has been said, it is impossible to give a definite and generally applicable figure for the quantity of stone dust required because of the wide variations in such factors as the size of the mine, the underground conditions, the rapidity with which coal dust is made each day, and the natural addition of inert matter; another and important factor is the variation in character of the coal dust itself with respect to sensitivity to ignition and relative ease of propagating an explosion. From time to time, however, statements concerning individual mines and the cost of application have appeared in British technical papers. The range is very wide. The first estimate, relating to the Altofts colliery, appears on page 115 of the "Record of the First Series of British Coal-Dust Experiments." The cost of grinding, including labor, steam, depreciation, and repairs, is said not to exceed 2s. (48 cents, on the basis of exchange at that time) per ton of stone dust ground. The dips of the coal beds at the Altofts colliery are low and the beds are very regular as compared with many British mines.

The tools used are two buckets and a shovel. Small tin scoops with handles have been tried, but without any advantage, since the dust spreads better and is thrown straighter with the bare hand. The quantity of dust used on the first application is about three-fourths hundredweight (84 pounds) per yard. Two lads are able to dust about 125 yards per shift. These lads are paid 4s. 5d. ($1.06) per day. The cost of treating such roads is therefore:

\[
\begin{align*}
\text{Per yard.} & \quad 0.85d. \\
\text{Wages underground} & \quad 0.85d. \\
\text{Cost of preparing dust, three-fourths hundredweight, at 2s. per ton} & \quad 1.00d. \\
\end{align*}
\]

If the whole of this length (referring to haulage roads) were dressed twice a year, the cost of dressing works out at a cost of one-eighth of a penny (0.25 cent) per ton of coal raised.

In the same report costs are given for steep underground workings at the New Moss collieries, Ashton. "The average gradient of the New Moss is 19°." At this mine two men distribute the dust from "two tubs in three hours, the length of the roadway covered being 25 yards. Their wages per day amount to 10s. 9d. ($2.58). * * *
the cost for putting on two tubs of stone dust is * * * 2d. per yard of roadway."

"Since the output from the colliery is about 420,000 tons per year, the cost of dressing with stone dust per ton of coal raised works out at about one-tenth of a penny (0.2 cent)."

In a paper on stone dusting at the Bentley colliery Robert Clive says that in the first application the quantity of stone dust required was between 56 and 224 pounds per linear yard of roadway. The following cost figures are given:

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<tr>
<th>Cost of preparing and distributing a ton (2,240 pounds) of stone dust.</th>
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<tr>
<td>Cost of sorting and grinding</td>
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<td>Cost of depreciation in plant and power</td>
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<td>Cost of hauling and cleaning up place</td>
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<tr>
<td>Cost of application</td>
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<tr>
<td>Total</td>
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Cost of stone dusting per ton of output of the coal, 0.2d. (0.4 cent).

In the discussion of the above paper W. D. Lloyd of the Altofts colliery stated that at Altofts "one youth about 20 years old was spreading six tubs, containing in all 60 hundredweight (6,720 pounds) of dust per shift." He also stated that "at Altofts stone dusting could be done at one-tenth of a penny per ton of coal production."

The foregoing figures relate to pre-war costs which were only one-third to one-half of post-war costs; moreover at Altofts, where the roof shale flakes off readily, the air courses were naturally stone dusted, which reduced the cost of the general application much below that in most collieries. A letter to the author, dated June, 1923, says with reference to a Scottish colliery that the cost of stone dust made from crushed shale was 6s. ($1.38) and cost of the stone dusting itself was 0.26d. for the materials per ton of coal produced and 0.28d. for the labor of spreading the dust and cleaning up the roads preparatory to dusting, a total of 0.54d. (about 1 cent) per ton of coal output.

A letter dated September 19, 1921, on the cost of stone dusting in a large colliery in the Midlands where Hulley stone-dusting machines were used, says that four men were required and the average number of yards of road dusted weekly was 12,000. The amount of stone dust necessary for this length of roadway was about 5 to 6 tons, and the management estimated that about 10 hundredweight (1,120 pounds) of stone dust is spread over 1,000 yards of roadway per week. "The average percentage of combustible made, found in the samples taken week by week, was 70 per cent." The stone dust used contained 70 per cent of 200-mesh dust. The cost of stone

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dusting, the management says, was considered less than 1d. (2 cents) per ton of coal raised.

These figures relate to stone dusting in the longwall mines, generally those where low-velocity haulage and tight-end mine cars are used, and the coal is not "topped" above the sides. The longwall system is used almost universally in Great Britain. Some information on the quantity of coal dust scattered daily along roadways of a mine by various agencies might be obtained from the quantity of stone dust required as compared with the output of coal. At the Bentley colliery—mentioned before as being one of the first collieries to adopt stone dusting and one where dusting is done efficiently—about 24 tons of shale dust are used and about 5,000 to 6,000 tons of coal hoisted daily. That is about $24 \div 6,000 = 0.004$ ton of 2,240 pounds = 9 pounds of stone dust used per ton of coal produced. The proportion of ash in the samples of road dust was reported to range between 60 and 90 per cent, and will be assumed to have averaged about 75 per cent. Before stone dusting was done in this colliery samples gathered in the roadways averaged 47 per cent ash (see p. 15). Accordingly the combustible matter plus moisture would be 53 per cent. Allowing that the pure coal averaged 6 per cent ash, then the pure coal dust present before stone dusting would have made about 56 per cent of the roadway dust and the natural stone dust 44 per cent. After stone dusting had been done the assumed average sample contained 75 per cent ash, which was made up of artificial and natural stone dust and ash of the coal itself. Thus 100 units of road dust after treatment would contain:

\[
\begin{array}{ll}
\text{Constituents of treated road dust.} & \text{Units.} \\
\text{Combustible free from ash} & 25 \\
\text{Artificial-stone dust} & 75 \times (100 - 47) = 40 \\
\text{Natural stone dust} & 75 \times 44 = 33 \\
\text{Coal ash} & 75 \times 3 = 2 \\
\text{Coal} & 25 + 2 = 27 \\
\end{array}
\]

As 9 pounds of stone dust is used per ton of coal produced, then if $x$ equals the pounds of coal dust made per ton of coal hoisted, $x:9:27:40$, and $x=6$ pounds. Therefore in a single day in that mine there is produced about $6 \times 6,000 = 36,000$ pounds = 16 tons of coal dust (through 28 mesh) which was spread along the mine roads. It must be understood that this figure is a rough approximation and is merely intended to give an idea of the amount of coal dust made daily in a large British mine.

