THIRD AND FINAL REPORT

OF THE

Committee appointed to investigate the Dangers arising from Coal-Dust in Indian Mines.

CALCUTTA: GOVERNMENT OF INDIA
CENTRAL PUBLICATION BRANCH
1932

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Third and Final Report of the Committee appointed to investigate the Dangers arising from Coal-Dust in Indian Mines by the Government of India, Department of Industries and Labour, in Resolution No. M-498, dated 24th July 1923.

CONSTITUTION OF THE COMMITTEE.

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Mr. H. K. Nag, Mr. P. B. Basu } nominated by the Indian Mining Federation.

Mr. A. Farquhar, nominated by the National Association of Colliery Managers, Indian Branch.

Mr. J. Thomas, nominated by the Mining and Geological Institute of India.

Mr. J. H. Lang, Inspector of Mines,

and

Dr. D. Penman, Principal, Indian School of Mines (also Secretary).

Former Members.

Messrs. J. G. Foster, H. C. Read, G. Naysmith and P. Bates.

TERMS OF REFERENCE.

To enquire into the danger of explosions of coal-dust in Indian coal mines; to make experiments on different kinds of coal-dust with a view to determine their liability to explode or otherwise; and to report what means, if any, are necessary or desirable to provide against the risk of coal-dust explosions in Indian coal mines.

INTRODUCTORY.

In our First Report we gave a brief resumé of the evidence of the explosibility of coal-dust together with a record of certain preliminary tests of the inflammability of dusts from Indian coal

seams. We made also some general recommendations which in our opinion would reduce the risk of explosions both in fiery and in non-fiery mines.

2. In our Second Report an account is given of more elaborate tests of the explosibility of Indian coal-dusts, and we indicated certain directions in which our investigations might usefully be continued.

3. Recently a series of experiments was carried out at the Indian School of Mines on the friability of Indian coals. Owing to the lack of suitable apparatus for the purpose considerable difficulties were encountered in the carrying out of these tests. As a result the determinations were somewhat inconsistent. A general deduction was, however, indicated, *viz.*, that certain seams are more friable than others and produce a larger percentage of fine dust. The results obtained however are incomplete and do not warrant inclusion in this report or any attempt at a classification of Indian coal in order of friability. Dr. B. B. Banerji of the Indian School of Mines carried out tests on the ignition of fine coal-dust by electric arcs. An account of his experiments is given in Appendix VII. The tests were on a laboratory scale and showed that under certain conditions an electric spark can ignite an air-dust mixture. More elaborate tests in other countries have proved the possibility of an ignition of coal-dust by electric arcs. We do not, however, think that the risk from this source is comparable with the risk from shot-firing. The danger of an ignition of inflammable gas by electric sparks or arcs is however in a different category and must not be overlooked by those who use electricity in situations in which there may be accumulations of firedamp.

4. In 1928, two demonstrations on the explosibility of coal-dust were carried out, one before the members of the Coal Dust Committee at the underground experimental gallery described in the Second Report, and the other before the Colliery Managers Association in India at the Indian School of Mines, in the experimental gallery described in the First Report (*see* Appendix 2). These tests did not reveal any new data and were carried out chiefly for their publicity value.

Effect of the Presence of Coarse Dust on the Explosibility of Fine Coal-Dust.

5. The tests recorded in the First and Second Reports, with the exception of Test No. 52, were carried out on dust which had been artificially ground and sieved so as to eliminate all the coarser dust. As a consequence in those tests the concentration of very fine dust was higher than normally exists in the roadways and working places of a mine. Moreover, since all the coarser pieces of coal had been removed, there was no obstruction to the raising of the dust in a cloud by detonation or shot-firing. Where the dust is intermixed and overlain by coarser particles, as is usual in a mine and particularly so at the working face, the up-lifting

of the fine dust is to a great extent obstructed. The finer dust settles into the cavities and irregularities of the floor and is covered by the larger pieces of coal. This is a characteristic of the conditions of working places and mine roadways which has been noted and commented on by investigators in other countries, and it is of such importance that in some cases the failure of an initial explosion of firedamp to be propagated by coal-dust has been attributed not to the absence or insufficiency of fine coal-dust in the workings but to its having been prevented from being raised into the air by reason of the weight and size of the overlying coarser particles.

It may be concluded, therefore, that as a general rule the presence of coarser particles of coal in coal-dust has a considerable influence in reducing the risk of a coal-dust ignition or propagation. It should be noted, however, that the same argument does not apply to fine dust which collects on the roof and sides of a mine roadway. This aspect of the problem we discuss more fully elsewhere (page 9) in this report.

Additional Tests in an Underground Gallery.

6. With a view to the testing of Indian coal-dusts under circumstances more closely approximating to actual working conditions than was done in the tests recorded in our First and Second Reports a series of tests was carried out in a portion of an old underground incline in No. 15 seam, Kendwadih colliery, Jharia, placed at the disposal of the Committee by the East Indian Coal Company, Limited. The dimensions of the incline are given in Fig. 1, and a description of the experiments is given in Appendix III.

In the first set of these tests slack coal collected from the floor and sides of a roadway in a mine was distributed on the floor of the experimental gallery so that the volume of the gallery over which the dust was spread was the same as the volume of the roadway from which the slack had been collected. The slack coal was not sieved in any way and was thus, as far as the methods of collecting the sample allowed, in the same state of division and presumably in the same relation with respect to mixing in the experimental gallery as in the mine roadway. In most of the tests charges of country-made gun-powder were used as the igniting medium. In one or two tests charges of gelignite were exploded on the floor of the gallery. In only two of the tests were ignitions of coal-dust observed. (Appendix III, pages 22 and 23).

7. We do not suggest that these tests are conclusive. They were carried out on a comparatively small scale in a gallery which had not been in use for a considerable time and in which there was no fine coal-dust remaining from previous operations. The dust used though collected from mine roadways as carefully as the conditions and means of collection allowed may not have contained the finest of the dust, which would naturally collect and settle in the smaller depressions and crevices in the floor and sides. Some

of the finest and most buoyant of the dust may also have floated clear of the area under treatment during the process of sweeping up the dust. Again we cannot be certain that the grading of the dust when laid on the floor of the experimental gallery was exactly the same as in the original state of the mine roadway. For obvious reasons it would be difficult to ensure absolutely similar grading in the two cases and, owing to the difficulties of making such tests, no grading tests were attempted. As far as possible, however, the dust was stirred up by foot before each test.

On the other hand the flame and concussion of the charges of explosives used were probably more intense than is usual in actual practice. The shot-holes, which were bored in the coal sides of the experimental gallery, were lined with steel pipes and the charges were abnormally heavy. These factors would undoubtedly to some extent counterbalance the possible deficiency of fine dust in the slack and the inaccuracy of the grading and distribution of the dust.

8. We are conscious also of the force of the argument that in a series of tests such as these, more weight ought perhaps to be given to one ignition than to a considerable number of non-ignitions. It is obvious to practical mining men that an ignition of coal-dust in a mine is not a probable contingency, as if it were so no mine would be safe and coal-dust explosions would be of every day occurrence. We have to deal with possibilities rather than probabilities. While therefore we realise that it would be unscientific and unwise to give too much weight to the results of these tests we opine that within their experimental limitations they indicate that the conditions must be more severe than is usual in actual practice before an ignition of coal-dust is likely.

9. In the second set of tests, contained in Appendix IV, tests were made on specially sieved dust. Slack was collected in the same way as for the tests described in Appendix III, but it was in this case sieved so as to obtain the included fine dust in three grades, *viz.*, dusts of sizes between 30 and 90 mesh, between 90 and 150 mesh and over 150 mesh. Three tests only were carried out and the igniting charge in all cases was a heavy shot of country-made loose gunpowder. The concentration of the dusts per cubic foot of air space in the length of gallery over which the dust was spread was in each case greater than the concentration necessary to form an inflammable dust-air cloud. No ignition was obtained with the two coarser grades, but a feeble ignition resulted with the finest dust.

These experiments although perhaps imperfectly staged from a scientific and practical view point indicate that fine coal-dust is more readily ignitable than coarse dust.

Visits to Representative Coal Mines.

10. In the course of our investigations we visited a number of representative collieries in the Jharia and Raniganj coalfields.

Our chief object was to see and examine the conditions as regards the presence of coal-dust. We visited three collieries in each field, and a brief report of the inspections is given in Appendix V. The general outcome of our observations may be stated as follows:—

Collieries in the Raniganj Coalfield.

11. *Colliery A. Seam—Dishergarh.*—Depth of shafts 1,500 feet. Conditions dry throughout. Inflammable gas given off. Stone-dusting applied throughout in the mine workings, except in a few working places where local watering is done. Permitted explosives are used where blasting is necessary. Ventilation good. The workings appeared to be adequately stone dusted.

Colliery B. Seam—Dishergarh.—Depth of shafts 1,175 feet. Conditions near the face of working galleries were usually wet but at a short distance from the face the roadway became dry and on several of the haulage roads the conditions were dry and dusty. Permitted explosives are used. The seam gives off inflammable gas. Ventilation good. Coal-cutting machines used extensively.

Colliery C. Seam—Poniati.—Depth of shafts 980 feet. Explosive used—gunpowder in tin tubes owing to the wetness of the shot holes. No inflammable gas given off. Ventilation good. Coal-cutting machines are in use. The haulage roads were moist and firm underfoot, all new drivings were wet, and depillaring areas were dry but not unusually dusty.

Collieries in the Jharia Coalfield.

12. *Colliery D. Seams Nos. 13 and 12.*—Depth of shafts 650 feet. Conditions in working galleries fairly dry, in depillaring areas damp, and on haulage roads in general dry and dusty. One part of this mine we would describe as dry and very dusty. The seam does not give off inflammable gas. Country-made gunpowder is used to a large extent. The coal in galleries is undercut mechanically. Ventilation good.

Colliery E. Seams Nos. 15 and 14-A.—Depth of shafts 400 feet. Conditions generally dry and in many places dusty. No inflammable gas given off. Country-made gunpowder used extensively. Ventilation good.

Colliery F. Seam No. 18.—Depth of shafts 450 feet. Permitted explosives used. Ventilation good. Haulage roads were damp and comparatively free from coal-dust, advancing faces were wet and depillaring places were dry.

13. Summarising, we may say that excluding Colliery A, which was dry throughout and in which precautions against the risk of coal-dust explosions are already being taken, the condition of the mines visited showed that the workings either in whole or in part contained deposits of dry coal-dust.

Analysis of Representative Samples of Coal-dust.

