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UNITED STATES
DEPARTMENT OF THE INTERIOR
HAROLD L. ICKES, SECRETARY

BUREAU OF MINES
JOHN W. FINCH, DIRECTOR

REPORT OF INVESTIGATIONS

METHODS OF ROCK-DUSTING AMERICAN COAL MINES

BY

J. J. FORBES

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METHODS OF ROCK-DUSTING AMERICAN COAL MINES[1]

By J. J. Forbes[2]

INTRODUCTION

Investigations by the Bureau of Mines and by mining-research departments of European countries have established definitely the value of rock-dusting to prevent or limit the propagation of coal-mine explosions. Its effectiveness in this connection has been demonstrated not only by research but by actual coal-mine explosions in which hundreds of lives have been saved because of its presence.

In a general way this paper gives pertinent facts concerning rock-dusting practices in the United States. Information has been obtained from many reliable sources, and various coal-mining companies have furnished data on cost and other details.

HISTORY OF ROCK-DUSTING IN THE UNITED STATES

The use of rock dust to prevent or limit coal-dust explosions in bituminous-coal mines was first suggested in England in 1891 by Sir William Garforth, who had noted that the Altofts mine explosion in 1887 had not penetrated any of the naturally shale-dusted passages. Rock-dusting has been advocated by the Bureau of Mines since 1910, but it was not until 1923 and 1924 that the mine operators in the United States considered it seriously, although a few mines had begun to use it experimentally as early as 1911 and 1913. The first mine in the United States to experiment with rock dust was the Delagua mine of the Victor-American Fuel Co., Delagua, Colo., which in 1911 applied rock dust on the main trolley haulage entries by a locally developed machine consisting of an electrically driven blower and a funnel-shaped hopper mounted on a mine truck.

During 1915, the Pittsburgh Coal Co. began rock-dusting experiments in two of its mines by applying limestone dust to the ribs and roof by hand. Following an explosion in one of its mines in Illinois in 1917, the Old Ben Coal Corporation began rock-dusting its mines.

1/ The Bureau of Mines will welcome reprinting of this paper, provided the following footnote acknowledgment is used: "Reprinted from Bureau of Mines Report of Investigations 3465."
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CONFERENCE WAS POSTPONED BECAUSE
OF CONDITIONS IN EUROPE

Interest in rock-dusting American coal mines was stimulated by investigation of rock-dusting methods in England and Europe by G. S. Rice in 1923 and earlier, and meetings in 1924 with coal-mining operators in the various coal-mining States, at which the necessity for rock-dusting was stressed, resulted in the rock-dusting of a number of mines.

INVESTIGATIONS ON ROCK-DUSTING BY THE BUREAU OF MINES

Since its organization in 1910, the Bureau of Mines has advocated rock-dusting as a method of preventing or limiting coal-dust explosions. At first it was suggested as an alternative for watering, but finally in 1924, after many experiments with watering, salt solutions, and rock dust, the latter was declared to be the most reliable method known for successfully combatting the hazard of coal-dust explosions.

Research work on rock-dusting as a means of preventing coal-dust explosions has been conducted by the Bureau nearly 30 years, and during that time many valuable data have been obtained and published. The explosibility of various sizes of coal dust from many coal beds has been determined, as well as the quantity of rock dust necessary to prevent ignition of coal dust and the propagation of an explosion.

Research work relative to rock-dusting has been carried on by the Bureau in cooperation with the Carnegie Institute of Technology and the Advisory Board of Operators and Engineers of Western Pennsylvania. Results of this work were published in 1925 in a bulletin on "Method and Costs of Rock-Dusting Bituminous Coal Mines."

STATE-LAW REQUIREMENTS FOR ROCK-DUSTING

In addition to the laws enacted by various coal-mining States requiring rock-dusting, one of the most helpful features in the advancement of rock-dusting has been the reduction by accident-liability insurance companies of the premium paid by coal companies on mines using rock dust.

Eleven of the 25 coal-mining States have enacted laws requiring rock-dusting in some form or other. In general, however, these laws are inadequate and in some States they are indefinite and leave the question of rock-dusting to the discretion of the mine inspector. Only three States (New Mexico, Utah, and Wyoming) have enacted laws that adequately define and require rock-dusting. In 10 of the States water may be used for sprinkling roadways and workings in lieu of rock-dusting, Utah being the only State that requires rock-dusting in both nongassy and gassy mines regardless of moisture.

TABLE 1. - State mine law requirements for rock-dusting and watering

Alabama:	Water or rock dust is required in any mine containing coal dust that will ignite or explode.
Colorado:	Water or rock dust (a minimum of 60 percent inert material) is required when in the opinion of the chief mine inspector it is necessary.
Indiana:	In mines not maintained wet, rock dust must be applied. A minimum of 55 percent inert material is required. Rock-dust barriers may be used in isolated panels. Monthly sampling is required.
Kentucky:	All dry and dusty operating sections must be watered or rock-dusted.
New Mexico:	All mines must be rock-dusted unless in muddy condition at all times. All entries, slopes, and aircourses in nongassy mines, and in gassy mines all entries, slopes, aircourses, rooms, crosscuts, and pillar workings must be rock-dusted to within 40 feet of the face. Minimum of 55 percent inert material required. Where rock-dusting on roadways is not practicable, watering is permitted. Sampling at 90-day intervals with record of such sampling and analysis is required. Barriers are required at or near entrance to panels or on main entries and aircourses to isolate panel or section.
Ohio:	A mine or section thereof containing accumulations of coal dust is required to be rock-dusted, sprinkled, or otherwise treated at discretion of inspector.
Oklahoma:	Dry and dusty sections of mines are required to be sprinkled or rock-dusted at discretion of mine inspector.
Pennsylvania:	In such portions of dry and dusty mines where explosive gas can be detected by safety lamp, rooms and entries must be moistened by water. In lieu of water, rock-dusting may be substituted or may be used in conjunction with water. A minimum of 65 percent inert material is required. Record of sampling and analysis is required at 60-day intervals. Watering and rock-dusting are required at discretion of State mine inspector.
Utah:	Rock-dusting is required in all active working sections of mines to last crosscut and 50 feet in all rooms and pillar workings. In nongassy mines, 55 percent incombustible material is required, and in gassy mines 65 percent. When dust becomes below minimum, the section must be fenced off. Barriers are required in worked-out sections.