An average American mine using the prevailing room-and-pillar system and comparatively strong blasting shots would probably make more coal dust at the face and, through the topping of the cars, the use of car doors instead of tight-end cars, and rapid
haulage, more dust would be scattered and ground under the wheels each day than at an average British mine. This difference must be considered in comparing requirements.

The writer was unable to obtain any records of amounts and costs of stone dust found necessary in British mines using the pillar-and-stall or more rarely used room-and-pillar system. In fact, few of the mines visited kept records on stone dusting. It was simply accepted as one of the things which must be done and included with other expenses for mine maintenance. At all events, it is safe to say that the cost of stone dusting under British conditions is insignificant as compared with other mine expenses. According to statistical reports, the cost of coal production during the 12 months ending June 30, 1923, ranged in the different districts from 10 to 20s. ($2.30 to $4.60) per ton of 2,240 pounds.

The cost of grinding shale for dust manifestly depends upon the degree of fineness of the dust. A manufacturer of grinding machinery states that for 85 to 90 per cent of the dust to pass through a 200-mesh sieve the total cost of grinding shale in a plant of a certain size is 4s. 2.3d. (97 cents) per ton. With the same machinery but grinding so that only 50 per cent will pass through a 200-mesh sieve, the cost is 2s. 6d. (59 cents) per ton, because of the larger output of the machine in making the coarser dust. These figures are for a ton of 2,240 pounds. The labor costs, which form the largest items in this estimate, are only one-third of those called for by the American coal-miners' wage scale.

Many collieries that do not have their own grinding plant or do not have a suitable shale or have not as yet put in grinding machinery buy ground limestone and gypsum dust. The cost of limestone to one Scottish colliery is 30s. at the quarry plus 7s. 9d. for freight, a total of 37s. 9d. ($8.68) per ton of 2,240 pounds, delivered at the colliery. A colliery near Sheffield used pulverized gypsum, which cost 25s. 6d. ($5.87) per ton of 2,240 pounds delivered at the colliery.

A mine in Lancashire used calcium carbonate residues from certain chemical processes. This cost 5s. 6d. ($1.27) per ton of 2,240 pounds but contained much water. When the sellers of the calcium carbonate dried their product the price was several times this amount.

FRANCE.

France is not nearly so far advanced as Great Britain in the application of stone dusting or what the French term "schistification." To what extent the earlier attitude of the French Government on the danger of coal dust influences the present situation is problematic. Certainly the present Government inspection service recognizes the danger from coal dust and so do many of the collieries, particularly in northern France.
This earlier attitude, which was discussed on page 2, resulted from the opinion of physicists, this opinion resting on the results of small laboratory tests, that coal dust by itself would not propagate an explosion and that if fire damp was carefully controlled and a source of ignition avoided, coal dust was of little importance. The Courrières disaster in 1906 with its loss of 1,100 lives was considered by competent English investigators to have been due to coal dust ignited from a blown-out shot. This was also the opinion, the writer was informed, of many French investigators. This disaster immediately (1907) led the Comité Central des Houillères de France (executive committee of the French Coal Mine Owners' Association) to establish the testing station at Liévin, with the sanction of the Government. This station was put in charge of J. Taffanel, a mining engineer in the Government service. Work at this station continued parallel with British and with later American investigations. The splendid research conducted by Taffanel on original lines greatly advanced knowledge of coal-dust explosion phenomena.

TAFFANEL BARRIER.

The application of Taffanel's conclusions was interrupted by the World War, but one development of his investigations—the Taffanel barrier—was widely adopted in the north of France. His original conception of the barrier was the placing of enough incombustible dust locally to extinguish the flame of an explosion when it struck the barrier. This is founded on the knowledge determined experimentally that preceding the flame are air waves which stir up the coal dust. His first step was to place a series of shelves, originally 10 in number, across the top of the passageway on which the shale dust was piled. Air waves blew off or knocked down the shelves and threw the shale dust into the air. The device was immediately put into use in some of the mines of northern France.

An explosion in the Clarence mine in 1913 passed the barriers, thus showing what had been found at the Bureau of Mines experimental mine in testing the original Taffanel barriers—that if an explosion is traveling very slowly, as when the road dust is not pure coal dust, the air waves are too weak to throw the shale dust from the shelves into the air in such manner as to extinguish the flame. As a result of the tests at Pittsburgh the writer developed mechanically operated barriers that are connected with surfaces or vanes at right angles to the moving air waves and are of large enough area to be swung not only by a high-velocity air current but also by a low-velocity blast of air. In swinging the vanes trip the barriers and start a heavy shower of dust. This dust shower lasts a number of seconds, instead of the rock dust falling en masse, and thus provides
for a delay in the arrival of the flame. These barriers developed are described in Technical Paper 84. Taftanel later modified his barriers, making them more sensitive.

MONTLUCON EXPERIMENT STATION.

The Liévin coal-dust gallery was destroyed in the World War and has not yet been replaced. It is anticipated that the coal-dust investigations will be started again at the new Montluccon experimental station under M. Audibert. The station at present is occupied with the investigation and testing of coal-mine permissible explosives and of fuels.

FRENCH CONCLUSIONS AND DECREES REGARDING COAL DUST.