14. In our First Report (1) we discussed in a preliminary way the conditions as regards coal-dust in Indian mines and gave some results of screen analyses of dust collected in a typical hand-cut gallery in an Indian mine. These tests showed 11·76 per cent. of the dust to be finer than 150 mesh, and 47·97 per cent. to be below 30 mesh. The concentration of dust below 150 mesh was 1 lb. 7 oz. per 100 cubic feet of roadway or 0·23 oz. per cubic foot of volume.

At our request Mr. N. Barraclough, B.Sc., Inspector of Mines in India, with the assistance of Mr. B. Sen of the Indian School of Mines, made a large series of screen analyses of dusts collected in a number of mines in the Raniganj and Jharia coalfields (see Appendix VI). These collieries were the same as those visited by us and the dust was collected from places selected by the Committee.

Taking dust below 30-mesh and excluding Colliery A for the reason mentioned in the foot-note (2), it will be seen that the concentration of dust in the tests of Jharia collieries is higher than in the collieries tested in the Raniganj field. This may be accounted for by the fact that as observed by us in our visits of inspections the conditions in Collieries D. and E. (Jharia Coal-field) are on the whole drier than in Collieries B and C (Raniganj Coalfield). Another noteworthy point is that in many cases the ash percentage of the samples is high.

15. Perhaps the most significant point which emerges from these analyses is that the fineness and concentration of dust is greatest on haulage roads. For example in Colliery E, the concentration of dust below 90-mesh in a machine-cut gallery was 0·09 oz. per cubic foot of air space, while the average of two samples collected from haulage roads in the same mine was 0·171 oz. per cubic foot of air space. Similarly in Colliery D the values of concentration of dust below 90-mesh were 0·133 oz. per cubic foot of air space in a working gallery, and 0·22 oz., 0·16 oz. and 0·68 oz. per cubic foot of air space on haulage roads. The last value is particularly high and this was due to the use of a rotary tippler which produced much fine coal-dust at the place where the sample was collected.

General Conditions in Indian Coal Mines.

16. On the whole in our view coal mines in India are for various reasons neither so dry nor so dusty as coal mines in such countries as Great Britain.

As regards dryness, most of the coal mines in India are comparatively shallow; there are only a few over 1,000 feet deep. Shallow mines are as a rule wetter than deep mines. Because of this the condition at the working face of many of the coal mines in India is not such as to be favourable to the production of dry fine coal-dust.

A different condition of things exists however on the majority of the main haulage roads. In many of the mines wet conditions at the working face gradually change to dry conditions in the main haulage roads, particularly if these are also intake airways. Moreover there is generally a greater accumulation of fine coal-dust on haulage roads than in working galleries.

17. Apart from conditions with respect to moisture however there are other important reasons why the quantity of coal-dust generally found in Indian mines is less than in mines in Great Britain. Work in Indian mines as a rule is carried on more leisurely than in the more highly organised mines of other countries. There is not the same hurry and bustle. In other countries, using highly skilled labour, mechanical coal-cutters and conveyors, and high speed haulage, the production of coal and the activities of transport are on a much more intensive scale than is usual in Indian mines. As a result in the latter within a given area and a given time less fine coal-dust is produced than under conditions in which activities are more intense.

18. It is also necessary to consider the effect of the ventilating current in drying and distributing such fine coal-dust as is produced in the mine. The drying power of the air in an Indian coal mine may be considerable. Such drying power is not the same in all mines. In shallow mines it is less than in deep mines. It is also less at some seasons of the year than at others.

Again the drying power of the air is greatest in the main intake airways because in them the air is travelling at a higher velocity and is still unsaturated. It is practically *nil* in the working places and in the main return airways. In the working places the air is as a rule almost stationary (except where there is a risk of accumulations of inflammable gas) and is approaching saturation, while in the main return airways the air is as a rule practically saturated.

For these reasons it will be found that even in mines which are naturally wet at the working face the main haulage roads, particularly if they are also intake airways, are invariably dry.

We have pointed out that the air-current is often sluggish in the working places. Because of this any fine coal-dust produced in such places is not re-distributed and kept in motion by the air-current. It may be disturbed from time to time by blasting or by the movement of tubs or workmen but soon after it settles again within the same locality. Fine dust on haulage roads where the air-current is strong is, however, being continually winnowed and re-distributed over the sides and floor of the roadway. Again a working gallery or a pillaring area in an Indian mine has, as a rule, a short life and soon ceases to be the scene of human activity,

(1) Paragraph 24, page 20.

(2) The results of the analyses of dusts from Colliery A cannot be compared with those of other collieries as this dust was chiefly incombustible dust due to stone-dusting.

whereas a main haulage road may have an active life extending over the whole history of the mine. Even in main haulage roads the speed of the ventilating current in an Indian mine is seldom as high as in a British mine owing to the greater thickness of the seams. In our view, therefore, the slower movement of the air-current is a factor of some importance which renders the coal-dust danger in Indian mines actually less evident than in British mines.

Recommendations of the Coal-Dust Committee already included in the Indian Coal Mines Regulations, 1926.

19. Since the publication of our First Report several recommendations made by us have been incorporated in the Indian Coal Mines Regulations, 1926. For example:—

(*a*) the recommendation that a supply of clay tamping should be provided at convenient places in the mine is embodied in Regulations 107 and 111,

(*b*) our recommendations regarding the examination of a working place for the presence of inflammable gas or dry coal-dust before the firing of a shot and the making safe of such a place before firing is covered by Regulation 115,

(*c*) our views on the use of "Permitted" explosives were met in Regulation 116,

(*d*) our comments on the particular danger resulting from narrow advance galleries in seams which give off inflammable gas have been partly given effect to in Regulation 124.

Proposed Emendations to Certain Regulations.

20. In our Second Report we refer in conclusion 3, page 7, to the desirability of "correctly proportioning" a charge of explosive. This is an important desideratum, since if the charge is too light for the work to be done it may simply blow out the tamping, and if it is too heavy much of the energy will go to produce heat and flame. It is, however, obviously impracticable to lay down any definite process of determining what is a correctly proportioned charge. Such determination must be left to the person whose duty it is to estimate the amount of the charge. On account of the nature of the work, blasting is hardly ever entrusted to inexperienced persons and any recommendation we can make cannot go beyond an injunction to bear always in mind the importance of suitably proportioning the charge to the work to be done. Proper proportioning is, however, of equal importance to proper drilling and placing, and accordingly we recommend that existing Regulation 107 be amended to read:—

> "The amount of every charge of explosive shall be proportioned to the work to be done, and the charge shall be placed in a properly drilled and placed shot-hole and shall have sufficient stemming. A sufficient supply of clay or other suitable stemming material shall be provided at places convenient to the shot-firers."

21. In our First Report we laid emphasis on the desirability of restricting the length of the narrow advance galleries which are common in pillar and stall workings in India and of conducting the ventilating current as near to the working face as is practicable. Accordingly we recommend that existing Regulation 124 be amended as follows:—

> "In every mine in which inflammable gas has been found during the previous twelve months safety lamps shall be used as a precautionary measure in all galleries driven to a distance greater than the length of two pillars ahead of the last connecting gallery and in all narrow advance galleries, and no narrow advance gallery shall be driven more than 10 feet ahead of the widened gallery; in every such gallery the ventilating current shall be conducted as near to the working face as is practicable."

22. Some of the aspects of the problem outlined in our First and Second Reports were discussed at meetings of the Mining and Geological Institute of India. In particular the Council of the Institute invited opinions on the following points:—

(*a*) Whether the proposal that all dust within a comparatively small radius of a charge of explosive should be removed before the shot is fired is approved.

(*b*) Whether it is reasonable to insist on the use of 'permitted' explosives only.

(*c*) Whether the precautions applied in Great Britain are necessary in India in whole or in part.

The consensus of opinion as revealed in the discussion was that—

(*a*) it was desirable to remove coal-dust before shot-firing;

(*b*) that a general enforcement of the use of 'permitted' explosives was impracticable and unnecessary; and

(*c*) that except in perhaps a few mines in which the danger from coal-dust was more evident than in the majority such precautions as are applied in Great Britain are not necessary.

23. The general question as to the necessity or otherwise of the usual precautions against the risk of coal-dust explosions is discussed elsewhere, but we wish here to make a few comments on the practicability of cleaning up the coal-dust before shot-firing. In our Second Report it is suggested that the removal of fine coal-dust from the vicinity of a shot might eliminate the risk of an ignition by that means. On fuller consideration, however, we are inclined to the view that in general such a course would be impracticable under actual working conditions. In the ordinary process of "cleaning up" in a working place it would be only the

coarser and hence least dangerous dust which could be removed by ordinary means. The finer dust would remain and indeed would be more accessible to dust-raising agencies than if the coarser dust were not removed at all. The removal of coal-dust in the vicinity of a shot since it cannot in practice be thorough is not a complete safeguard and would have to be followed by watering or stone-dusting before the risk of an ignition of coal-dust would be effectively prevented.

Where watering or stone-dusting is to be carried out previous removal of the coal-dust as far as possible is to be recommended since less water or less stone-dust, as the case might be, would then be necessary. But where no additional palliative is to be applied it is doubtful if the removal of the dust, unless very thorough, would in itself be sufficient. The suggestion to be worth anything in practice would involve careful sweeping up of the fine dust before every shot and we greatly doubt if that is practicable. We feel that in cases where there is an obvious danger cleaning up the dust must be followed by watering or stone-dusting to be of any use, and if the danger is not a serious one, as in our opinion in general in a non-gassy mine it is not, it is perhaps better not to attempt any sweeping up of the dust before shot-firing. At the same time we approve of the removal of as much of the small coal as possible from the mine so as to minimise the amount of fine dust produced.

We wish also to draw the attention of mine managers to the possibility of fine coal-dust from screening plants being carried into the mine, and the desirability of taking steps to minimise or prevent this occurring.

General Discussion of tests included in the First and Second Reports.

24. In our Second Report we stated (1) that the dust of any coal seam of commercial value in India, if in a sufficiently fine state of sub-division and in sufficient quantity, is capable of rendering an atmosphere of ordinary air explosive. We also concluded that dust from a seam having a large percentage of ash and a low volatile content was less readily ignitable than dust from a seam low in ash and high in volatiles. For example, out of ten ignition tests of dust from the Dishergarh seam there was only one non-ignition, and of three ignition tests of dust from Sanctoria seam the non-ignitions were *nil*; while out of thirteen ignition tests of dust from No. 15 seam, Jharia, there were eight non-ignitions. Again out of five propagation tests of dusts from the Dishergarh and Sanctoria seams all resulted in inflammations, while out of six similar tests of No. 15 seam there were three failures. In our view the greater inflammability of dusts from the Dishergarh and Sanctoria seams, as compared with Jharia

(1) Conclusion 1, page 7.