TABLE 1. - State mine law requirements for rock-dusting and watering - Cont'd

West Virginia:	Requires dry dust to be removed as far as practicable, and all dry, dusty sections watered or rock-dusted.
Wyoming:	All coal mines, unless consistently damp in judgment of State inspector, must sprinkle dry and dusty places twice a week. In lieu of sprinkling, mine may be rock-dusted. Rock dust is to be maintained at a minimum of 60 percent inert, with 10 percent increase with each 1 percent methane. The State inspector is required to sample and analyze dust. Barriers are permitted in trackless entries.

PROGRESS IN ROCK-DUSTING

Accurate records showing the progress of rock-dusting in American mines are not available for the years prior to 1926. Not much consideration was given to rock-dusting by coal-mine operators before 1923; however, by 1926 at least 177 mines in the United States were using rock dust, and by 1927 the number had increased markedly to 463 mines. By 1933, the number of rock-dusted mines had decreased to 382, but by 1936 it had increased again to 462. The fact that in 1936 (the last year for which statistics are available) only 462 mines reported the use of rock dust shows that the progress of rock-dusting is by no means satisfactory.

The favorable side of the record shows that the annual output of the mines using rock dust has increased from a low of 88,600,000 tons in 1932 (the lowest depression year) to 161,000,000 tons in 1936; the mines using rock dust during 1936 produced more than 37 percent of the country's bituminous coal. The fact that mines using rock dust represent but 7.5 percent of the total number of operating mines, yet produced 39.3 percent of the coal and employed 32.5 percent of the underground employees in 1936 indicates that it is chiefly the larger-capacity mines that are using rock dust.

Mines in 18 States used rock dust to some extent during 1938, but it was used most widely in Utah; about 90 percent of the State's production (including all rail-shipping mines) was from mines using rock dust. Wyoming, New Mexico, Alabama, and West Virginia rank next to Utah in this respect.

West Virginia reported 179 mines (33.4 percent) rock-dusted during 1938, compared to 89 mines rock-dusted in 1928. Although many Pennsylvania mines use rock dust, the State Compensation Rating and Inspection Bureau has given compensation credit to only 8 mines as being rock-dusted in accordance with its standards.

Although progress in rock-dusting in coal mines in the United States has improved considerably since 1923, when scarcely a dozen mines used rock dust, the 462 mines rock-dusted in 1936 represent only a small percentage of the total number of mines in operation.

The application of rock dust to underground surfaces in American mines has been an important factor in preventing widespread explosions; however, while some of the most dangerous mines have been rock-dusted fairly adequately, in other mines rock dust has been applied without regard to the amount required to prevent propagation of flame.

SPECIFICATIONS

Specifications[3] for rock-dusting were formulated by the American Engineering Standards Committee in 1927 and no changes have been made since then, although a committee of the American Institute of Mining and Metallurgical Engineers is now considering revision of these standards. The principal requirements are:

Size of dust. - The finer the dust, the more easily is it raised into the air with coal dust to prevent propagation of an explosion. All of the dust should pass through a 20-mesh sieve, and at least 50 percent should pass through a 200-mesh sieve. (If a coarser dust is used, the amount applied must be proportionately larger.)

Tests conducted by the Bureau of Mines show that finer dust is advantageous but that there is no additional advantage in having it finer than 70 percent through 200-mesh.

Character of dust. - The dust preferably should contain not more than 5 percent combustible matter nor more than 25 percent free silica. The rock dust should be as light in color as possible.

Enough dust must be present to maintain the incombustible matter at or above 55 percent. Where methane is found in the ventilating current, the amount of incombustible material specified must be raised approximately 10 percent for each 1 percent of gas.

Redusting. - After dusting, samples should be taken at regular intervals and analyzed to determine whether or not additional rock-dusting is necessary.

The maximum permissible percentage of combustible matter varies with the rank of the coal. Each coal bed has its own limits.

Moisture. - The dust should not absorb moisture from the air to such an extent as to cake and destroy its effectiveness as a dry dust.

3/ Rice, G. S., Sayers, R. R., and Harrington, D., Rock-Dusting in Coal Mines: Bureau of Mines Inf. Circ. 6030, 1927, 3 pp.