As a result of the first group (first to fourth series) of tests at the Liévin station, the Minister of Public Works issued a decree on August 13, 1911, classifying mines in three "categories" or groups according to the danger from the presence of coal dust. The observations accompanying this decree state in effect: The tests of the experimental station at Liévin have shown the influence of the main factors on which depends the degree of danger from dust in mines. Among these factors are the proportion of volatile matter in the coal, the percentage of ash, and the fineness of the dust. It is not possible to formulate fixed rules that would serve to classify a mine in the first, second, or third categories, but it may be said that a mine should be classified in the first category when the dust deposited is such that a hole fired without stemming under conditions similar to those obtaining at the Liévin experimental station would be very apt to initiate a general dust explosion, and that mines are to be classed in the third category when the dusts can not practically give rise to an explosion. The second category embraces intermediate conditions.

The engineers [of the mine-inspection service] will realize from all the conditions in what particular category a mine or a part of a mine should be classed. They will consider not only the factors already mentioned but also others, such as the amount of dust, the average dimensions and humidity of the galleries, and the percentage of fire damp in the main airways.

In case the mine operator protests against the classification of his mine, samples of the dusts shall be taken under the direction of the Service des Mines, and sent to Liévin, where their degree of inflammability will be determined by the director, to whom full particulars and instructions shall be sent.

A general review of the reports by Taftanel of the Liévin coal-dust experiments, 1907 to 1914, inclusive, would be too voluminous for this bulletin, but a few comments will be abstracted from that

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part of Audibert’s review of these investigations which relates to precautionary measures. He divides these in three groups:

1. Precautions in explosives, lighting, and electrical appliances. Measures to prevent starting an explosion.

2. Generalized neutralization:
   (a) Lessening and removal of coal dust.
   (b) Schistification (rock dusting).
   (c) Sprinkling.


1 and 2 (a). General Precautions.

Precautions in explosives, lighting, and electrical appliances and the lessening and removal of coal dust need not be discussed here except to note that under the decree of August 13, 1911, mines of the first class (which have most dangerous dusts) should have tight mine cars and the cars should be sprinkled soon after loading.

2 (b). Rock Dusting.

With respect to 2 (b) (schistification) Audibert, after pointing out what schistification is and referring to Taffanel’s formulas, says of the application of schistification that a degree of safety (No. 1) is reached under Liévin gallery conditions, with no fire damp present, if the mixed dust contains:

<table>
<thead>
<tr>
<th>Per cent.</th>
<th>Per cent.</th>
</tr>
</thead>
<tbody>
<tr>
<td>40–50 ash, when the volatile content of the coal is</td>
<td>15–20</td>
</tr>
<tr>
<td>50–60 ash, when the volatile content of the coal is</td>
<td>20–25</td>
</tr>
<tr>
<td>55–60 ash, when the volatile content of the coal is</td>
<td>25–30</td>
</tr>
<tr>
<td>70–75 ash, when the volatile content of the coal is</td>
<td>30+</td>
</tr>
</tbody>
</table>

A higher degree of safety (No. 2) is attained when the mixed dust contains:

<table>
<thead>
<tr>
<th>Per cent.</th>
<th>Per cent.</th>
</tr>
</thead>
<tbody>
<tr>
<td>60–65 ash, when the volatile content of the coal is</td>
<td>15–20</td>
</tr>
<tr>
<td>65–70 ash, when the volatile content of the coal is</td>
<td>20–25</td>
</tr>
<tr>
<td>70–75 ash, when the volatile content of the coal is</td>
<td>25+</td>
</tr>
</tbody>
</table>

These results closely correspond with those obtained in the experimental mine (Bruceton, Pa.) for “pulverized” coal dust.

2 (c). Sprinkling with Water.

Taffanel believes that there are advantages in the watering method when well done, inasmuch as it better prevents any ignition of coal dust. On the other hand Audibert says the method if done efficiently is expensive and it must be done constantly. He cites the explosion disaster at the Reden colliery (Saar) in 1907 which had 150 victims as due to the coal dust having dried out over Sunday, when no sprinkling was done.

3. PREVENTION OF PROPAGATION OF AN EXPLOSION ALREADY INITIATED.

Taffanel proposed that protective zones be created by sprinkling with water or by rock dusting stretches of roadway, but finally concluded that such protective zones do not effectively prevent the passage of an already violent explosion. In other words, it is implied that general neutralization is best. "Arresting" shale-dust barriers and water barriers were developed by Taffanel and under conditions of test were found effective in extinguishing flame. The writer of this bulletin noted, however, that while such arresting barriers are extensively used by many collieries in the Pas-de-Calais and Nord districts, most of them seem to be regarded as supplementary checks or additional safeguards. This is also the view of the Bureau of Mines.

AUDIBERT'S PAPER ON GENERAL NEUTRALIZATION METHODS.

In a later paper Audibert 37 gives, but in more detail, the same opinions on neutralization as in the paper reviewed above. Referring to sprinkling with water he again says that while it prevents any ignition of coal dust, it is expensive, ventilating currents dry the sprinkled surfaces, and certain shales swell when moistened. He says general sprinkling in French mines has never been practiced; sprinkling is confined to special areas or working faces and is always a localized practice. In the Pas-de-Calais conditions favor stone dusting, though it is more difficult to apply in the thicker beds if the coal is friable. Removal of dust is practicable if the coal is not naturally dusty. In collieries in which there is much blasting of coal, as at Bruay, generalized stone dusting is necessitated. However, these collieries do not stone dust the faces of the working places because they deem it impossible to neutralize all the coal dust which is made so rapidly, but they thoroughly dust all inclined planes and roadways. However, "in blasting they put up a rock-dust barrier (a temporary shelf) a short distance in front of the hole and carefully remove coal dust from the intervening space."

Under the head of preparation for rock dusting in a mine Audibert says the factors to be determined are:

1. Quantity of fine coal dust deposited per cubic meter.
2. Percentage of volatile matter in the coal.
3. Proportion of incombustible to combustible in the road dusts.
4. Amount of fire damp in the gallery under consideration.
5. Normal degree of dampness of that gallery.

Audibert emphasizes that samples must be taken and analyzed systematically and the results classified under the following heads:

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Main intake entries, main return entries, district roads, inclined planes, subsidiary haulage roads, and galleries for 200 meters (620 feet) on either side of rock-dust barriers.