No. 15 seam, is chiefly due to the larger percentages of volatile matter.

It was also shown that in order to obtain an explosion under the same conditions as with richer seams dust from No. 10 seam Jharia, for example, had to be crushed to a finer state of sub-division.

The Indian Coal Grading Board classify the coals of Bengal and Bihar and Orissa in two groups, *viz.*, low volatile coal and high volatile coal. We are of the opinion, and the view is supported by more elaborate tests in other countries, that dust from a high volatile coal under similar conditions is more inflammable than dust from a low volatile coal.

25. In considering the tests described in the First and Second Reports it must be remembered that the conditions were much more severe than are likely to obtain under normal conditions in a mine. The dust was ground artificially to a greater degree of fineness than is usually to be found in mine workings, and the source of ignition of the dust was more severe than that ordinarily obtainable from shot-firing in a mine. At the same time although the conditions were abnormal it is not impossible to obtain conditions equally severe in a coal mine, as witness the circumstances giving rise to the explosion which occurred at Parbelia Colliery in 1923. There the conditions were ideal for an ignition of coal-dust, a badly placed shot the charge from which ejected a large column of hot flame into a narrow gallery containing a large accumulation of very fine dry coal-dust.

Proposals in Respect of Coal Mines Working Seams which do not give off Inflammable Gas.

26. We have given careful consideration to the question of what safeguards, if any, are necessary against the possibility of a coal-dust explosion in mines in which inflammable gas has not been found. We have also discussed this matter with many mining engineers and colliery managers. The consensus of opinion appears to be that in such mines the risk of an explosion of coal-dust is remote and that no special safeguards are necessary.

One of the main arguments put forward has relation to the extensive use of gunpowder in these mines and the practical non-existence of any evidence of an ignition of coal-dust (1). It is argued that not only are many charges of gunpowder fired every day in these mines, but that many of them must unavoidably result in partially and occasionally completely blown-out shots, since in some mines the coal is blown from the solid face without undercut or side-cut. This argument must, we feel, be given considerable weight.

(1) The only instance of an inflammation which may have been due to coal-dust is that which occurred at Sijua Colliery and is mentioned in our First Report.

Furthermore in our view the amount of fine dust in working galleries is as a rule so meagre and so mixed with coarser particles of coal that the possibility of an inflammation in the absence of inflammable gas is remote. Consequently we do not feel justified in suggesting that any additional precautions should be taken at the coal face beyond a general recommendation that colliery managers should instruct all subordinate officials to take special care in the proportioning, placing and tamping of charges so as to avoid blown-out shots.

27. We recommend, however, that two additional regulations be made applicable to all coal mines as follows:—

> "As far as practicable main haulage roads shall be kept free from accumulations of fine coal-dust;" and
>
> "All coal tubs shall be so constructed and maintained as to prevent, as far as practicable, coal-dust escaping through the sides, ends or floor of the tubs."

The object of these regulations would be to minimise the production of fine coal-dust as far as practicable. Much fine dust, as we have pointed out elsewhere, is produced on haulage roads, and the greater the accumulations of small coal on such roads the greater the production of fine dust which may be carried by the ventilating current and by other agencies to other parts of the mine.

Proposals in Respect of Coal Mines Working Seams which give off Inflammable Gas.

28. The arguments based on the extensive use of gunpowder and the absence of any definite ignition of coal-dust though potent when applied to non-gassy mines in India are not applicable to mines in which inflammable gas is found. Other things being the same, a coal-dust explosion is much more likely to eventuate in a gassy mine than in one in which inflammable gas is absent. The presence of even a small percentage of inflammable gas in the air will greatly increase the inflammability of a dust-air mixture. Moreover an initial explosion of fire-damp provides an ideal pioneering wave which stirs up and raises any fine dust in the vicinity, and the magnitude of the flame of the gas explosion renders it probable that dry coal-dust if present will become ignited and propagate the explosion beyond the limits of the inflammable gas.

Again in India a seam which gives off inflammable gas is as a rule rich in volatiles. The evidence of coal-dust explosions even in gassy seams in India may not be so weighty as in other countries, chiefly perhaps because the number of mines working such seams in India is small compared with the number in other countries, but in our opinion it is sufficient to warrant a clear

distinction being made in our recommendations between gassy and non-gassy mines. We have the evidence of the part played by coal-dust in the explosions at Khost in 1908 and Chowrassie in 1913 and more recently at Dishergarh West Colliery in 1930. The explosion at Parbelia Colliery in 1923, while said to have been a pure coal-dust explosion, occurred in a seam which constantly gives off inflammable gas.

In our view, therefore, more stringent precautions with respect to the danger from coal-dust should be applied in gassy than in non-gassy mines.

29. Under Regulation 116 of the Indian Coal Mines Regulations, 1926, "permitted" explosives are required to be used in any mine in which inflammable gas has been found in the previous twelve months.

We recommend that additional regulations respecting the use of "permitted" explosives be made as follows:—

> *Suggested Regulation 116-A.*—"In any place where the use of 'permitted' explosive is enjoined by the Regulations all shots in a round of shots shall be fired simultaneously."
>
> *Suggested Regulation 116-B.*—"In any place where the use of 'permitted' explosive is enjoined by the Regulations the aggregate charge in any number of shots fired simultaneously in coal shall not exceed the permissible maximum charge for the kind of 'permitted' explosive used."
>
> *Suggested Regulation 116-C.*—"In any place where the use of 'permitted' explosive is enjoined by the Regulations no shot shall be fired in coal which has not been undercut, overcut or sidecut, and the length of the shot-hole shall be at least 6 inches less than the length of the cut."

30. In suggesting these further precautions in respect of the use of "permitted" explosives we desire to emphasise the fact that the use of a "permitted" explosive instead of an ordinary explosive is no more than a partial safeguard. In the year 1929 eight explosions of fire-damp due to the firing of shots of "permitted" explosives occurred in Great Britain. In India the explosions at Parbelia and Dishergarh collieries were caused by the firing of shots of "permitted" explosives. It is evident, therefore, that the protection afforded by using "permitted" explosives in place of ordinary explosives is not enough to prevent an explosion of inflammable gas or coal-dust.

We invite attention to the recommendation contained in the report of the Court of Inquiry into the explosion at Dishergarh West Colliery in 1930 that shot-firers in gassy mines be required to hold a certificate of ability to test for inflammable gas. We fully endorse this suggestion and believe that it is an obvious and necessary safeguard.

31. In addition we suggest the desirability of applying the following new regulations to certain coal mines:—

"All airways, haulage and travelling roads and working places or parts of same which contain dry coal-dust shall be treated in one of the following ways:—

(*a*) they shall be treated with fine incombustible dust in such manner, and at such intervals, as will ensure 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;

(*b*) they shall be treated with water in such manner, and at such intervals, as will ensure that the dust on the floor, roof and sides throughout shall be in such a wet condition that it cannot be raised in a cloud; or

(*c*) they shall be treated in such manner as the Chief Inspector of Mines may approve.

NOTE.—The incombustible dust used for the purposes of this regulation shall be prepared from shale or other material containing no injurious free silica."

These recommendations follow on the lines of regulations in use in Great Britain but are much less stringent since we have omitted the requirements regarding sampling and testing. We think that it will be sufficient to leave the proper application of the foregoing safeguards to the judgment of the mine manager and the vigilance of the officers of the Department of Mines.

32. There remain to consider the particular mines or classes of mines to which the new regulations suggested in the preceding paragraph should apply. We doubt the necessity of applying them to all coal mines in which inflammable gas is found or likely to be found, or to all mines in which safety lamps are required to be used in compliance with Coal Mines Regulation 123. In our opinion the number of coal mines in India in which there is any appreciable danger of an explosion of coal-dust is few. In South Africa and Australia—where underground conditions in coal mines are similar to those in India—precautions in respect of coal-dust are applied at the discretion of the Inspector of Mines. We consider that this example may well be followed, and we recommend that the Chief Inspector of Mines be empowered to apply the regulations detailed in the preceding paragraph to any mine in which in his opinion the risk of an explosion of coal-dust is such as to require the taking of precautions additional to those enjoined in respect of all coal mines.

GENERAL REMARKS AND CONCLUSION.

33. Before concluding our report we wish to point out that our investigations have necessarily been less elaborate than those carried out in more important coal mining countries such as Great Britain, France, Germany, and the United States of America. The

funds at our disposal were relatively small and we had to rely chiefly on investigators who could devote only a small portion of their time to the work of the Committee. As was pointed out, however, in our First Report many of the facts of cardinal importance have been adequately established in other countries and with a precision which we, with our limited resources, could not hope to emulate. We have not, therefore, considered it necessary to follow either in form or in magnitude the course of investigations elsewhere but rather to gather such data with respect to conditions in India as would enable us to arrive at an accurate appreciation of the problem as it exists in this country. We are satisfied that the information at our disposal is sufficient for the purpose for which we have been constituted and that the recommendations we have put forward are such as will provide reasonable and sufficient safeguards against the risk of explosions of coal-dust in Indian coal mines. A summary of the recommendations made is given in Appendix I.

34. In conclusion we wish to express our cordial appreciation of the valuable assistance given by owners, agents and managers of coal mines in the provision and erection of the test gallery, the supply of samples of coal, and in many other ways. The experimental work has been personally supervised by Dr. D. Penman, and in its later stages by Mr. N. Barraclough. The Committee gratefully acknowledges the valuable work done by these gentlemen on its behalf.

R. R. SIMPSON.

JAS. E. PHELPS.

H. K. NAG.

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J. THOMAS.

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P. B. BASU.

JAS. H. LANG.

D. PENMAN.

APPENDIX I.

Summary of Recommendations.

1. That Regulation 107 be amended to read:—

"The amount of every charge of explosive shall be proportioned to the work to be done, and the charge shall be placed in a properly drilled and placed shot-hole and shall have sufficient stemming. A sufficient supply of clay or other suitable stemming material shall be provided at places convenient to the shot-firers."

Page 8, para. 20.

2. That Regulation 124 be amended as follows:—

"In every mine in which inflammable gas has been found during the previous twelve months safety lamps shall be used as a precautionary measure in all galleries driven to a distance greater than the length of two pillars ahead of the last connecting gallery and in all narrow advance galleries, and no narrow advance gallery shall be driven more than 10 feet ahead of the widened gallery; in every such gallery the ventilating current shall be conducted as near to the working face as is practicable."