TABLE 2. - Summary of data for mines in United States using rock dust

Year	Number mines using rock dust	Percent of all underground mines using rock dust	Production from mines using rock dust, short tons	Percent of total production from underground mines using rock dust	Percent of total underground employees in mines using rock dust	Percent of total man-hours worked in mines using rock dust	Rock dust used, pounds	Rock dust used per ton of coal mined in rock-dusted mines, pounds
1926	177	-	-	-	-	-	-	-
1927	463	6.5	137,280,000	24.0	21.3	-	-	-
1930	474	8.4	148,634,912	33.2	27.5	30.1	137,738,000	0.93
1931	449	8.3	115,904,819	31.9	26.8	29.1	119,621,000	1.03
1932	393	7.5	88,632,327	30.6	25.7	27.1	74,938,000	.85
1933	382	7.2	96,691,753	30.7	25.4	27.4	73,150,000	.76
1934	414	7.0	112,500,000	33.2	28.4	29.8	104,234,000	.93
1935	413	6.9	116,600,000	33.4	28.4	29.9	99,188,000	.85
1936	462	7.5	161,000,000	39.3	32.5	35.7	153,686,000	.95

TABLE 3. - Rock-dusting in West Virginia

Year	Rock dust used, tons	Rock dust used per ton of coal mined in rock-dusted mines, pounds	Mines using rock dust	Rock dust used per mine, tons	Commercial mines
1936	32,495.00	-	133	244	542
1937	40,775.78	1.297	162	245	549
1938	42,698.83	1.562	179	239	536
1939 1/	12,587.62	1.596	168	-	-

1/ January to March.

It is common for interior surfaces of coal mines in many parts of the United States to "sweat" during the summer months as moisture in the air is deposited on the roof, ribs, and timber. In some mines the rock dust on the ribs and roof becomes "slimy" mud while in others it may be dry or moist. This absorption of moisture virtually destroys the effect of the rock dust. If coal dust, usually difficult to wet, is mixed with rock dust the entire mixture becomes wet; a thin layer of coal dust settling later on the surface of the wet rock dust is likely to become wet also, but the top of a thick layer of coal dust may remain dry.

On drying, some dusts remain caked and will not disperse readily, if at all, while othersvirtually regain their original dispersibility.

Sampling. - Passageways should be sampled at regular intervals to give an accurate cross section of the condition of the mine with respect to dust.

Analysis of dust sample. - A comparatively simple fire analysis may be used to determine the total combustible matter, except when limestone is used. The Bureau of Mines modification of the Taffand volumeter may be used to determine the combustible content of any kind of rock dust and is accurate within practical limits.

Extent of rock-dusting. - The Bureau of Mines recommends that all coal mines except anthracite be rock-dusted in every part and that rock-dust barriers be used as a secondary precaution but not in lieu of general dusting.

TYPES OF DISTRIBUTORS

Mechanical rock-dust distributors were assembled as early as 1911, in which year W. J. Murray, of the Victor American Fuel Co., developed a rock-dust distributor employing a fan, hopper, and flexible hose. This machine was used in the Delagua mine in Colorado. In 1914 the Bureau of Mines assembled a fan, nozzle, hopper, and rubber hose and mounted them on a truck, which was used principally for demonstration purposes.

When rock-dusting was actively revived in the United States in about 1924, a number of coal companies built rock-dust distributors in their own shops. One of the first commercial distributors was placed on the market in June 1924. Others followed shortly afterward, but only three companies now are actively merchandising rock-dusting machines that have been approved by the Bureau of Mines.

The first permissible machine - that is, approved by the Bureau of Mines as safe in a gassy or dusty atmosphere - was approved November 5, 1926, and a second machine was approved on December 28, 1926. Shortly afterwards another machine, known as a high-pressure model, was developed to force dust through a hose so that trackless entries could be rock-dusted. The first high-pressure machine was approved on July 2, 1927.

Two types of rock-dust distributors are used in the United States. Low-pressure dusters are used for application of dust on mine openings having tracks, and high-pressure machines are used principally for dusting areas not accessible to the low-pressure machines. Construction of both types of machine is similar in many respects. A modified V-shaped hopper of varying length contains the dust. Generally, a screw conveyor in the bottom of the hopper carries the dust to the front end of the hopper and allows it to fall into a mixing chamber. The fine dust tends to form an arch, and consequently a constant feed is not always obtained; this condition is overcome by using agitators. One type of distributor uses a steel shaft 1-5/8-inch in diameter provided with a number of steel prongs. As the shaft revolves, the prongs cause the dust to fall onto the screw conveyor. Other models have two screw conveyors rotating in a direction opposite to that of the feed conveyor. Some of the earlier models of low-pressure dusters deliver dust into an airduct at the bottom of the machine along the full length of the hopper. Back pressure was formerly prevented by placing a cover on the machine. The later type machines use the mixing chamber, which is placed at the front end of the hopper. As the dust falls into the chamber, it is mixed with the air and is forced through the discharge in a fluid mass.

Low-Pressure Distributors

A number of low-pressure machines still in use are provided with a flexible wire-reinforced hose about 4 to 6 inches in diameter and approximately 4 feet long. A handle near the discharge end allows the operator to direct the air-dust stream towards the roof and rib or crosscuts to obtain suitable coating of the surfaces. Usually enough dust spills to coat the roadway.

Another low-pressure duster is provided with a fixed discharge nozzle having two modified cones, one placed within the other in such a manner that dust is discharged around the periphery at the base of the two cones. A modified fishtail discharge nozzle is employed by a third type of low-pressure duster. This machine is designed to make two trips over the same entry; on the first trip the dust is directed approximately at the junction of the roof and one rib, and the second trip is made with the nozzle pointed toward the junction of the roof and the other rib.

Air for low-pressure dusters generally is provided by a fan capable of developing from 10 to 15 inches water-gage pressure. The discharge in low-pressure machines ranges from 50 to 200 pounds of dust per minute.