LOCATION OF ROCK-DUST BARRIERS.

Audibert says a rock-dust barrier (group of shelves laden with fine ashes) should be placed at the entrance and exit of each panel and its position so chosen that the flame of an explosion before it reaches the barrier must traverse a straight passage at least 100 meters long. Furthermore, care should be taken not to place the barriers too far from possible explosion centers.

To isolate districts in a mine or to isolate connecting mines, heavy stoppings of cement and packing strong enough to resist any explosion are put in the connecting tunnel and only water or compressed-air pipes equipped with special joints (for disconnecting) at the ends of the stopping are to pass through a stopping. Communication is permitted by a detour with four right-angle turns and expansion chambers between the turns. Each branch of the detour is fitted with an iron door strong enough to resist a pressure of 20 kg. per sq. cm. (394 pounds per square inch, presumably breaking strength). The writer saw detour connections of this kind in the Bruay mines. In these installations there are supplementary iron doors closely fitting to the sides, which can be closed if the main doors are destroyed.

ADOPTION OF SCHISTIFICATION IN FRANCE.

As indicated in the foregoing review of papers by Audibert, who has charge of the research work conducted jointly by the French Government and the coal operators (Comité Central), schistification or rock dusting has been officially approved and has been extensively applied in the mines of the Pas-de-Calais and Nord districts, but the writer of this bulletin observed that the method has not been adopted, except for the occasional use of Taffanel barriers, in other districts of France which he visited. However, French officials are urging a wider use of rock dusting in the more dangerous mines. The admirable precautions that the French authorities have always taken as to ventilation and preventing accumulations of fire damp and the ignition of gas and coal dust have minimized the danger from coal dust. In fact, there is no other country, unless it be Belgium, which is as careful in preventing explosions as is France, and there have been only a few disasters of this type since that at Courrières, proportionately less than in any other country except Belgium. However, under the natural conditions generally found in France and in Belgium, there is much less explosive road dust than in coal mines of most other countries. Furthermore, the mining methods in those two countries are conducive to much less danger from coal dust than is
found elsewhere. The beds are so folded and faulted that the main roads are tunneled through the rock or shale of the coal measures, and only the secondary working levels and inclines are in coal. The shales of the coal measures are generally so friable that particles of roof and floor mix in and dilute the coal dust.

Some of the requirements that tend to decrease the explosion hazard in France and Belgium are as follows: Ascensional (return-air) ventilation, as required by law, prevents the accumulation of bodies of fire damp. Concrete or brick arches are extensively used for lining main haulage roads. The use of explosives in the mines is limited; in most mines they are practically never used in blasting coal; for this purpose only permissible explosives are used and they must be used carefully. Electricity is only employed for pumps near the main shafts or for underground hoists with motors of special design. Open-flame lamps are not used. Mining excavations must be filled with débris from the mine, or if there is not enough of that, with rock and débris brought from the surface, thus leaving no spaces in which fire damp may accumulate; or else the preferential method of filling, hydraulic sand stowing, must be used.

In addition to these commendable precautions and others prescribed by regulation, the Government is gradually bringing pressure upon mine owners to adopt complete rock-dusting methods, and many of the leading companies have complied.

As implied in Audibert’s papers, previously quoted, the wetting of coal dust as an explosion preventive was never generally practiced in France, because the mine operators, like those of England, had found that to sprinkle water where the roof, sides, and floor were naturally dry caused serious slackening and even collapse of the passageways.

TYPES OF DUST IN USE.

Most mines in the north of France use chalk dust for schistification; others use clay. At one colliery the writer saw screened cinders and flue dust on Taffanel barriers; the timbers and sides of the passageways were whitewashed. In one group of mines visited the chalk dusting was admirably done and the walls of the passageway were white from the chalk, greatly benefiting illumination. As material for a preventive dust cloud, chalk does not seem to be as good as shale dust; it packs under foot and consequently the coal dust, if deposited rapidly, may remain on the surface and the chalk dust may not be brought into suspension. In the mines visited, however, so little coal dust showed that it did not present any menace and the loose particles of chalk on the timbers and side ledges would be dislodged by a concussion and undoubtedly neutralize more coal dust than was actually present.

The Bruay mines obtain chalk from a surface quarry in a thick bed of chalk. Layers of flints are sorted out and used for road making.
The chalk is put through a hammer crusher which appears to crush the bulk of the chalk successfully and makes a large amount of float material. This plant produces daily 60 tons of chalk for use in the various mines of the company which have a combined daily output of about 8,500 tons of coal.

**METHOD OF DISTRIBUTION.**

The chalk in the mines is distributed partly by hand and partly by an air-dusting device, consisting of a small V-shaped hopper with a screen in the top of the V. A flexible air pipe is connected at the bottom of the V to the compressed-air lines of the mine and the chalk is merely shoveled into the top of the hopper, whence it is blown out by the compressed air and distributed along the passageways by the ventilating current. In one mine of the Bruay collieries visited eight of these devices were in use. Chalk-dusting is not done at the longwall faces but it is thoroughly done elsewhere throughout the mine.

**LABORATORY TESTS OF SAMPLES.**

Samples of the road dusts are systematically gathered, put into paper sacks, marked with the zones from which they are taken, and then sent to the laboratory to be tested and to have their combustible matter determined. In June, 1923, analyses of such samples from the six mines belonging to the company showed an incombustible content ranging from 84 to 96 per cent and averaging 90 per cent for all the mines. The incombustible included the inert matter from natural dusting from the roof, moisture, and chalk dust.