Page 9, para. 21.

3. That two additional regulations be made applicable to all mines as follows:—

"As far as practicable main haulage roads shall be kept free from accumulations of fine coal-dust; and

"All coal tubs shall be so constructed and maintained as to prevent, as far as practicable, coal-dust escaping through the sides, ends or floor of the tubs."

Page 12, para. 27.

4. That additional regulations respecting the use of "permitted" explosives be made as follows:—

Regulation 116-A.—"In any place where the use of 'permitted' explosive is enjoined by the Regulations all shots in a round of shots shall be fired simultaneously."

Regulation 116-B.—"In any place where the use of 'permitted' explosive is enjoined by the Regulations the aggregate charge in any number of shots fired simultaneously in coal shall not exceed the permissible maximum charge for the kind of 'permitted' explosive used."

Regulation 116-C.—"In any place where the use of 'permitted' explosive is enjoined by the Regulations no shot shall be fired in coal which has not been undercut, overcut, or sidecut, and the length of the shot-hole shall be at least 6 inches less than the length of the cut."

Page 13, para. 29.

5. That shot-firers in gassy mines be required to hold a certificate of ability to test for inflammable gas.

Page 13, para. 30.

6. That to certain coal mines a new regulation, as follows, be applied :—

"All airways, haulage and travelling roads and working places or parts of same which contain dry coal-dust shall be treated in one of the following ways :—

(*a*) they shall be treated with fine incombustible dust in such manner, and at such intervals, as will ensure 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;

(*b*) they shall be treated with water in such manner, and at such intervals, as will ensure that dust on the floor, roof and sides throughout shall be in such a wet condition that it cannot be raised in a cloud; or

(*c*) they shall be treated in such manner as the Chief Inspector of Mines may approve.

NOTE.—The incombustible dust used for the purposes of this regulation shall be prepared from shale or other material containing no injurious free silica."

Page 14, para. 32.

7. That the Chief Inspector of Mines be empowered to apply the regulation detailed in the preceding paragraph to any mine in which in his opinion the risk of an explosion of coal-dust is such as to require the taking of precautions additional to those enjoined in respect of all coal mines.

Page 14, para. 32.

APPENDIX II.

Demonstration Tests.

Tests Nos. 74, 75, 76.—These tests were carried out at the experimental underground gallery at Godhur on the 27th January 1928 (see Second Report, page 11). The condition of the floor of the gallery was damp due to running rain water.

Test No. 74.—The testing gun was placed at a distance of 150 feet from the mouth of the incline and charged with three-quarters of a pound of English compressed gunpowder. The floor of the gallery was strewn with dust from No. 13 seam, Jharia, 80 per cent. of which was ground to pass a sieve of 150 meshes per linear inch.

Result.—No ignition.

Test No. 75.—Repeat of No. 74 but with the gun brought up to a dry place at 35 feet from the mouth of the incline. A small amount of fresh dust was placed on the floor near the mouth of the cannon.

Result.—An ignition, large volumes of flame being ejected from the mouth of the incline.

Test No. 76.—Repeat of test No. 75.

Result.—An ignition similar to that in test No. 75.

Tests Nos. 77, 78, 79.—These tests constituted a demonstration of the inflammability of Indian coals to members of the Colliery Managers' Association in India and were carried out, in the steel test gallery at the Indian School of Mines, Dhanbad, on the 9th July 1928.

Test No. 77.—Seam No. 13, Jharia. Fineness of dust 75 per cent. passed through 200 mesh sieve. Source of ignition—Three-quarters of a pound of English compressed gunpowder fired from the test cannon. Dust strewn on floor of test gallery for a distance of about 25 feet.

Result.—Ignition with large volume of flame emerging from mouth of tube.

Test No. 78.—Repeat of No. 77 but without spreading any more coal-dust.

Result.—Ignition as in test No. 77.

Test No. 79.—Repeat of Nos. 77 and 78, but with dust which was six months old.

Result.—Ignition as in tests Nos. 77 and 78.

APPENDIX III.

Tests in an underground gallery with sweepings collected from working galleries and haulage roads.

Date:—21st February 1931.

In the majority of previous tests artificially ground fine coal-dust was used and the tests were made under conditions which were very favourable to an explosion or ignition being obtained. The following tests were made with dust in, as far as possible, the same state of sub-division as it was found in the mine.

The tests were conducted in an underground incline in 15 seam which was prepared and placed at the disposal of the Coal-Dust Committee by the kindness of the East Indian Coal Company, Limited, the owners of Kendwadih Colliery. The dimensions of the incline are shown in Figure 1.

Tests Nos. 80, 81 and 82.—Dust used.—A dry hand-cut gallery in 15 seam was swept clean for a distance of about 15 feet from the face and the whole of the material collected, with the exception of pieces of coal exceeding a 1-inch cube, was placed in kerosene tins. From a volume of 973 cubic feet of gallery and a floor area of 122 square feet, a quantity of 375 lb. of dust and small coal was obtained.

At the experimental incline the material was evenly spread on the floor over an area such that the volume of the gallery was the same as the volume of the gallery from which the sample was obtained.

Test No. 80.—Two shot-holes about 4 feet deep were drilled in the coal side of the experimental incline and lined with iron pipes having an internal diameter of about 2 inches. The holes were 18 inches above the floor and inclined so that they pointed towards a point on the floor in the centre of the gallery.

The object in lining the holes was to produce blown-out shots and to prevent the sides of the incline being unduly shattered. The holes were charged each with 1 lb. of country-made gunpowder and stemmed with 2 inches of clay.

The shots were fired electrically, the second shot being fired about 1 second after the first.

Result.—The first shot raised a cloud of dust but no flame other than the flame from the explosive was observed. The second shot did not cause an ignition of the dust cloud.

Test No. 81.—This test was a repetition of No. 80 as described above, but the first shot was a charge of 2 lb. and the second 1½ lb. of country-made gunpowder. An interval of about 10 seconds elapsed between the firing of the two shots.

Result.—The first shot raised a cloud of coal-dust but no flame other than the flame of the shots was observed.

Test No. 82.—The conditions were the same as in tests Nos. 80 and 81, but the charges were 6 oz. of gelignite and the interval between the firing of the two shots was about 2 seconds.

Result.—The dust cloud formed by the first shot appeared to be smaller than the clouds produced by the charges of gunpowder in the previous tests. One cartridge of gelignite was projected from the second shot-hole and continued to burn on the floor of the gallery until it was consumed. No ignition took place.

Sieve analysis of a representative sample of the dust used in tests Nos. 80, 81 and 82.

Total weight of sample.	Remained on 30 mesh sieve.	Remained on 90 mesh sieve.	Remained on 150 mesh sieve.	Remained on 200 mesh sieve.	Passed through 200 mesh sieve.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
3 lb. 9·05 oz.	77·7	13·8	4·7	2·1	1·7

Proximate analysis of coal-dust used in tests Nos. 80, 81 and 82.

Ash.	Moisture.	Volatile matter.	Fixed carbon.
18·35	2·51	27·20	51·94

It is interesting to note that in the experimental incline the concentration of dust which was capable of being passed through a 150 mesh I.M.M. Sieve was ·228 oz. per cubic foot of air space; a concentration in excess of that required for an explosion.

The fine dust, however, was mixed with 25 times its own weight of coarser dust, which would, to a considerable extent, prevent it being raised in a cloud by the blown-out shots.

Tests in an underground gallery with sweepings collected from a machine-cut gallery.

Date:—26th February 1931.

Dust used.—The mixture of small coal and dust was taken from a gallery in 15 seam which was being driven along a barrier to prepare a pillar for extraction. The gallery being to the rise of an area in which pillars were being extracted was perfectly dry. The face had been undercut by a coal-cutting machine and the normal amount of sweeping and cleaning up had been done preparatory to blasting the face. Although the gallery looked clean there was still a fair amount of the finer dust left on the floor. There was practically no dust on the sides. From a volume of 2,182 cubic feet of gallery and a floor area of 336 square feet, 375 lb. of dust and small coal were obtained.

At the experimental incline the material was evenly spread on the floor over an area such that the volume of the gallery was the same as the volume of the gallery in the mine from which it was obtained.

Test No. 83.—Two shot-holes drilled in the coal side of the experimental incline and lined with iron pipes, 2 inches in diameter and 4 feet long, were each charged with 1 lb. of country-made gunpowder and tamped with about 1½ inches of clay. The first hole was 1 foot above the floor and inclined so that it pointed towards a point on the floor in the centre of the gallery and the second hole was almost horizontal and 3 feet above the first hole. The first hole was fired by ordinary fuse, and the second was fired by electric fuse 1 second after the first shot exploded.

Result.—The first shot raised a cloud of dust and there was a slight ignition of the coal-dust with a flame which appeared to be about 4 feet in diameter and to extend for a distance of 4 or 5 feet across the gallery. There was no ignition with the second shot. The noise made by both shots indicated

that in the absence of the lining pipes they would have done a normal amount of work. The pipes were not damaged and both shots were blown-out shots.

Test No. 84.—This test was a repetition of test No. 83 as described above, but both holes were charged with 2 lb. of country-made gunpowder.

Result.—The first shot raised a cloud of dust but neither of the shots produced an ignition of coal-dust. Although the shots were " blown-out shots " the lining pipes were torn longitudinally and the coal at the face of the holes was shattered.

Test No. 85.—Three, two ounce, cartridges of gelignite were tied together and laid on the dust, as it was spread over the floor for the previous tests, and fired by a fuse detonator.

Result.—A loud detonation with a small bright flame but no ignition. The dust cloud raised by this means was barely perceptible.

Test No. 86.—About 50 lb. of unsieved material was placed on the floor in a pile about 15 inches in diameter and three catridges of gelignite, arranged as in the previous test, were buried in the dust to a depth of two or three inches.

Result.—There was a loud detonation but no more flame than in Test No. 85, and although a large concentrated cloud of dust was formed no ignition took place. The dust from a radius of 18 inches was blown off the floor.

Test No. 87.—One shot-hole 4 feet deep and lined with an iron pipe, 2 inches in diameter, placed 12 inches above the floor and inclined so that it pointed towards the floor was charged with 2 lb. of country-made gunpowder and stemmed with 1½ inches of clay.

Result.—A " blown-out " shot accompanied by a loud detonation. There was an ignition of coal-dust; the flame being observed very distinctly. It traversed the floor, the opposite side and the roof and appeared to die out on the side in which the shot-hole was placed. The flame seemed to be more intense round the perimeter of the gallery than in the centre. The ignition did not appear to extend outwards although there was dust on the floor for a distance of 20 feet from the shot-hole towards the incline entrance. It seemed to be confined to a section of the gallery, 5 to 10 feet long, in which the concussion and the velocity of the products from the blown-out shot raised a cloud of dust.