High-Pressure Distributors

High-pressure distributors use 3-inch fire hose ranging in length from 25 to 500 feet. In one mine, however, up to 800 feet of hose is used. The distributor stops opposite an opening in a stopping, the hose is carried through the opening, and a man directs the air-dust stream onto the roof and ribs, enough dust being spilled to coat the bottom.

Some of the machines employ a rotary-type valve to prevent back pressure from blowing the dust back into the hopper. Other machines have the hopper covered to accomplish the same purpose. Usually, a blower replaces the fan on the low-pressure machines. Pressures developed range from 30 to 166 inches water gage, the higher pressure being developed with 500 feet of hose. The machines generally deliver 50 to 100 pounds of dust per minute.

Semiportable Distributors

The advent of mechanical mining has presented new rock-dusting problems because track models cannot be used with conveyors. To meet this problem, two manufacturers have developed a small machine modeled after the larger ones. The pressure developed ranges from 3-1/2 to 7-1/2 inches water gage. Each machine uses 4 feet of 4-inch reinforced hose; the capacity ranges from 30 to 50 pounds of dust per minute.

On slopes where electric power is not available, two types of rock-dusting machines are used. One consists of a conventional track-type machine in which power is provided by means of a chain attached to the axle and to the blower, so that when the machine moves, the blower is operated, providing necessary air for the dust. One coal company has constructed a truck on which storage batteries are placed to provide the electric power necessary to operate the dust distributor.

In some of the mines in the State of Washington an injector-type nozzle has been developed that greatly increases the induced air flow. A small hopper placed near the inlet of the injector allows dust to be fed into the device. Compressed air flowing through the injector blows the dust from the discharge end, and this allows the faces of working places to be rock-dusted where electric power is not available.

METHODS OF ROCK-DUSTING

Two complementary methods of rock-dusting are employed in American Mines - general rock-dusting by machine and, frequently, supplementary dusting by hand.

Procedure before initial dusting varies to a marked degree. In many mines no effort is made to remove dust, pieces of coal, rock, and other materials from the road bed, ribs, and timbers. In many of the better-maintained mines the loose material is loaded from the road bed before the rock dust is applied. Several mines have attempted, also, to remove surplus dust from the ribs and roof by washing them thoroughly with water from a hose, and in at least one mine by using a specially constructed high-pressure sprinkling car designed to throw a number of strong streams of water against the roof and ribs.

Recently, in one mine, after an explosion had thrown dust on ribs, roof, and timbers, excess dust was dislodged with compressed air before rock dust was applied.

The most rapid retrogression of rock dust generally occurs on main haulage roads and on secondary haulage roads where animal haulage is employed. Naturally, entries having track in them were the first to be coated with rock dust, and the application formerly was begun at the drift mouth or the shaft bottom and progressed inby. Present-day high-pressure machines are capable of dusting trackless entries as well as regular haulage entries.

Fixed-nozzle machines proceed along the entry slowly against the air current so that the dust will be blown away from the operators. Generally the machine is stopped under high places in the roof to allow the dust to reach the high surfaces. Machines with flexible nozzles may be stopped under high roof and opposite crosscuts so that the dust stream may be directed at the surfaces of these openings.

In most up-to-date mines all entries now are rock-dusted before the track is removed. A large percentage of rock-dusted mines apply a thick coat of rock dust before the track is removed, and this may remain effective for several years. Frequently 8 to 10 pounds of dust per linear foot of entry is applied in coal 5 to 7 feet high in entries 12 to 16 feet wide. Samples collected 4 and 5 years later have shown the incombustible content in such trackless entries to be above the lower recommended limit. It should be emphasized, however, that mines where this condition was observed use water freely at face regions for allaying coal dust raised into the air during mining operations. Generally, the application of rock dust on haulage roads is approximately 3 pounds per linear foot, ranging from 1-1/2 to 6-1/2 pounds per linear foot of entry.

Many mines had miles of entry in which there was no track when rock-dusting was initiated. At first these entries were protected only with rock-dust barriers, but it soon became evident that all open areas should be rock-dusted thoroughly. A few companies had these entries rock-dusted by hand. This proved a slow and expensive process and other methods were tried. One coal company had the trackless entries swept with brooms. Openings were then made in stoppings and a steel door was placed on each side of the opening. A short length of hose was carried through the opening to the entry beyond and, with the rock-dust distributor on the haulage track, dust was blown through the hose. Dust was applied to the surface near the end of the hose and then discharged into the air, which carried and deposited it along the trackless entries. Although some dust was carried for considerable distances, the distribution was not entirely satisfactory. The need for better distribution was met by manufacturers who developed the high-pressure machine capable of blowing dust through 500 to 800 feet of flexible hose.

Methods of making openings in stoppings for the hose vary, but in general pipes 4 to 6 inches in diameter are built into the stopping. Each end is threaded and a cap is screwed over one end. The hose is drawn through the pipe, and the ribs, roof, and floor of the trackless entries are coated with rock dust when necessary.

Recently, in dusting trackless entries in a relatively small mine, 20-pound (per yard) rails were laid in the entries, using steel ties, and a low-pressure rock-dusting machine drawn by a storage-battery locomotive was used to rock-dust these entries thoroughly. This method, however, is costly and would not be feasible in many mines owing to falls in return airways and trackless entries.

While it is desirable from a safety and health standpoint to pull the rock-dust distributor against the air current, it is not always possible to do so because the air travels in on one or more entries and out on parallel entry or entries; consequently, it is necessary to pull the machine in the direction of the air or to turn the distributor around. In some mines this is done by using a "Y" in the track. Several mines have provided rigid couplings and push the machine.