In the laboratory three methods of testing are employed: (1) The Taffanel flame-length test, which uses an apparatus for blowing the dust sample through a tube with oxygen. The mixture is ignited at the mouth of the tube. The apparatus has arrangements for measuring the length of the flame, which is compared with that of known mixtures of coal dust and chalk dust. This apparatus, designed by Taffanel, is manufactured by Et. Poulence, Boul. St. Germain, Paris, and costs 500 francs (at present exchange about $30). (2) The Taffanel volumeter, with which rapid determinations can be made by relative densities of the particular coal dust and the incombustible part, which includes the dust employed in schistification. (3) Incineration and allowance for carbon dioxide and moisture expelled in the incineration in the usual laboratory manner. The first method was favored, as being the quickest, and it was claimed that the figures obtained were quite accurate.

**TAFFANEL BARRIERS AS SECONDARY DEFENSE.**

In addition to the general schistification, a large number of the Taffanel barriers of a modified type and using fine ashes are installed
at the Bruay mines as a secondary defense. These are placed in or near the entrance to panels, and especially in "inclines" or "gravity planes," where the dust is deposited most rapidly by the lowering of mine cars loaded with coal. A typical barrier installation on such an incline comprises 22 cross shelves inclined backward over the roadways. Fine ashes are piled up on these shelves, which are in such position that any strong rush of air would blow off the ash dust.

In another type of barrier, installed at the entrance to a panel, the shelves, which were 60 centimeters (20 inches) wide, were balanced on a narrow board about 15 centimeters (6 inches) wide so that a concussion in the air would upset them.

**QUANTITY OF CHALK DUST USED IN BRUAY MINES.**

At Bruay the first incombustible dust used after the explosion disaster at the neighboring Clarence mine in 1913 was shale dust. Then chalk dust was tried. According to Audibert it proved far superior because of its lighter color. The dust is spread by two men shoveling the chalk dust from a pit car. In some places the compressed-air distributor, already mentioned, is employed. Audibert comments that the speed with which a film of coal dust forms on the chalk-dusted areas calls for repeated dusting at frequent intervals rather than the use of much material at one time.

The Bruay collieries have a daily production of 8,500 metric tons of coal. Their galleries had a total length of 240 kilometers (149 miles) in 1921, and used an average of 75 metric tons of crushed chalk a day for schistification—an average of 1,100 pounds per mile, or about 0.22 pound (3.5 ounces) per linear foot of gallery.

In permanent haulageways the timbering is whitewashed periodically.

**COST OF SCHISTIFICATION AT BRUAY.**

In December, 1920, the cost of schistification per ton of coal extracted at Bruay, including distribution, sampling, and whitewashing, was 0.192 franc (1.2 cents at the rate of exchange then prevailing).

**QUANTITY AND COST OF ROCK DUSTING AT FERFAY-CAUCHY.**

In the Ferfay-Cauchy colliery the coal is more friable and dusty than at Bruay, and the mine gives off enough fire damp to place it in the first or most fiery class; hence, a proportionately larger amount of shale dust must be used, or 7½ tons of shale daily for 600 tons of coal hoisted, equal to 1.2 per cent of the coal produced.

In 1921 the cost of quarrying and distributing the 7½ tons of shale, according to Audibert (1921), was 150 francs, which is equivalent to 0.25 franc per metric ton of coal hoisted. At the rate of exchange in 1921 this is equal to 1.5 cents.
ROCK DUSTING IN GERMAN MINES.

ROCK DUSTING IN THE LOIRE BASIN.

In the collieries of the Loire basin (St. Etienne) visited by the writer, schistification had not been introduced extensively; in fact, it was limited to the use of Taffanel barriers. In many of the mines, however, there was considerable natural stone dusting by the quantities of rock dust brought from the surface for tightly packing the mine workings in the thick coal beds. Some mines employ hydraulic stowing, which makes the galleries wet.

ROCK DUSTING IN THE SAAR AND IN LORRAINE.

In the Saar basin where the mines are now owned by the French Government and the administration is under an international commission, German mining methods, generally speaking, continue to prevail and rock dusting has not been introduced. However, the common German practice of watering the coal dust is also little used. To prevent the initiation or propagation of coal-dust explosions, reliance seems to be placed on cleaning up the coal dust, which is supplemented in some mines by whitewashing the haulage roads. These practices also prevail in the neighboring mines of the Saar Basin extension in the Province of Lorraine, which is again part of France.

ATTITUDE TOWARD ROCK DUSTING IN GERMANY.

In Germany the watering method has always been required by regulations, even in the deep hot mines. In consequence miners have to work in hot humid air that impairs their efficiency and also at one time led to a great development of hookworm disease which was later eliminated by sanitary precautions. Before the war the tests at the government station at Dortmund were mainly in the direction of water protection devices. Since the war rock-dusting methods have been tested.

According to an article by Schultze-Rhonhof quoted on page 18 of the Colliery Managers' Pocketbook, 1923, rock dusting with fine flue dust is being done in Ruhr collieries. To prevent ignition from a shot, 2 kilograms (4½ pounds) of incombustible dust is used for external stemming. Also dust is scattered within a radius of 10 meters (31 feet) of a shot. In ripping up the floor, the flue dust is shoveled over the shot holes; in blasting the face, it is heaped on an iron plate suspended in front of the hole or is placed on pegs inserted in the coal. The roadways of each district are dusted during the night shift every 8 or 10 days by two gangs of four men each, who distribute 6 tons of dust over about 2,500 meters (1½ miles) or 4½ pounds per linear yard. The men walk behind the pit car of
dust with their backs to the air current, and throw the dust with one hand over the roof and walls, a sufficient proportion falling on the floor. In the gate roads (or longwall branch roads) the dust is distributed with the aid of nozzles connected by hose to compressed-air lines. Rock-dust barriers are also employed in each ventilation section; in a section 18 miners may work. The barriers consist of 10 shelves extending over 20 meters (62 feet) of roadway.

In the Zwickau coal district and in upper Silesia the writer did not find rock dusting practiced, but as mentioned on page 3 of this paper, its adoption is being seriously considered, partly as the result of an explosion in 1922 in the Heinitz colliery at Beuthen, which killed 155 men. In that colliery watering was supposed to be practiced. Germany has had in the past a number of explosion disasters in spite of watering being compulsory.