The fact that an ignition of this extent was obtained when previous shots of similar charge had not resulted in such an ignition is explained by the fact that the fine dust of the dust clouds raised in previous experiments had been deposited on the floor roof and sides and thus a condition favourable for an ignition was gradually created.

The results so far obtained indicate that where fine dust, which is free to be raised in a cloud, is present in a gallery a blown-out shot can raise and ignite a dust cloud of considerable volume but if the fine dust is intermixed with many times its own volume of coarser dust a blown-out shot is unlikely to raise and ignite a dust cloud of such a concentration and volume as might initiate a coal-dust explosion.

Sieve analysis of a representative sample of the dust used in tests Nos. 83—87.

Total weight of sample.	Remained on 30 mesh I. M. M. sieve.	Remained on 90 mesh I. M. M. sieve.	Remained on 150 mesh sieve.	Remained on 200 mesh I. M. M. sieve.	Passed through 200 mesh I. M. M. sieve.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
4 lb. 12·25 oz.	67·5	17·4	8·4	4·1	2·6

Proximate analysis.

Ash.	Moisture.	Volatile matter.	Fixed carbon.
18·67	2·20	27·64	51·49

In the experimental incline and in the machine-cut gallery from which the dust was obtained the concentration of dust capable of being passed through a 150 mesh sieve was ·184 oz. per cubic foot of air space; a concentration capable of propagating an explosion. It will be noted that the percentage of dust which passed through a 150 mesh sieve was 6·7 per cent. whereas the percentage of dust of the same fineness obtained from a hand-cut gallery (see tests 80—82) was 3·8 per cent. The hand-cut gallery had not been cleaned up before the sample was collected.

By sweeping a gallery with a wisp or coarse broom as was done in the machine-cut gallery before the sample was taken the fine dust is concentrated on the floor.

Tests in an underground gallery with sweepings collected from a haulage road.

Date:—1st March 1931.

Dust used.—The sample consisted of unsieved small coal and dust collected from the floor and sides of a dry section of haulage road in No. 15 seam. The floor could not be swept clean as there was a considerable thickness of small coal which formed the packing of the haulage line and from the floor a superficial layer, not more than ¼ inch thick, was included in the sample. From a volume of 2,340 cubic feet of roadway and a floor area of 234 square feet, 375 lb. of dust and slack coal were obtained.

At the experimental incline the material was evenly spread on the floor over an area such that the volume of the gallery was equal to the volume of the roadway in the mine from which it was collected.

Test No. 88.—Two shot-holes in opposite sides and about 12 inches above the floor of the gallery were made 4 feet deep and lined with strong iron pipes, 2 inches in diameter. The outer end of the holes pointed towards the floor. Each hole was charged with 1 lb. of country-made gunpowder, the first shot being primed with ordinary fuse and the second with an electric fuse.

Result.—The first shot was a " blown-out shot " and raised some dust but no ignition of the dust cloud occurred. It was the intention to fire the second shot one second after the first but it misfired due to a defective electric fuse.

Test No. 89.—Test No. 88 was repeated but two holes were each charged with 2 lb. of country-made gunpowder.

Result.—The first shot, which was ignited by an ordinary fuse, resulted in a loud detonation and was a " blown-out shot ". Although a dust cloud was formed and there was considerable flame with the blown-out shot, there was no ignition of the coal-dust. Despite the fact that two electric fuses were used the second shot was a misfire.

Test No. 90.—One hole, 12 inches above and pointing towards the floor, was charged with 2 lb. of country-made gunpowder and fired by means of ordinary fuse. In order to encourage the formation of a more concentrated dust cloud and create conditions more favourable for an ignition, additional dust was spread on the floor in the line of the shot-hole.

Result.—No ignition. This shot was not a blown-out shot as the lining pipe was destroyed and about 1 ton of coal was blown off the side of the gallery.

Sieve analysis of a representative sample of the dust used in test Nos. 88, 89 and 90.

Total weight of sample.	Remained on 30 mesh I. M. M. sieve.	Remained on 90 mesh I. M. M. sieve.	Remained on 150 mesh I. M. M. sieve.	Remained on 200 mesh I. M. M. sieve.	Passed through 200 mesh I. M. M. sieve.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
4 lb. 8·8 oz. .	73·2	12·8	7·5	4·0	2·5

Proximate analysis.

Ash.	Moisture.	Volatile matter.	Fixed carbon.
17·68	2·98	26·86	52·48

Tests in an underground gallery with sweepings collected from a gallery in the Dishergarh seam.

Date:—7th March 1931.

Dust used.—The unsieved dust used in these tests was obtained from a mine in the Raniganj coalfield and from a district in the Dishergarh seam which was being extended towards the rise. The thickness of strata above the seam was about 850 feet. As the dust at working faces was damp and unsuitable for the purposes of the tests the sample was taken from a dry travelling and carrying road situated about 100 feet from the nearest working face. The faces were being cut by hand, and coal-cutting machines had not been used in the district. The quantity of dust on the sides of the gallery was negligible and the whole of the sample, weighing about 390 lb. was obtained by sweeping the floor. In order to avoid loss of fine dust during transit the sample was transported from the mine to the experimental incline in sealed tins.

At the experimental mine the material was evenly spread on the floor over an area such that the volume of the gallery was about half that of the gallery from which it was obtained.

Sieve analysis of the dust used in tests Nos. 91—95.

Total weight of sample.	Remained on 30 mesh I. M. M. sieve.	Remained on 90 mesh I. M. M. sieve.	Remained on 150 mesh I. M. M. sieve.	Remained on 200 mesh I. M. M. sieve.	Passed through 200 mesh I. M. M. sieve.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
5 lb. 7·35 oz. .	83 9	8·5	2·6	2·3	2·7

Proximate analysis.

Ash.	Moisture.	Volatile matter.	Fixed carbon.
10·10	3·14	35·02	51·74

In the unsieved dust used in the tests the quantity of dust capable of being passed through a 150 mesh sieve was 312 oz. and in the experimental incline the concentration of dust of this fineness was 0·17 oz. per c. ft. of air space.

Test No. 91.—Two shot-holes made in the coal side of the experimental incline and lined with iron pipes, 4 feet long and 2 inches in diameter, were each charged with 1 lb. of country-made gunpowder and tamped with about 1½ inches of clay. The shot-holes were about 12 inches above the floor and 4 feet apart and arranged so that the gaseous products from the shots would strike the floor at about the centre of the gallery. The first shot was ignited by means of ordinary fuse and the second was fired about one second later by an electric fuse.

Result.—The shots which were " blown-out shots " disturbed and dispersed some of the coal-dust in the vicinity of the shot-holes but the cloud of coal-dust which was formed was not ignited.

Test No. 92.—After some fresh dust had been strewn in front of the shot-holes to replace the dust dispersed by the previous shots the holes were each charged with 2 lb. of country-made gunpowder and fired in the same manner as described in test No. 91.

Result.—The charge of the first shot burnt without exploding and gave a large flame for several seconds. The second shot was fired about one second after the flame of the first shot was first observed and it resulted in a loud detonation and a blown-out shot. There was no ignition of coal dust.

Test No. 93.—One shot-hole at the opposite side of the incline to the holes used in tests Nos. 91 and 92 and about 6 feet closer to the incline entrance, was charged with 1¼ lb. of country-made gunpowder. The hole was 12 inches above and pointing towards the floor. The fine dust separated from the coarser particles by the previous tests had been deposited as a thin film on the floor and sides and it was thought that an ignition might be obtained.

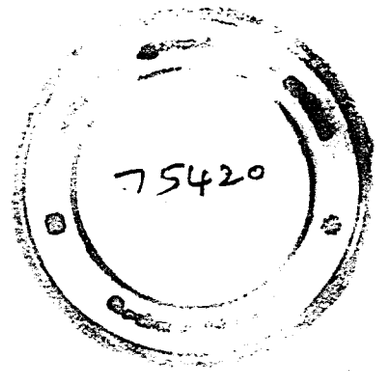
Result.—A blown-out shot but no ignition of coal-dust occurred.

Test No. 94.—One shot-hole 12 inches above the floor was charged with 8 oz. of Monobel (Permitted explosive).

Result.—A blown-out shot and the lining pipe was ejected from the hole. No ignition took place and no flame was observed.

Test No. 95.—Another hole 12 inches above the floor was charged with 10 oz. of Monobel and tamped with about one inch of clay.

Result.—A blown-out shot and the lining pipe was shattered and blown out of the hole. The detonation was sharp and a flame 9 to 12 inches long was observed. There was no ignition of coal dust.



APPENDIX IV.

Ignition tests in an underground gallery with screened coal-dust of various sizes.

Date:—8th March 1931.

Dust used.—The dust used in the following tests was obtained from a machine-cut gallery in 15 seam which had been cleaned up preparatory to blasting. It was screened through 30,90,150 and 200 mesh I.M.M. standard sieves. Great care was taken in screening the dust to avoid, as far as possible, any of the finer dust remaining with that of a coarser mesh. At the experimental incline the dust of each size was tested separately. As the quantity of dust available was limited it was strewn on iron plates laid on the floor in front of a shot-hole. The shot-hole used throughout the tests was 12 inches above the floor and directed towards a point in the centre of the iron plates, and in each test it was charged with 1 lb. of country-made gunpowder, lightly tamped with 1½ inches of clay and fired by means of an electric fuse.

Table showing conditions and results of tests.

Number of test.	Size of dust used.	Quantity of dust used.	Approximate length of gallery dusted.	Concentration of dust per c. ft. of air space.	Result.
		oz.	ft.	oz.	
96	Through 30 mesh and on 90 mesh.	100	5	·35	No ignition.
97	Through 90 mesh and on 150 mesh.	43·8	4	·19	Do.
98	Through 150 mesh and on 200 mesh.	17·5	3	·17	An ignition.
	Through 200 mesh	11·2			

After tests Nos. 96 and 97 it was observed that the dust had been blown off the iron plates for a width of 2 to 3 feet. As Dr. Penman thought that the failure to obtain ignitions in tests Nos. 96 and 97 might have been due to the dust being blown off the smooth iron plates in advance of the flame of the blown-out shots, several lumps of coal were placed on the plates before spreading the dust from test No. 98 so that there would be greater turbulence in the dust cloud. In test No. 98, when an ignition was obtained the flame appeared to traverse the floor, opposite side and the roof of the gallery, and it was of about the same volume and intensity as the flame observed in test No. 87. After the test particles of coked dust were found on the iron plates.