Rooms generally are not rock-dusted, but a few mining companies require rooms to be dusted by hand after each cut of coal has been loaded out. Each working place is provided with a sack of rock dust, and after cleaning up a cut of coal, miners are required to throw the dust onto the ribs and roof by hand. In a few mines, the advance development in rooms is rock-dusted by machine once each week.

Hand-dusting is not as efficient as machine dusting. Frequently the quantity applied by hand is much less than that applied by machine and the cost of application is considerably higher. The dust thrown by hand generally is not as well distributed and does not adhere as well as dust applied by machine; moreover, the force of the air-dust stream often removes and mixes the dust on the ribs with the rock dust.

The application of noncombustible dust at the face to guard against dust ignitions is not practicable during the cutting and loading of coal, but dust raised during mining operations may be allayed through judicious application of water at the coal face. Methods of allaying coal dust in mines are discussed in a paper by D. Harrington.

A few mines have used calcium chloride along the floor, especially along manways where mules and horses travel daily. The hygroscopic property of the salt tends to moisten the dust and prevent rapid retrogression of the rock-dusting. One mine in Colorado applies natural salt water to road beds to help allay dust. Several companies in the eastern and also far western part of the United States "sprinkle" or wet the road beds at intervals to prevent dust from being raised into the air.

Some mining companies endeavor to maintain compact roadways by frequently cleaning up the coal that falls from tops of loaded coal cars during transportation and by subsequently watering such roadways. Where coal is gathered from producing entries by animals, large quantities of dust are formed and thrown into the air by the animals stepping on and pulverizing the coal that spills along the roadways. This situation presents a serious problem, especially in mines where watering is not done to allay dust in face regions or where water is not used to wet such roadways. Generally, the best practice is to clean roadways and apply rock dust. Some mining companies ballast such roadways with ashes or other inert material to assist in maintaining enough incombustible matter on them to prevent propagation of an explosion.

QUANTITY OF ROCK DUST USED

The quantity of rock dust that must be used for initial dusting for any particular stretch of passageway depends on several factors, such as (1) character of coal, (2) size of particles of coal dust, (3) percentage of inert matter naturally present, and (4) quantity of road and rib dust before rock-dusting.

The quantity of rock dust that must be used for redusting is determined by sampling at regular intervals along passageways. Analysis of samples will indicate whether additional rock-dusting should be done and whether cleaning up is necessary before redusting. Frequency of redusting will depend on the number and extent of the dust-producing and disseminating processes in the mine, including spilling along haulageways and the amount of float dust deposited on the haulageway surfaces and in the airways. Sprinkling of loaded trips eliminates much of the coal-dust deposit along haulageways, and sprinkling at face regions and use of water on mining machines, mechanical loaders, and conveyors eliminates much of the float-dust deposit in rooms as well as in haulage and aircourse entries.

According to table 2, the quantity of rock dust actually used in mines of the United States over a 7-year period averaged about 0.9 pound per ton of coal mined in rock-dusted mines. The average use of this small amount of rock dust bears out previous statements that mines are not being rock-dusted adequately. Recent investigation of a number of individual rock-dusted mines in various parts of the country revealed that as much as 4.5 pounds of rock dust per ton of coal mined have been used by certain mines for 1 year.

The quantity of rock dust necessary per linear foot of entry depends on the cross-sectional area of the entry. In the investigation referred to, it was found that 3.5 pounds of rock dust per linear foot was being used in one mine with entries 55 feet in cross-sectional area; while another mine, with an entry area of 72 feet, was using 6.9 pounds per linear foot of entry.

ROCK-DUST BARRIERS

Rock-dust barriers have been recommended by the Bureau of Mines as a secondary means of defense and not as a substitute for general rock-dusting. Before development of a machine for coating trackless entries, barriers were fairly generally thought to be necessary, especially at the entrances to panels and side entries.

Concentrated types of barriers have been recommended by the Bureau of Mines, but few if any are used in commercial mines. V-trough barriers were adopted to some extent shortly after 1924 but generally were placed in little-traveled parts of the mine, and the absorption of moisture caused the rock dust to cake or even to become soaked with moisture, and dispersion in event of an explosion was doubtful in some cases and impossible in others. Material spalling from the ribs frequently fouled the end of the troughs, and fallen roof often was found on top of the barriers. When practical and economical rock-dusting of open areas was developed, most of the mining companies abandoned the use of barriers.

At present a company in Washington, one in Utah, and a mine in Illinois have a new V-trough barrier, and a few are to be found in mines in West Virginia and other coal-mining States.

A barrier using rock dust in bags was developed and installed recently by a large coal-mining company in Illinois. Details of the barrier are given in Bureau of Mines Report of Investigations 3411 (1938), "Tests of a Barrier Using Rock Dust in Paper Bags."

The attitude taken by most of the large coal-mining companies is that the barriers may become ineffective at any time, due to falls of roof or rib, and no longer afford protection; consequently rock-dusting of open areas is held to be the most effective practice at the present time.

SAMPLING

Samples are not collected in most rock-dusted mines unless the State laws require it. On the other hand, a few large progressive companies collect samples regularly.

The Bureau of Mines has been largely instrumental in initiating rock-dusting in the United States and has given instructions for sampling in mines to determine the effectiveness of the rock dust. An effort should be made to obtain true average conditions, no dust should be taken from recesses in the ribs such as hitches, from places where rock-dusting machines have been filled, nor from those where the machine has discharged for a long time in one spot.