**PROTECTIVE MEASURES IN BELGIUM.**

In Belgium the coal beds are invariably thin and the workings, always of longwall type, are thoroughly packed with shale or rock. Great care is taken to prevent coal dust from being scattered in the roadways. In consequence of the natural conditions and the precautions, no coal dust is observable back from the face. In spite of the fact that Belgian mines are on the whole more gaseous than coal mines of other countries, no widespread explosion has occurred in the past 30 years. Special precautions are taken in shot firing; no shots are permitted in the coal itself but only in rock. The regulations require that when a shot is to be fired the vicinity of the shot must be wet down.

The experimental station at Framères, Belgium, has tested the use of shale dust in connection with shot firing. Victor Watteyne, the former chief inspector of mines, who had charge of that station, designed the "exterior dust barrier" or external stemming, for use in blasting, which is now used in some collieries in France and in the Ruhr. An extemporized shelf is piled with shale dust and placed on pegs or hung from timbers just over the mouth of the shot.

Mr. Lemaire, who is now in charge of the testing station, has followed up the idea of a shale-dust barrage by designing an explosive cartridge in which shale dust is placed in a sheath surrounding the explosive. Lemaire says that tests show that this placing of the rock dust gives a dust cloud that is as good for preventing ignition of coal dust as the external stemming, and is more convenient. However, he later replaced dust with certain salts, which he considered more efficient.
APPLICATION IN AMERICAN MINES OF EUROPEAN EXPERIENCE
IN STONE DUSTING OR SCHISTIFICATION.

DISADVANTAGES OF WATERING.

American mines have heretofore relied on watering and the prevention of ignition to avoid coal-dust explosions. Although it is agreed that watering is successful if done with absolute thoroughness, engineers of the Bureau of Mines have rarely, if ever, found watering so perfectly done that if a source of ignition was present in imperfectly watered parts of the mine a coal-dust explosion would not follow. This remark, of course, does not apply to Pennsylvania anthracite mines, the dust of which has not been found to be explosive, but does apply to all bituminous, semibituminous, and subbituminous coal mines. Especially in the cold dry months, watering is effective for only a short time after it has been done, because the air current rapidly dries the coal dust. Tests in the experimental mine of the Bureau of Mines have shown that even with 25 per cent of water a pure fine coal dust will propagate an explosion, Mere wetness of the floor or sides will not be enough to halt an explosion wave if on the timbers, in the overhead cavities, or on ledges there is coal dust which may be dislodged by the concussion that precedes the flame. To keep long haulage roads and old workings thoroughly wet all the time is difficult because of the rapidity with which moisture dries or sinks into the ground. Moreover, it is difficult to wet fresh coal dust. When undisturbed, coal dust will float so thickly on water for long periods that the top layer may be fanned into the air. The bureau's investigators constantly find evidence after an explosion that the explosion traversed not only wet places but those where the water was deep in the roadway. Not only is the dust overhead, on timbers or adhering to the walls, dislodged and ignited, but if there is excess dust at some place further back it is carried along by "pioneering" air waves and feeds the flame of the explosion.

The difficulty of finding employees who will water a mine thoroughly and conscientiously may nullify the best intentions of the management. One of the greatest American coal-dust explosion disasters was attributed by the State inspector to failure to water the mine on a holiday that preceded the explosion. Recent explosions in the United States, cited previously, have practically demonstrated the failure of the watering system as ordinarily practiced.

ADVANTAGES OF ROCK DUSTING.

The effect of rock dusting is not so ephemeral. Many roadways do not have to be redusted for a week or two. Other parts of the mine may not need redusting for months. A light-colored dust is visible and has the advantage of greatly increasing the illuminating effect of
a miner's lamp instead of decreasing it by making the walls black, as watering does; the increased illumination prevents many smaller accidents along the passageways. If properly applied, the stone dust fills the cavities and crevices and lies on the ledges ready to be dislodged by a concussion and to extinguish an explosion—an effect directly opposite to that of coal dust lying in such cavities, on ledges, and on timbers. If there is an explosion of gas where rock dusting is used the air waves carry the combustible dust along with the coal dust inevitably present, and the rock-dust particles extinguish the flame by absorbing heat and by coming between particles of coal dust.

One of the greatest advantages of rock dusting is that failure or delay to apply the dust for a day or a few days is not so vital as the omission of watering. The condition of the roadways can be largely determined by inspection and checked positively by the gathering of samples. This applies not only to inspection from day to day by the management, but also to the more occasional State inspection. For example, a State inspector may find the condition of a watered mine admirable as far as coal dust is concerned on the day of inspection, but he can not tell whether the mine will be safe the next day. Usually a month or more will elapse before he makes another inspection of that particular mine. Meantime the effectiveness of the watering can not be positively checked in the same way that samples of dust gathered and tested by the management can be if made a matter of daily record.

**ELIMINATING SOURCES OF IGNITION.**

The second means of preventing coal-dust explosions is to eliminate sources of ignition. Elimination has been shown to be uncertain, even under the careful disciplinary methods of European mines, where there is no electric trolley haulage or other nonexplosion-proof electrical machinery, because gas is encountered unexpectedly, even though miners work carefully, and ignition may occur by reason of machinery defects or breakages, or in shot firing. Even when permissible explosives are used, if some one puts in an excessive charge, fires the shots improperly, uses coal dust in tamping, or fires into a pocket of gas, ignition may follow, because a charge much less than the “maximum” charge limit of a permissible explosive will ignite an explosive mixture of methane and air. Again, by error a shot may nearly penetrate a thin pillar and blow through into gas in an abandoned working. Ignition has occurred in this way. Furthermore, the human element can not be kept under absolute control. Matches may be carried into the mine; a safety lamp may be open (this is known to have caused several explosion disasters in this country) or may be defective, and occasionally a frictional spark struck by mining machines may cause ignition. In certain gaseous mines in which
electricity was used, explosions when no one was in the mine have accompanied falls of roof under conditions that are unknown. Explosions caused by sparks from cutting picks of undercutting machines setting fire to gas are not so rare; one recent explosion in the Southwest was attributed to that cause.