APPENDIX V.

Note on the visit of the Coal-dust Committee to a colliery in the Raniganj Coalfield on the 15th December 1930.

Colliery A.

The party descended by the upcast shaft which is about 1,500 feet deep. Hygrometric readings taken in a main return airway near to the shaft bottom were, wet bulb 76° F., dry bulb 89° F. The south-east section of the mine was inspected and the workings were found to be very dry. The mine makes very little water and no pumping is necessary.

The general impression obtained from the underground inspection was that the workings were adequately stone dusted, and that the percentage of incombustible matter in the dust was higher than fifty. In the return airways the stone-dust on the floor was of a considerable thickness and when it was disturbed it readily rose in a cloud.

Stone dusting was not done close to the working faces, but as the faces were well ventilated and no shots were being fired in them there appeared to be no danger in leaving a short length of gallery without stone-dust. We were informed that "permitted" explosives were used in certain places on the broad side of pillars and that when a shot was about to be fired the immediate area was drenched with water instead of being stone dusted.

Stone-dust which was prepared from red burnt shale and occasionally from a buff coloured river silt was ground in a steel ball mill. The cost of grinding and spreading the stone-dust, and of cleaning the roads, prior to spreading the stone-dust was stated to be Pies 9·4 per ton of coal raised, and in 1930, when the output was 143,688 tons, 1,466 tubs of stone-dust were sent into the mine.

Note on the visit of the Coal-dust Committee to a colliery in the Raniganj Coalfield on the 29th December 1930.

Colliery B.

Descent was made by No. 1 (upcast) pit, 1,175 feet deep to the Dishergarh seam, 13 feet thick. Along the main east level the haulage road was fairly dry and caked underfoot. On the No. 1 S. E. haulage road it was dry and dusty for about 600 feet and there was a quantity of caked and loose dust on the sides of the pillars. The tram lines here and elsewhere are ballasted with boiler ash (some 15 tubs of ashes are lowered daily). On No. 9 east level there was a certain amount of moisture on the floor and not much dust, but the face, where pillar extraction has been commenced, was dry and there was a fair quantity of slack and dust. The goaved parts, however, contained no slack. We were informed that all coal, even slack and dust, is valuable and that it pays to remove it.

No. 13 level was distinctly damp and this condition obtained throughout the whole of the workings near No. 1 east haulage dip. On No. 18 level between No. 1 east haulage dip and No. 1 west haulage dip it was dry and dusty, but less so near the No. 1 west haulage dip and on the dip itself it was damp. The main dip workings were fairly wet throughout the parts seen, but at certain points conditions were dry within 100 feet of the face. The No. 1 west haulage road was dry in places, and there was not much dust.

In the main west return airway for a stretch of 110 feet near the upcast shaft the conditions were dry and dusty. This was the only part of the return airway examined.

8,000 gallons per hour is pumped and this water is given off from
f the working faces to the other.

of stonobel and 3,000 detonators are used in an average month
tput of 14,000 tons. 75 per cent. of this is got by electric coal

ntilation was good. The last measurement made on 15th December
111,000 cubic feet per minute. The fan was not working at the
it is not used during the cold weather months.

the visit of the Coal-dust Committee to a colliery in the Raniganj Coalfield on the 29th December 1930.

COLLIERY C.

t was made by the downcast shaft No. 2—980 feet deep to the
am (Poniati) 16 feet thick. We went along south main haulage
s was firm underfoot and free from slack and dust. We went
5 west haulage dip which was damp throughout and towards the
water was dropping from the roof. The south machine galleries
hroughout. Travelled north to No. 1 west dip haulage depillaring
ssing C. P. driven galleries on the way. The whole of this was
. We returned by No. 4 west and main north all of which were
e main haulage roads are all packed with boiler ashes—some
s per day being used for the purpose.

one-third of the output is got from machine galleries from an
20,000 tons per month. The percentage of slack is about 30
(below 1½"). Forty per cent. of the slack passes through ½" mesh.
acking is not done as a precaution against the danger from coal

b. of country gunpowder is used per month. Gelignite is used
riving through dykes.

on fan produced 100,000 cubic feet of air per minute.

illaring areas were dry but all new drivings were wet.

er is fired in tin tubes on account of the wetness of the holes
of these are used per day. They are only used in virgin ground.

gallons of water are pumped per hour.

of the Coal-dust Committee at a colliery in the Jharia Coalfield on Monday, 5th January 1931.

COLLIERY D.

ty descended by No. 11 shaft, 350 feet deep, to No. 13 seam.

main dip haulage the conditions were dry, there being dust along
ear the floor, but the upper half of the sides and the roof were
cumulations of dust. On No. 3 east level the conditions were
those on the haulage road until a dyke was reached when condi-
damp. In the top east pillaring section the conditions were
water was dropping from the roof in the goaf. It was stated
onditions generally were moist in de-pillaring areas.

visited parts in which machines were being used to split pillars.
alleries the conditions were dry. All coal is loaded out as run-of-
—no slack being left behind. The lower part of the main dip
s similar to the upper part and at No. 5 pit bottom the condi-
dry and very dusty. This was due to the fine dust given off
oal in the rotary tippler.

The drift into No. 12 seam was wet. In No. 12 seam we visited several machine-cut galleries. The conditions there were dry.

The workings in No. 12 seam are in general, however, damper than those in No. 13 seam.

We asked if it was considered that the conditions at the bottom of No. 5 shaft constituted a danger and were told that as there was no shot-firing within a quarter of a mile of No. 5 shaft bottom no danger was anticipated. It was stated that the dust was cleaned up daily and that if it was thought to be a danger a simple plan would be to instal water sprays on both sides of the tippler.

Additional information:—

(1) Water pumped from the colliery—1,500 gallons per minute.

(2) Ventilation:—One fan exhausting 200,000 cubic feet per minute and one exhausting 125,000 cubic feet per minute, each dealing with different districts.

(In general we found the ventilation good.)

(3) Country gunpowder is used—
10,000lb. are used per month.

(4) Output—27,000 tons per month.

(5) All coal is machine-cut.

(6) Depth of shafts, No. 11—350 feet, No. 5 shaft—650 feet.

(7) The seam does not give off gas.

Mr. Barraclough was asked to take samples at the following places:—

(*a*) Top of main haulage dip.

(*b*) In a gallery off No. 3 level.

(*c*) In a gallery in No. 13 seam.

(*d*) On the level near the rotary dump.

Each sample at any place to be taken in 3 parts:—

(i) Floor, (ii) sides together, and (iii) roof.

Samples to be analysed for fineness, moisture and incombustibles.

Meeting of the Coal-dust Committee at a colliery in the Jharia Coalfield on Monday, 5th January 1931.

COLLIERY E.

The route taken was as follows:—Descended No. 1 pit, then went by north level and up north-east jig for about 600 feet. The level was clear of dust, firm under foot and damp. The jig was in a somewhat similar condition but got drier farther up.

We then came down the jig, and went down north side main dip about 200 feet turning off to north machine section. This district is dry throughout. The working galleries were well cleaned up, indeed they were swept up. They were, therefore, as clear of dust as is practicable. (The galleries are swept after every machine cut). The tram lines in the levels in this district were packed with stone and coal slack. It was said that this was common practice throughout the mine and throughout the coal-field. We then returned to the north side main dip and went down it for 400 feet. This dip was dry and dusty.

From the dip we passed through a stone drift into No. 14-A seam, traversing a part of the workings of that seam and emerging on south side main dip into No. 15 seam. The workings of No. 14-A seam were also dry and dusty but the dust appeared to be coarser than the dust in the district visited in No. 15 seam. We now came up south side main dip which was dry for half its length, the remaining portion being damp.

A visit was paid to the south side main return, in which there was a film of dry fine dust over the sides, and the floor was also dry and dusty. We were told that this was the accumulation of a quarter of a century.

Additional information was supplied as follows:—

(1) No blasting is done in No. 14-A seam.

(2) Practically all galleries in No. 15 seam are machine-cut, and are blasted by means of country gunpowder. Shot holes are drilled by compressed-air percussion drills.

(3) Country gunpowder used per month 2,100 lb.

(4) Output for this expenditure of gunpowder—4,500 tons.

(5) The depth of the shaft—400 feet.

(6) Composition of seams:—

No. 15 seam—	
Ash	11·00
Moisture	1·98
Volatile matter	22·00
Fixed carbon	65·02
No. 14-A seam—	
Ash	8·60
Moisture	1·67
Volatile matter	23·40
Fixed carbon	66·33

(7) Quantity of air in circulation—67,000 cubic feet per minute for No. 1 pit, and No. 2 pit 40,000 cubic feet per minute. The ventilation is natural.

(8) The seam does not give off fire-damp.

(9) The reason for not using machines and not blasting in No. 14-A seam is not because of any apprehension of a danger from coal-dust.

Samples to be taken as follows:—

(1) North side main dip.

(2) A gallery in north side machine section No. 15 seam.

(3) A gallery in No. 14-A seam.

(4) South side main dip.

Meeting of the Coal-dust Committee at a colliery in the Jharia Coalfield on Monday, 19th January 1931.

Colliery F.

Depth to 18 seam—430 feet. Thickness of seam—11 feet. The seam dips from the shaft at varying gradients. Present greatest depth of workings 750 feet.

Route.—Descended No. 1 pit, traversed shaft level for a distance of about 250 feet, then down the cross-cut dip and along east level where several galleries were inspected.

Conditions.—Comparatively free from dust and damp throughout and wet at many places, particularly at the working machine faces.

We then returned to cross-cut dip and went down it for a distance of about 1,000 feet. Conditions on the dip—comparatively free from dust and fairly damp.

From the dip we went along the level on the rise side of No. 3 panel area. Conditions were similar to those on the dip.

We then went to the pillar extraction area through the dyke. In this area there was dry slack lying on the floor.

We then came along the level to the main haulage dip and up to No. 1 shaft level again.

Ventilation.—A fan is provided which gives 140,000 cubic feet per minute. In the cold weather the fan does not run and the quantity got by natural ventilation is over 90,000 cubic feet per minute. The seam gives off gas in most new galleries but particularly rise galleries. In through galleries and in depillaring areas no gas is given off.

	Per cent.
Analysis of seam—	
Volatiles	29·76
Fixed carbon	58·40
Ash	11·84
Moisture	1·14

Explosives used—

Permitted—Monobel.