Some companies establish sampling stations and place boards painted with the station number on the rib on the haulage entries. Samples are collected on parallel entries at points approximately opposite the sampling station. The stations usually are placed at definite intervals of 500, 1,000, or 1,500 feet. The stations frequently are placed just outby switches, at the bottom of dips, and at other points where spilled coal quickly lowers the incombustible content of the dust on the surrounding surfaces. Mining companies do not sample in producing rooms or chambers to any appreciable extent; it is the exception rather than the rule.

Samples are collected at various intervals based on knowledge of conditions. Places near faces mined mechanically, at shaft bottoms, and similar points may be sampled every 2 weeks. Haulage roads are sampled every month, every 2 months, or every 3 months, whereas trackless entries are likely to be sampled only once or twice a year. Occasionally the points of sampling are selected by the foremen or by the safety engineer after a preliminary visual inspection of the dust condition of the mine surfaces.

Retrogression of rock dust in trackless entries in most instances is considerably less than on haulage roads, but where mechanical loading is employed the excess dust is very likely to be carried into the return airways and the rock dust contaminated. In one mine, 2 weeks after dusting a trackless entry near coal faces where mechanical loaders were operating, the white rock dust was virtually hidden by black coal dust. Special cases like these require a change in the regular sampling intervals.

Virtually all sampling consists of brushing all loose dust from the surface sampled to a width of 6 inches or a multiple of this width. Where the dust is deep, the sample is taken only from the top inch. If considerable sand has accumulated at or near the rail, care is taken not to include the sand or to overbalance the sample with a preponderance of sand.

Two types of sampling kits are available. One consists of a wedge-shaped scoop, the top of which contains a 10-mesh screen. The dust is sifted through to the interior of the scoop; the oversize is rejected; the minus-10-inch material is drawn off through an opening about 1 inch square at the back of the scoop, which is 6 inches wide. A 2- or 3-inch paint brush will dislodge all loose dust and brush it into the scoop satisfactorily.

Another kit consists of a 2- or 4-inch paint brush, a 6-inch scoop, and a telescopic box about 8 inches square and 3 inches deep. The smaller section has a 10-mesh screen in the bottom. The dust is sifted through this screen. The minus-10-mesh material usually is placed in cardboard containers of suitable size. If the sample contains more dust than can be placed in the container, the dust is mixed thoroughly and quartered according to standard sampling practice.

Entries containing timber or steel crossbars are sampled by brushing the dust from the timbers and crossbars; the very fine dust lodged here is important, as it is most likely to be thrown into suspension by an explosion.

The amount of roof dust is considerably less than that from the ribs and road; consequently, the rib and roof dust generally is included in one sample and the road dust in another. Some coal companies require the collection of a complete "round" or peripheral sample, and in Pennsylvania, where the mining law requires that "a representative sample of dust" be "gathered at each sampling point from the roof, sides, and floor", a peripheral sample usually is collected, based on a strict interpretation of the law. That a true picture of dust conditions is not given by a peripheral sample is indicated by table 4.

TABLE 4. - Unweighted arithmetical average of rib roof and road dust

Sample	Percent incombustible matter			
Rib and roof dust.........	93	95	92	87
Road dust.................	32	67	49	34
Arithmetical average......	62	81	71	61
Peripheral................	43	62	50	33

The unweighted arithmetical average shows the average of the rib-, roof-, and road-dust samples if the same weight of material were collected in each sample. This is not the true average, but would be the average if the peripheral samples were taken to an equal depth from the ribs, roof, and road. In the first group, the road dust contains about a third as much incombustible matter as the rib- and roof-dust sample, and the unweighted average is 62 percent; however, the peripheral sample contains 43 percent, showing that more road dust than rib and roof dust had been collected. Actually, the sampler collected a thin coating from the road dust, so that the incombustible matter approaches the unweighted average more closely than any other peripheral samples. The amount of dust in the average road-dust sample is about 10 to 15 times as much as in the average roof- and rib-dust sample. The effect of such large quantities of road dust on the peripheral samples is shown in the tabulation, the road-dust and peripheral samples agreeing relatively closely. Therefore, it can be seen readily that a peripheral sample does not give a true indication of the condition of the rock-dusted surfaces, and to determine the true condition, roof and rib dust should be sampled separately from the road dust.

In making an explosion-hazard examination, the Federal Bureau of Mines collects representative samples of dust at carefully selected locations. The road dust is sampled separately from the rib and roof dust, and all of the dust in each sample is sent to the coal laboratory for analysis. Where no rock dust has been applied, a proximate analysis is made; and in samples from rock-dusted areas, moisture, incombustible matter, and carbon dioxide are reported. The weight and size of dust in each sample is recorded so that a weighted average of incombustible matter may be calculated from the roof-, rib-, and road-dust samples at each sampling point. The degree of hazard then may be estimated from the size of the dust and from the combustible matter present.

Field samples are taken to a laboratory or to a sampling room at the mine and rescreened through a 20-mesh sieve. Wet or moist dust in the mine often makes screening difficult with a 20-mesh sieve. Wet material collected is air-dried before final sampling. The incombustible content is determined with the volumeter in most instances, although calcination is used by a few companies, in which case separate determination of CO_2 is necessary if the real condition is to be ascertained.

Practice of reporting results of sampling varies according to State laws or company regulations. At some mines the safety engineer collects and analyzes samples or supervises these operations; he then determines where redusting is required. In Pennsylvania a special book is provided by the State, and results must be entered and countersigned as required for fire bosses and mine foremen.