The remarks above apply to mines where the management is careful and every known safety precaution is employed, but, as is well known, open lights are used in the great majority of so-called nongaseous coal mines of the country. Most of the shot firing is done by nonpermissible explosives, and nonpermissible drilling machines, cutting machines, and loading machines are freely used; electric trolley haulage is even used in return airways. Although trolley locomotives and trolley wires have been the cause of many of the great mine explosion disasters in this country, the author of this report does not believe that it is necessary, in the effort to prevent explosions, to abandon trolley locomotives—that most important element in mine economy—in any but the most gaseous mines if the trolley is confined to truly intaking airways; that is such airways as receive, directly from outside, air that has not traversed either old places or active working places. Doing away with trolley locomotives would cause a serious economic loss, because of the long hauls required in this country. Many disastrous explosions have been traced to the ignition of coal dust on main haulage roads by electric trolley; therefore the coal dust must be treated so that it will neither ignite nor propagate an explosion. Rock dusting supplies this treatment and is the only protection known to be effective when coal-dust clouds rise from a wrecked trip of loaded cars, the cause of several of the greatest American coal-mine disasters and numerous lesser explosions.

**SIMPPLICITY AND LOW COST OF ROCK DUSTING.**

Rock dusting is not complicated; this has been shown very fully by the experience of British and of certain French mines. A great many British mines, some of large capacity—4,000 to 6,000 tons a day—have used rock dust for more than 10 years. The majority of British mines for the past four years and practically all mines for the last two years have been using stone dust. No coal-dust explosions have occurred or have been propagated in any part of a mine that has been thoroughly stone dusted, whereas there have been a number of explosion disasters in recent years in British mines where the watering method was practiced or in certain parts of mines which were supposed to be so wet naturally that they did not need stone dusting.

The cost of installing rock dusting, or stone dusting, is less than that of putting water-pipe lines in every passageway of the mine.
The cost of rock dusting in American mines per ton of coal produced is believed to be much less than that of efficient watering. In Great Britain and France, under the conditions, natural and otherwise, that prevail there, the cost per ton of coal hoisted is very small, as stated before, but British figures can not be applied directly to American mining conditions.

COMPARISON OF CONDITIONS IN GREAT BRITAIN AND THE UNITED STATES.

In Great Britain most of the main haulage is by endless rope, which moves the cars slowly. Therefore they are not subjected to as much bumping as cars in the rapid haulage used in this country. Furthermore, dust tends to blow from rapidly-hauled cars. In Great Britain the cars are generally loaded only bed full, and, moreover, are required to have tight ends. Unfortunately, in America cars are too often topped so that coal spills off; moreover, most of them have gates that allow small coal to sift out. Tight-end cars and the use of rotary dumps are much preferable. Coal spilled on the rails is promptly ground to dust.

Natural dilution and neutralization of coal dust is more common in British mines than in those of this country. In Great Britain practically all the mines use longwall or semilongwall methods and the passageways therefore have rock-built walls, and as the roof gradually sinks and brushing is required the roadways tend to creep up into the roof strata with the result that the walls of old roads are usually shale, which as it falls off dilutes the coal dust on the roadways. In the United States there are very few examples of longwall mining; therefore the mine roadways have coal ribs and these in many mines tend to spall and thus form coal dust. Moreover, in many American mines the roadways in the working places are ballasted with small coal and as the mine advances this coal becomes crushed or ground to dust.

Much can be done in American mines to prevent dust making, but even with conditions as they are, it is believed that as a preventive of explosion, rock dusting would be a vast improvement over watering methods practiced in the customary inefficient manner.

DETERMINATION OF DEGREE OF INFLAMMABILITY OF DUSTS.

Bureau of Mines engineers who gather samples of road dust and make explosion-hazard investigations find that the ash-plus-moisture content of road dusts is 25 to 40 per cent or even more. This inert matter comes from the roof or from the clay floor and therefore in many mines only a relatively small amount of incombustible dust would need to be added to make the coal mixture nonexplosive; the amount of course would depend on the quantity of natural road dust
present and the comparative degree of inflammability of the pure
dust in the mixture.

The mine management can easily determine the amount of rock
dusting necessary by systematically taking samples throughout the
mine. The comparative degree of inflammability of the coal dust
can be ascertained from such figures as have been determined by the
Bureau of Mines in its explosion-hazard tests in the experimental
mine of dust from some typical mine in the district concerned or by
submitting small samples to the Pittsburgh laboratory of the bureau
for preliminary study.

USE OF ROCK-DUST BARRIERS.

Rock-dust barriers, much used in France but not in Great Britain,
of a type developed at the experimental mine of the bureau and
described in Technical Paper 84 (pp. 21–42) and Bulletin 167 (pp.
567–585), are admirable for secondary defense at critical points, such
as entrances to panels, but are not in themselves enough to safeguard
the mine.

Explosions may and can be stopped within a panel if the barriers
are of proper type and are in good order, but should the lives of the
men within that panel be sacrificed? If the panel is large, the volume
of afterdamp may penetrate other panels and kill more men. The
proper function of the “barrier” is to supplement—like a safety
valve on a boiler or a safety catch on a cage—but not to be the main
and only protection against the propagation of explosions.

The coal-dust hazard can only be eliminated by rock dusting every
part of the mine except the immediate face of each working place,
where dusting may not be practicable. An explosion of gas or coal
dust at the face will die away at the mouth of the working place if
rock dusting is done efficiently out by the immediate face.

Rock dusting efficiently done costs a few cents more per ton of
coal than does watering in the usual imperfect way. This small
extra cost is a low price for protecting human lives and for insurance
against disasters that involve heavy financial losses from the payment
of death and injury benefits and through damage to property.

CHARACTER OF MATERIAL SUITABLE FOR ROCK DUSTING IN
THE UNITED STATES.

In the discussion of British stone-dusting material, it was pointed
out that the stone or rock dust must not have more than a few per
cent of silica or quartz particles, as these have sharp angles and may
be injurious if regularly breathed. Silica apparently is not harmful
if it is not in the form of sharp-edged particles.