Maximum quantity per day—51 lb.

Maximum number of shots fired per day—105 shots.

Output per month—10,000 tons, 90 per cent. of which is from machines.

Quantity of water pumped per hour—13,500 gallons. Water is fairly generally distributed over the workings.

Mr. Barraclough was asked to take a sample in the pillaring area, the conditions in respect of coal-dust there although not bad and not representative of the mine were the worst seen by the members.

APPENDIX VI.

Note regarding samples of Dust collected at mines in the Raniganj and Jharia Coalfields.

Method of collecting samples.—In order to ascertain if the quantity of dust present was sufficient to propagate an explosion, a transverse section of the roadway or gallery, one foot wide, was swept.

Near working faces where there were no tram lines and no great thickness of materials, the floor was swept clean, but on haulage roads where the materials on the floor were of an appreciable thickness this was not possible and a superficial layer not more than half an inch deep was removed. The intention was to include in the sample only such dust as would be likely to be raised in a cloud by an explosion. This procedure was followed throughout so that from the results it is possible to compare the conditions obtaining at the various mines. From each sample about an ounce of the dust was placed in an air-tight bottle for the purpose of analysis.

The samples collected on haulage roads were taken at points where the conditions of dryness and dustiness were fairly representative of the general condition of the whole roadway.

Concentration of coal dust necessary for the propagation of an explosion.—In paper No. 31, Safety in Mines Research Board, it is stated that Allison (an American investigator) found from experiments conducted in a small experimental gallery, 17 feet long and 8 inches in diameter, that the definite lower limit of inflammability of Pittsburgh coal dust was ·034 oz. per cubic feet of air space. With concentrations above the lower limit of inflammability the flame length increased to a maximum with a dust density of ·5 oz. per cubic feet of air. In dust clouds of higher concentrations the lengthening of the flame was less than in clouds of the optimum concentration. The dust used in the experiments was passed through a 20 mesh sieve (Tyler standard—about 15 mesh I. M. M.).

Extract from a paper "The testing of mine dusts" by Godbert and Wheeler read before the Midland Institute of Mining Engineers on 16th January 1931.

The limits of concentration.—"The lower limit is usually well defined and can be determined experimentally, but the upper limit, since it implies the continued maintenance of a dense cloud in the air, is probably indeterminate and has but little practical significance. For the lower limit between 0·075 and 0·10 oz. per cubic feet of air has been found for fine dusts (85 per cent. through 200 mesh sieve). For each coal-dust there is an optimum concentration at which its inert-dust limit (which is a measure of its inflammability) is greatest. In the Safety in Mines Research Board's tests the optimum concentration has ranged between 0·11 and 0·60 oz. per cubic feet of air, being between 0·18 and 0·38 oz. for the majority of the dusts tested."

Extract from Bulletin 167, Bureau of Mines.

Effect of fineness of dust.—"An extensive series of tests was made to determine the effect of the fineness of coal-dust on its explosibility. It was found that particles coarser than 20 mesh (Tyler standard, nearly equivalent to 15 mesh I. M. M. Standard) has little effect in influencing the development of an explosion of Pittsburgh coal-dust. The pressures developed and the velocity of the explosion increased as the percentage of fine sizes increased; moreover, the percentage of shale-dust necessary to prevent propagation increased with the percentage of fine sizes. An increase from 50 per cent. to 80 per cent. of shale-dust was necessary to prevent propagation when the percentage of 200 mesh (Tyler standard—about 160 I. M. M. Standard) was increased from 10 per cent. to 80 per cent. of the coal-dust through a 20 mesh screen."

The fineness of a coal-dust is of paramount importance as it determines (*a*) the ease with which a dust cloud can be formed, (*b*) the rate of reaction between oxygen of the air and the combustible particles, and (*c*) the rate at which heat can be absorbed by the particles. Tests in India have proved that a charge of 1¼ lb. of country-made gunpowder tamped with clay and fired in a steel cannon is capable of causing an explosion of coal-dust 50 per cent. of which had passed through a 150 mesh I. M. M. sieve. Recent tests, however, have indicated that when fine coal-dust is mixed with many times its own volume of coarser dust a blown out shot of even 2 lb. of country-made gunpowder is unlikely to cause an explosion.

A more severe source of ignition such as an explosion of inflammable gas would be likely to raise the fine dust in a cloud even if the fine dust were intermixed with many times its own volume of coarser dust.

Conclusions to be drawn from the analyses of dust samples collected in the Raniganj coalfield.

Colliery C.—Of the samples collected at this colliery only sample No. 3 can be considered to indicate a dangerous condition. This sample had a low moisture and ash content and it contained sufficient fine dust to render it capable of propagating a coal-dust explosion. The fine dust, however, was mixed with nearly four times its own weight of coarser dust which would militate against the formation of a dust cloud. The seam does not normally give off inflammable gas and open lights are in use throughout the mine. Two of the samples collected on haulage roads contained insufficient fine dust to support an explosion and the third had a moisture and ash content exceeding 50 per cent.

Colliery B.—Of the samples collected at this mine samples Nos. 6, 7 and 9 indicated that there was sufficient fine dust present to support an explosion. The seam gives off inflammable gas and the use of safety lamps is necessary throughout the mine. In the event of a firedamp explosion the fine coal-dust in the quantity found in samples Nos. 6 and 7, which were collected from the vicinity of working faces, would have constituted an additional danger as it would, in all probability, have propagated an explosion over a more extensive area. The majority of the working faces in this mine were wet but a number of galleries in the area from which samples Nos. 6 and 7 were taken were approaching to dryness. These galleries had lagged behind the faces on the flanks with the result that the water normally present in the seam had been drained by the more advanced galleries.

Colliery A.—With the exception of sample No. 13 all the samples collected at this mine contained more than 70 per cent. of moisture and incombustible matter. All the workings are stone dusted to within a short distance of the working faces. Sample No. 13 was collected 15 feet from the face of a hand-cut gallery where stone-dust had not been applied but a small amount of inert-dust had been deposited by the ventilation. From this sample it will be noted that there was sufficient fine dust present to support an explosion and that 28·6 per cent. of the dust passed through a 30 mesh sieve (I. M. M. Standard).

(Sd.) N. BARRACLOUGH,
Inspector of Mines.

TABLE I.

Result of Sieve tests and analyses of dust collected at mines in the Raniganj coalfield.

Serial No.		Place from which sample was taken.	Name or number of seam.	Area of roadway sq. ft.	Total weight of sample collected.	Percentage of sample passing through 30 mesh I. M. M. sieve.	Concentration of dust passing 30 mesh sieve. Oz. per c. ft. of air in roadway.	Analysis of sample. Ash.	Analysis of sample. Moisture.	Remarks.
								Percentage.	Percentage.	
1	Colliery C. . .	No. 4 West Dip Haulage near top level into W. Panel. Intake airway.	Poniati . .	104	11 lb.	5·9	0·1	46·92	4·1	Haulage line packed with boiler ash. Little dust on sides.
2	Do. . .	No. 1 West Dip Haulage near bottom level into W. Panel. Intake airway.	Do. . .	104	6 lb. 10 oz.	1·4	0·01	20·21	12·0	The haulage line was packed with boiler ash. Floor was moist.
3	Do. . .	Loading line in 1. Panel 50 ft. from place of pillar extraction.	Do. . .	200	13 lb.	23·1	0·24	13·51	4·1	The road was dry and dusty.
4	Do. . .	No. 5 West Dip Haulage near top level of I. Panel. Return airway.	Do. . .	78	8 lb. 11 oz.	1·9	0·03	12·60	11·9	The surfaces of the roadway were moist. The haulage line was packed with boiler ash.
5	Colliery B. . .	West Dip Haulage near No. 14 Level.	Dishergarh 1 .	110	6 lb. 3 oz.	2·0	0·02	11·55	7·01	Surfaces of roadway were moist.
6	Do. . .	150 ft. from face of No. 21 Level gallery.	Do. .	105	9 lb. 13 oz.	8·0	0·12	15·95	2·44	Floor was moist for 2 ft. on dip side of gallery. Gallery was dry up to face.
7	Do. . .	50 ft. from face of 19 Level . .	Do. .	105	5 lb. 10 oz.	10·6	0·09	9·49	3·26	The gallery was fairly clean but dry.
8	Do. . .	No. 1 East Dip Haulage near No. 12 Level.	Do. .	130	5 lb. 5 oz.	3·1	0·02	18·19	10·36	Floor damp and compacted. A small amount of dust on sides.
9	Do. . .	No. 1 East Dip Haulage near No. 5 Level.	Do. .	145	4 lb.	26·4	0·11	20·22	6·20	Part of floor was moist. A fair amount of dust on sides.
10	Colliery A. . .	No. 20 Dip Haulage near No. 3 Level 300 ft. from face.	Do. .	105	11 lb.	43·9	0·73	69·0	1·0	Very little dust on sides.
11	Do. . .	No. 2 S. E. Cross-cut near No. 5 Level.	Do. .	100	8 lb. 6 oz.	34·4	0·46	72·3	1·6	
12	Do. . .	No. 8 Dip Haulage 1,500 ft. from face.	Do. .	104	16 lb. 1 oz.	37·8	0·93	80·0	1·2	
13	Do. . .	15 ft. from face of gallery. No. 20 Level.	Do. .	78	5 lb.	28·6	0·29	21·2	2·2	No stone dusting had been done. The face was hand worked.
14	Do. . .	No. 8 Dip gallery 10 ft. above No. 20 Level 80 ft. from face.	Do. .	78	8 lb. 4 oz.	62·0	1·05	74·0	5·0	Sample taken at limit of stone dusting and 70 ft. from serial No. 13.
15	Do. .	No. 3 Dip Haulage road between Nos. 10 and 11 Levels.	Do. .	108	9 lb.	39·8	0·53	75·0	1·9	

NOTE.—The incombustible and moisture determinations were kindly made by Mr. B. Sen at the Indian School of Mines.