The best practice, followed by many of the larger companies, is to make a permanent record in a bound book and to send copies of the results to the superintendent, mine foreman, and safety engineer. This procedure provides a triple check on the existing status as to dust and insures that required action will be taken to correct substandard conditions.

TYPICAL ROCK-DUSTED MINE

The Bureau of Mines recommends what are considered ideal conditions for rock-dusting coal mines, but no one mine follows the program completely. One mine, considered to be 100-percent rock-dusted by the Pennsylvania Department of Mines, presents a typical example of what the industry considers to be full protection by rock dust.

Entries are cleaned of combustible material before rock-dusting is begun. In rooms, waste material is gobbed on one side, but the opposite side of the track is kept free from excess dust and lumps. Several mining machines are equipped with tanks to hold water to be applied on the cutter bars during cutting of coal.

Back entries are swept with brooms before they are dusted for the first time by blowing dust into the air at break-throughs, allowing dust to be carried by the air stream.

Haulage entries and rooms in this mine were rock-dusted by a rock-dusting machine in 1924 and 1925. Dust was blown into the main air courses, but it was thought that not enough dust was deposited on roof and ribs to give full protection. In December 1937 a high-pressure rock-dusting machine was purchased and dusting of trackless entries was begun.

Limestone dust is purchased with a guarantee of 98 percent calcium carbonate and a fineness of 85 percent through 200-mesh. The dust is delivered in paper bags containing 80 pounds each.

The rock-dusting crew consists of two men, one of whom is a certified fire boss. He enters a working place and makes an examination for gas before the rock-dusting machine enters. The two rock-dusting machines in use at the mine are permissible, but the management does not wish to take unnecessary risks, and this is excellent safety procedure.

The crew applies dust about 3 days per week. Average coverage of surface with rock dust for one 7-hour shift is 350 feet of trackless entry and 6,600 feet on haulage roads. This also includes rooms, which are dusted by machine. No hand-dusting is done at this mine. Some sections of the roadway are wet, but these sections are rock-dusted when the rest of the area is dusted.

The main air courses were rock-dusted with a high-pressure distributor about 2 years ago and still are well coated. A 6-inch pipe line has been laid on the bottom of the road bed since the application was finished, but about 3/4 inch of air-borne coal dust has settled on the pipe. Perhaps the extensive application of rock dust helps to offset any air-borne coal dust in these entries.

The mine foreman is charged with designating points to be sampled. An engineer collects the samples and determines the incombustible content. About 10 samples are collected each week.

The results are noted in the special book provided by the State, and a report is made direct to the superintendent, with a copy each to the general superintendent and the safety engineer. The mine foreman is required to countersign the record book.

A sample of the record in the book, selected at random, is given in tables 5 and 6.

Samples were collected on all parallel entries approximately opposite one another; peripheral samples were taken, hence the same analyses for bottom, roof, and ribs in each sample.

The report on barriers shows the condition of each to be good. The State law allows substitution of rock-dusting for barriers, and at present virtually all barriers have been abandoned in favor of rock-dusting in the trackless entries.

Data are not available on the application of rock dust on a basis of pounds per linear foot; however, during the calendar year 1938, 444 tons of limestone dust was applied, the equivalent of 1.36 pounds of dust per ton of coal mined. The total cost for labor and materials was less than 1 cent per ton for rock-dusting during 1938.

COST OF ROCK-DUSTING

To a large extent, the cost of rock-dusting depends on the quantity of dust used per linear foot of entry or per ton of coal mined. For comparative purposes, the cost of rock-dusting per ton of coal mined probably is the most equitable basis.

The cost of rock-dusting in 27 widely scattered mines is shown in table 7. Most of these are large mines and their rock-dusting program is more consistent than that of the average rock-dusted mine. Therefore, these cost figures do not represent the cost of rock-dusting in the average mine in the United States, but represent the cost in mines that are more concerned with safety than is the average mine.

The cost of rock-dusting ranges from $0.0019 to $0.0184 (an average of $0.0089) per ton of coal mined. The cost per linear foot of entry ranges from $0.0110 to $0.0417 (an average of $0.0229 per foot).

Not a great many data are available concerning cost of hand dusting. However, cost data from one mine on the hand dusting of 1,015 feet of 6- by 10-foot entry show that the cost of applying 8.1 pounds of dust per linear foot of entry was $0.0467. At another mine the cost of applying by hand 4.1 pounds of dust per linear foot was $0.0326.

The cost per linear foot of applying 3.4 pounds of rock dust in trackless entries with a high-pressure dust distributor through a 4-inch hose is reported by another company as $0.0326.

TABLE 5. - Record of rock dust analyses

Date	By whom collected	Heading and location	Date analyzed	Percent of incombustible		
				Bottom	Roof	Sides
9/1/38	J.H.T.	#4 east at 7380	9/1/38	86	86	86
		#5 east at 7350	9/1/38	70	70	70
		#6 east at 7325	9/1/38	66	66	66
		#7 east at 7310	9/1/38	64	64	64
		#1 north at 500	9/1/38	65	65	65
		#2 north at 515	9/1/38	64	64	64
		#3 north at 490	9/1/38	72	72	72
		#4 north at 495	9/1/38	86	86	86
		#5 north at 525	9/1/38	70	70	70
		#6 north at 510	9/1/38	72	72	72
		#7 north at 530	9/1/38	60	60	60
9/8/38	J.H.T.	#1 entry, 1 south at 40	9/8/38	60	60	60
		#1 entry, 1 south at 2040	9/8/38	78	78	78
		#1 entry, 1 south at 4000	9/8/38	80	80	80
		#2 entry, 1 south at 40	9/8/38	80	80	80
		#2 entry, 1 south at 2000	9/8/38	88	88	88
		#2 entry, 1 south at 4040	9/8/38	76	76	76
		#3 entry, 1 south at 40	9/8/38	70	70	70
		#3 entry, 1 south at 2040	9/8/38	58	58	58
		#3 entry, 1 south at 4100	9/8/38	76	76	76
		#4 entry, 1 south at 40	9/8/38	82	82	82
		#4 entry, 1 south at 2000	9/8/38	85	85	85