Dusts of pure shale, limestone, dolomite, and gypsum do not have
injurious effect, nor does coal dust, as British physiological investiga-
tions and experience have indicated. The British coal-mine roof-shales have generally been found free from objectionable qualities and most limestone, dolomite, and gypsum dusts do not contain harmful amounts of quartz particles. Comment on a British shale dust (sample No. 2, Grand colliery shale, from 30-inch Griffin mill at the Powell Duffryn works, South Wales) follows. This "typical" shale was obtained in England for comparison with American material.

SHALE DUST USED IN A BRITISH COLLIERY.  

The shale corresponds very closely to samples submitted from various localities in this country and might easily pass for local material. Its two chief minerals are kaolin, discolored by hydrous iron oxides, and quartz. The former is present in much greater amounts than the latter, and forms almost the whole of the rock. Quartz, the mineral of most interest with respect to health, constitutes not more than 5 per cent of the total.

DESIRABLE QUALITIES.

In many American coal mines the immediate roof material is not generally so suitable for rock as that in the mines of Great Britain. The roof is either apt to be sandy or to contain too much combustible matter, so that a much larger amount is necessary to insure safety. Nevertheless, a search may disclose a stratum of suitable shale above the immediate roof or at the surface.

When there is a question as to the effect of a specified dust on health, samples should be submitted to a petrographer or to the Bureau of Mines.

The lighter colored the dust used the better; subsequent visual inspection to estimate the amount of coal dust present in a roadway will be facilitated and passageways will be more easily illuminated by a miner's lamp.

COST OF GRINDING SHALE.

British and French costs have been given, but little American experience is available to show the cost of grinding shale in the small amounts needed for coal mines with capacities of, say, 1 to 5 tons an hour. Estimates of American manufacturers vary from $1 to $3 a ton, depending on the fineness of pulverizing, capacity an hour, and unit cost of labor.

SOURCES OF SUPPLY.

When a shale suitable for dusting can not be found, or when it is desired to try out the method or to obtain dust pending the instal-
lation of grinding machinery, it will usually be possible in most coal fields to purchase dust from limestone, dolomite, anhydrite, or gypsum quarries at a reasonable figure. Such materials are usually free from silica.

SIZE OF DUST PARTICLES.

As mentioned in previous discussions there is in Great Britain a diversity of opinion on the size of incombustible particles, except that mines must meet the Government requirement that 50 per cent of the dust pass through a 200-mesh sieve.

Bureau of Mines investigations (Bulletin 167, p. 391) have indicated general agreement with the British requirements, which assume that all the dust that is effective must pass through a 20-mesh sieve. The question arises whether it is better to grind more finely and thus cut down the capacity of the grinder, necessarily increasing the cost a little, or to use more of a coarser dust.

DISTRIBUTION OF DUST.

If the dust is to be distributed mechanically—the manner generally best suited to American conditions because of the high cost of mine labor—fine grinding is undoubtedly best as it makes a larger proportion of dust more easily transported by air currents.

Appliances for distributing dust mechanically, as practiced in Great Britain, and somewhat similar American appliances have been discussed on page 10.

Daniel Harrington, of the Bureau of Mines, reports recent experiments made in a New Mexico colliery with a cement gun stationed at the intake end of the entry to eject a stream of dry shale dust into a strong ventilating current.

The tests indicated that the shale dust was discharged at the rate of 1 ton per hour. The velocity of the air current in one test was 800 to 1,000 linear feet per minute at the intake and about 400 linear feet at a point 6,000 feet distant. The dust cloud at this point was very dense 25 minutes after the cement gun was started, and definite evidence of dust settlement was found as far as 9,000 feet from the gun.

When the air current that passes through the entry being dusted is uniform, the amount of deposited dust is necessarily greatest near the point where the dust is ejected. To obtain even distribution of dust through an entry, shifts of the location of the dusting machine from time to time would be necessary.

In an entry such as that described, of 98 square feet cross section and 6,000 feet long, to obtain a deposit of, say, 4 pounds per linear foot, at the rate of 1 ton (of 2,000 pounds) an hour, 12 hours operation of the mechanical distributor would be required.
PUBLICATIONS ON EXPLOSIBILITY OF COAL DUST AND PREVENTION OF COAL-DUST EXPLOSIONS.

A limited supply of the following publications of the Bureau of Mines has been printed for free distribution. Requests for all publications can not be granted, and applicants are asked to limit their selection to publications that may be of especial interest to them. Requests for publications should be addressed to the Director, Bureau of Mines.

The Bureau of Mines issues a list showing all its publications available for free distribution as well as those purchasable from the Superintendent of Documents, Government Printing Office. Interested persons should apply to the Director, Bureau of Mines, for a copy of the latest list.

PUBLICATIONS AVAILABLE FOR FREE DISTRIBUTION.

**Bulletin 20.** The explosibility of coal dust, by G. S. Rice, with chapters by J. C. Frazer, Axel Larson, Frank Haas, and Carl Scholz. 1911. 204 pp., 14 pls., 28 figs.


**Technical Paper 84.** Methods of preventing and limiting explosions in coal mines, by G. S. Rice and L. M. Jones. 1915. 45 pp., 14 pls., 3 figs.

**Technical Paper 144.** The quick determination of combustible matter in coal and rock dust mixtures, by A. C. Fieldner, W. A. Selvig, and F. D. Osgood. 1918. 36 pp., 1 pl., 10 figs.

**Miners' Circular 21.** What a miner can do to prevent explosions of gas and of coal dust, by G. S. Rice. 1915. 24 pp.

PUBLICATIONS THAT MAY BE OBTAINED ONLY FROM THE SUPERINTENDENT OF DOCUMENTS.


**Bulletin 82.** International conference of mine experiment stations, Pittsburgh, Pa., September 14–21, 1912, compiled by G. S. Rice. 1914. 99 pp., 4 figs. 15 cents.


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