TABLE

Result of Sieve tests and analyses of samples

Serial No.		Place from which sample was taken.	Number of seam.	Area of cross section of roadway sq. ft.	
1	Colliery D. . .	Main dip haulage road 70 ft. down from No. 11 pit West Level.	13	135	Floor . Sides .
2	Do. . .	Cross-cut between Nos. 2 and 3 panels used as locomotive haulage road.	13	135	Floor . Sides .
3	Do. . .	No. 3 panel, No. 3 Rise gallery West off No. 1 Main Rise.	13	132	Floor . Sides .
4	Do. . .	No. 5 pit Main West Level, 150 ft. West of car-dumper.	13	108	Floor . Sides .
5	Colliery F. . .	1st Intermediate off No. 7 Level. A rib of coal between two sand packed galleries was being extracted.	18	152	Floor . Sides .
6	Colliery E. . .	No. 1 pit, South dip haulage near No. 4 Level.	15	124	Floor . Sides .
7	Do. . .	No. 1 pit, 2nd Rise gallery from North dip haulage.	14A	42	Floor . Sides .
8	Do. . .	No. 1 pit North side main dip haulage road between Nos. 1 and 2 Levels.	15	154	Floor. Sides .
9	Do. . .	No. 1 pit, about 20 ft. from face of machine-cut gallery.	15	68	Floor .

NOTE.—The incombustible and moisture determinations were kindly made

II.

of coal-dust collected at mines in the Jharia Coalfield.

Total weight of sample collected. Oz.	Percentage of sample passed through 30 mesh sieve.	Percentage of sample passed through 90 mesh sieve.	Concentration of dust passed through 30 mesh sieve. Oz. per c. ft. of air space.	Concentration of dust passed through 90 mesh sieve. Oz. per c. ft. of air space.	ANALYSIS OF SAMPLE.		REMARKS.
					Ash.	Moisture.	
	Percentage.	Percentage.			Percentage.	Percentage.	
192	29·4	12·8	·42	·18	29·0	1·56	Floor and sides were dry and dusty.
40	32·5	14·5	·10	·04	21·1	1·74	
153	27·2	10·8	·31	·12	40·5	1·2	Floor and sides were dusty.
46	31·3	12·4	·11	·04	25·0	9·34	
169	21·6	10·5	·31	·13	14·9	7·5	Pillars were being split and roof coal blasted in vicinity. The fine dust on floor was probably due to flitting of coal cutting machine.
3	33·3	13·3	·01	·003	17·4	9·0	
77·2	58·7	46·1	·42	·33	20·8	10·6	Floor was damp. Sides were extremely dusty. The dust from car-dumper was being carried in by ventilation.
80·0	61·1	46·7	·45	·35	14·8	2·8	
275	28·7	10·3	·52	·18	21·6	1·64	
16	17·5	5·6	·02	·006	15·34	0·95	
155	25·7	13·4	·31	·17	16·6	1·1	
0·8	87·5	50·0	·007	·003	14·5	4·9	
80·5	13·0	8·1	·25	·15	10·63	0·9	Hand-cut gallery, no blasting being done.
1·0	90·0	50·0	·02	·002	11·45	2·2	
90·0	46·6	23·6	·27	·14	10·96	0·9	For 9 months all coal hauled on this road was from 14A seam.
20·0	34·5	19·5	·04	·03	13·15	1·34	
40·5	38·3	14·8	·23	·09	15·25	1·98	The gallery looked clean and had been swept. The quantity of dust on the sides was negligible.

by Mr. B. Sen at the Indian School of Mines.

APPENDIX VII.

Laboratory tests of the ignitibility of a Coal-dust cloud by an electric arc, made by Dr. B. B. Banerji.

Description of apparatus.—The apparatus employed which was of the simplest construction is shown, diagrammatically, in Figure 2.

A glass tube, $1\frac{1}{2}''$ diameter and 12" long, was closed at both ends by cork stoppers A and A-1. Passing through the stopper A was a glass tube into which a copper wire W (No. 20 gauge) had been fused, and through a second hole there was a glass tube with a bulb B at its upper extremity. The glass bulb B was provided with four or five holes of about 1/20" diameter. Passing through the cork stopper A-1, there was a glass tube fitted with a copper wire W-1 similar to the wire W, and also a short piece of glass tube bent at right angles which served as an air release pipe.

The apparatus was mounted vertically with the bulb B at the bottom and the lower end of the tube E was connected to a foot-blower. The copper wires W and W-1 were coupled to four Leyden jars connected in parallel which, in turn, were connected to the secondary winding of a Rhumkorff induction coil. Current in the primary circuit of the induction coil was provided by two accumulators joined in series and controlled by a suitable switch.

The gap between the wires W and W-1 was about $\frac{1}{4}''$.

Experimental details.—A small amount of fine coal-dust (the fineness was not determined) was introduced into the apparatus by opening the stopper A-1, and after replacing the stopper air was pumped into the apparatus by means of the foot-blower in order to maintain a cloud of coal-dust inside the tube. Immediately afterwards a spark was passed between the wires W and W-1. Although a fat and steady spark was maintained the coal-dust cloud was not ignited. The experiment was repeated with coal-dust which had been dried in a steam oven and cooled in a desiccator. This time the coal-dust cloud was ignited, and further experiments resulted in ignitions and occasionally explosions which caused a popping out of the cork stoppers.

Later, as the conditions of the experiments became more and more familiar, it was found possible to maintain a steady flame in the middle of the tube by judiciously pumping the foot-blower. It was observed that the inflammation of the coal-dust occurred when the coal-dust cloud was subsiding and as the density of the cloud decreased further the flame disappeared. It appeared, therefore, that the coal-dust had definite limits of concentration in air beyond which the cloud was incapable of being ignited. Although careful observations were made in course of the later experiments it was impossible to ascertain the mechanism of the start of the flame.

APPENDIX VIII.

Regulations in respect of Coal-dust applying to coal mines in Great Britain and South Africa.

Great Britain.

Extracts from Coal Mines Act, 1911, and the General Regulations made under the Act.

Prevention of Coal-dust.

Section 62.—In every mine, unless the floor, roof, and sides of the roads are naturally wet throughout,—

(1) arrangements shall be made to prevent, as far as practicable, coal-dust from the screens entering the downcast shaft; and, in the case of a mine newly opened after the passing of this Act, no plant for the screening or sorting of coal shall be situated within a distance of eighty yards from any downcast shaft unless a written exemption is given by the Inspector of the Division;

(2) the tubs shall be so constructed and maintained as to prevent, as far as practicable, coal-dust escaping through the sides, ends, or floor of the tubs, but any tub which was in use in any mine at the date of the passing of this Act may, notwithstanding that it is not so constructed, continue to be used in that mine for a period of five years from the said date;

(3) the floor, roof and sides of the roads shall be systematically cleared so as to prevent, as far as practicable, coal-dust accumulating;

(4) Such systematic steps, either by way of watering or otherwise, as may be laid down by the regulations of the mine shall be taken to prevent explosions of coal-dust occurring or being carried along the roads.

Regulation.—1. The following regulations shall apply to all mines in which coal other than anthracite is worked.

2. The floor, roof and sides of every road or part of a road which is accessible shall be treated in one of the following ways, either:—

(*a*) they shall be treated with incombustible dust in such manner, and at such intervals, as will ensure that the dust on the floor, roof and sides respectively shall always consist throughout 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 ensure that the dust on the floor, roof and sides respectively is always combined throughout with 30 per cent. by weight of water in intimate mixture; or

(*c*) they shall be treated in such other manner as the Board of Trade 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.

Provided also that the obligation imposed by this Regulation shall not apply in respect of any road or part of a road, either

(*a*) in a seam in which anthracite only is worked, or

(*b*) if, and so long as, the natural conditions thereof as regards presence of incombustible dust and moisture are found by tests made in accordance with these Regulations to be such as to comply with the foregoing requirements.

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.

6. Paragraph 3 of Section 62 of the Act shall be amended to read as follows:—The floor of every travelling 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.

"Travelling road" means a road used by the main body of any shift employed in the mine for travelling 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, offices, stables, engine-houses, motor switch and transformer rooms and pump-rooms, shall not be deemed to form part of any road.

South Africa.

Extracts from the Mines and Works Act of the Union of South Africa as amended up to 1917.

Regulation 3 (7).—At every coal mine the screening or other plant for the treatment of minerals shall not be erected within ninety feet of any shaft or other entrance to the mine. At existing mines as far as practicable adequate provision must be made to prevent coal-dust from entering the shaft or other entrance to the mine.

Regulation 65 (1).—In any coal mine or part thereof which, in the opinion of the Inspector of Mines, is dry and dusty, protective measures approved by him shall be taken for the prevention of coal-dust explosions.

Regulation 65 (2).—Any mine or portion thereof may be exempted from Section (1) of this Regulation by the Inspector of Mines provided fire-damp has not been reported within the preceding six months and where the proportion of marsh gas contained in the body of the air in any return air-way is less than one-half per cent.

Regulation 65 (3).—(*a*) In any coal mine, not exempted by the Inspector of Mines, every main haulage road and every main intake air-way shall be protected from coal-dust explosion by adequate watering, stone-dusting, or other protective measures approved by the Inspector of Mines.

(*b*) These protective measures shall extend from the shaft to within one hundred (100) yards and, where watering is employed, to within thirty (30) yards of the working face.

(*c*) The floor, roof and sides of the haulage roads and intake air-ways shall be systematically cleared so as to prevent as far as possible coal-dust accumulating, and such coal-dust shall be sent out of the mine.

4. (*a*) In each ventilating district of any fiery mine not exempted by the Inspector of Mines there shall be maintained at a maximum distance of one hundred (100) yards from the working face a protective zone, not less than 50 yards in width, which shall effectively separate such ventilating district from the main return air-ways, adjacent districts and disused workings.

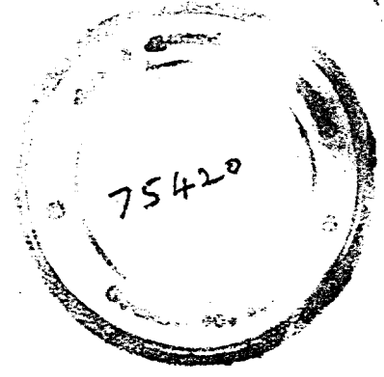
(*b*) Such protective zone shall be safe-guarded against explosions by adequate watering, stone-dusting, or other measures approved by the Inspector of Mines.

(*c*) No such ventilating district shall at any time contain more than two hundred (200) persons.

5. In any coal mine which is dry and dusty the coal tubs shall be so constructed and maintained as to prevent as far as practicable coal-dust escaping through the sides, ends, or floors.

6. Any stone-dust used for the purposes of this Regulation shall be non-inflammable, finely ground dust, prepared from shale or other material containing no injurious free silica.

106 (11) The ganger or miner shall not blast in a coal mine if the place where the shot is to be fired is dry and dusty, unless a permitted explosive as referred to in Regulation 98 be used or unless the place of firing and all contiguous accessible places within a radius of 20 yards therefrom are at the time of firing in a wet state through watering or other treatment equivalent to watering in all parts where dust is lodged, whether roof, floor or side.



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