TABLE 6. - Record of condition of rock-dust barriers

Date inspected	By whom inspected	Location of barrier	Condition of barrier		
			Dust	Frame	Mechanism
9/15/38	R.E.J.	#4 entry of 2 south	Good	Good	Good
9/15/38		#0 entry of 2 south	Good	Good	Good
9/15/38		#2 in 5 east	Good	Good	Good
9/15/38		#3 in 6 east	Good	Good	Good
9/15/38		#4 in 7 east	Good	Good	Good

TABLE 7. - Cost of rock-dusting in 27 widely scattered mines

Mine	State	Cost		Area of entries, sq. ft.	Rock dust used per linear ft. of entry, pounds
		Per ton of coal mined	Per linear foot of entry		
A	West Virginia	$0.0080	$0.0275	72	6.25
B	do.	.0184	-	-	3.5
C	do.	.0150	-	-	2.5
D	do.	.0050	-	-	1.2
E	do	.0066	.0174	96	-
F	Pennsylvania	.0086	-	-	1.3
G	do.	.0080	-	-	3.1
H	do.	.0130	-	84	4.5
I	do.	.0071	.0131	72	1.9
J	do.	.0134	.0220	72	6.9
K	do.	.0165	.0288	72	-
L	do.	.0094	.0181	55	3.53
M	do.	.0019	.0110	75	-
Av. 7 mines	Utah	.0090	-	-	1.0
Av. 4 mines	Illinois	.0044	-	-	-
N	Wyoming	.0040	.0250	96	3.5
O	New Mexico	.0031	-	-	4.1
P	Washington	-	.0417	54	2.5
Q	do.	-	.0250	54	2.5
Average	-	.0089	.0229	-	2.5

AVAILABILITY OF MATERIAL FOR ROCK-DUSTING

As general use of limestone or gypsum in rock-dusting coal mines depends to some extent on the cost, and the cost in turn depends chiefly on transportation, a survey was made some years ago by the Bureau of Mines of sources of these materials close to coal mines or on railway lines that would provide, at low freight rates, ready access to coal fields. The result of this survey has been published[4] with maps of the coal fields of the United States showing locations of quarries and giving names and addresses of companies operating quarries. The survey shows that limestone or gypsum is readily accessible to all the coal fields of the country; suitable rock-dusting material is more readily available today than when this survey was made.

INSTANCES WHERE ROCK DUST IS BELIEVED TO HAVE STOPPED OR LIMITED EXPLOSIONS

Notwithstanding the inadequacy of rock-dusting in most of the mines of the United States, numerous instances are on record indicating the well-founded basis of the claims regarding the effectiveness of rock dust in stopping the propagation of explosions.

Bureau of Mines records during the past 9 years show that in 60 rock-dusted mines where explosions occurred, rock dust is credited with stopping or limiting the explosions in 26 of them. In several instances the element of luck unquestionably was present, in that the explosion happened to occur in one of the few sections of the mine where rock-dusting had been done. No accurate figure is available on the number of lives saved in these 26 explosions, but it is almost certain that several hundred were saved and much property damage avoided because of the rock dust used in these mines.

CONCLUSIONS

1. Although the number of mines using rock dust is increasing and more rock dust is being used, rock-dusting practices in the United States fall far short of giving absolute protection against coal-dust explosions.

2. State laws regulating the safety of mines are, in general, entirely inadequate with respect to rock-dusting.

3. The Bureau of Mines recommends that all coal mines except anthracite be rock-dusted in every part and that rock-dust barriers be used as a secondary precaution but not in lieu of general rock-dusting.

4. Machinery for distributing rock dust, as well as analytical equipment for inspection purposes, has reached a fairly advanced stage of development.

5. Limestone or gypsum is readily accessible to all coal fields of the United States, and this material can be delivered to the mines for rock-dusting purposes at a reasonable cost.

4/ Bowles, Oliver, Sources of Limestone, Gypsum, and Anhydrite for Dusting Coal Mines to Prevent Explosions: Bureau of Mines Bull. 247, 1925, 70 pp.

6. The average cost of rock-dusting in 27 mines where the practice is considered good amounts to $0.0089 per ton of coal mined, or $0.0229 per linear foot of entry.

7. During the past 9 years rock dust is credited with having stopped or limited explosions in 26 of 60 partly rock-dusted mines and thereby unquestionably saved the lives of several hundred persons.

Although the Bureau of Mines has advocated the use of rock dust as a preventive of widespread explosions since its establishment in 1910, comparatively few mines in the United States today are adequately rock-dusted. Of the country's approximately 6,000 bituminous- and lignitic-coal mines, probably fewer than 100 are adequately rock-dusted. This situation exists because State laws requiring protection of life against explosions are inadequate and the coal operator is inclined to take chances in the hope that he will not have the misfortune to suffer an explosion in his mine.

The cost of rock-dusting is by no means prohibitive when the value of the protection it affords is taken into consideration, and unquestionably rock-dusting of coal mines of the United States should be more universal than it is at present.

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