HOME OFFICE.

EXPLOSION AT SENGHENYDD COLLIERY, GLAMORGANSHIRE.

REPORTS

TO THE

RIGHT HONOURABLE THE SECRETARY OF STATE FOR THE HOME DEPARTMENT

ON THE

Causes of and Circumstances attending the Explosion which occurred at the Senghenydd Colliery on Tuesday, 14th October, 1913.

BY

R. A. S. REDMAYNE, C.B.,
H.M. CHIEF INSPECTOR OF MINES
(COMMISSIONER),

AND

EVAN WILLIAMS
CHAIRMAN OF THE SOUTH WALES AND MONMOUTHSHIRE COALOWNERS' ASSOCIATION

AND

ROBERT SMILLIE
PRESIDENT OF THE MINERS' FEDERATION OF GREAT BRITAIN
(ASSESSORS).

Presented to Parliament by Command of His Majesty.

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Home Office,
Whitehall, S.W.,
31st March, 1914.

SIR,

ON December 18th, 1913, you issued a Warrant of Appointment in connection with an Inquiry which you desired should be held into the circumstances of the explosion which occurred on the 14th of October, 1913, at the Senghenydd Colliery, which is situate near Caerphilly, Glamorganshire, and is one of the mines belonging to the Lewis Merthyr Consolidated Collieries, Limited. The Warrant of Appointment was in the following terms :—

" In pursuance of Section 83 of the Coal Mines Act, 1911, I hereby appoint Mr. R. A. S. Redmayne, Chief Inspector of Mines, to hold a formal investigation of the causes and circumstances of the disaster which occurred at the Universal Colliery, Senghenydd, Glamorganshire, on the 14th October, 1913.

" And I further appoint Mr. Evan Williams and Mr. Robert Smillie to act as Assessors in holding the investigation."

And you were pleased to appoint Mr. H. K. Beale, of Messrs. Beale and Company, Birmingham, to render legal assistance to myself.

A formal inquiry was accordingly held, and I now have the honour to submit my report.

The Explosion.

(1) The explosion, which in point of loss of life constitutes the greatest disaster in the annals of British mining, happened at about 8.10 a.m. on Tuesday, the 14th October, and, accompanied by Dr. Atkinson, the Inspector of Mines for the South Wales Division (who was in London at the time in attendance at the Home Office), I arrived at the colliery late in the afternoon of the same day, and went underground. I was present at the colliery during the four succeeding days also, making another underground inspection on the 17th October. When the west side of the mine was sufficiently recovered to allow of an extensive inspection being made, I again visited the mine, viz., on the 2nd and 16th December, and inspected the Mafeking and Ladysmith Districts, and part of the Kimberley District, with a view to determining, if possible, the originating point and track of the explosion.

With a like object Mr. Evan Williams made an inspection on January 21st, travelling the Kimberley, Mafeking, and part of the Pretoria Districts, and Mr. Smillie on the 7th of February, visiting the Mafeking and Pretoria Districts.

(2) The number of persons killed by the explosion or who died from the effects of the afterdamp was 439 and one man lost his life on the day following the explosion whilst engaged in work at the fire on the main west level, being killed by a fall of stone.

The name, age, and address of each of the dead, with cause of death, is given in Appendix A, and the position in which each body was found is shown on plan No. 1.

The opening of the Inquiry and hearing of evidence.

(3) That part of the Inquiry relating to the hearing of evidence was opened at the Law Courts, Cardiff, on the 2nd January, 1914, at 10 a.m., and the hearing occupied the whole of that and the succeeding day, when, owing to the intervention of the Coroner's Inquest—which was opened at Senghenydd on the 5th January—the Court adjourned *sine die*, but resumed its sittings on the 27th January, and continued on the following days, viz., January 28th, 30th, and 31st. On 29th January the Court witnessed some experiments at New Tredegar which Mr. Nelson, His Majesty's Electrical Inspector of Mines, had arranged with a view to determining whether the electric signalling apparatus in use at the pit would ignite firedamp. Evidence was heard again on February 5th, 6th, 9th, 10th, 11th, 12th, 13th, and on 20th and 21st February the Court, sitting at the Home Office, heard the addresses of counsel and others representing the various interests concerned.

The Inquiry was closed by me at 1.15 p.m. on 21st February.

The hearing of evidence alone occupied thirteen days, during which time 21,837 questions were put to witnesses.

Interests represented at the Inquiry.

(4) The different interests represented were :—

The Lewis Merthyr Consolidated Collieries, Limited (the owners of the Senghenydd Colliery), and the Agent and Manager of the Senghenydd Colliery :—By Mr. John Sankey, K.C., and with him The Hon. Trevor Lewis (instructed by Messrs. C. and W. Kenshole, Aberdare).

A number of the bereaved families :—By Mr. Clement Edwards, M.P.

The Miners' Federation of Great Britain, and the Monmouthshire and South Wales Colliery Enginemen, Stokers, and Surface Craftman's Association :—By Mr. W. P. Nicholas (of Messrs. Walter Morgan, Bruce and Nicholas, Pontypridd) and with him Mr. W. E. Harvey, M.P., and Mr. Edward Hughes.

The South Wales Miners' Federation, and the Senghenydd workmen :—By Mr. William Brace, M.P., with him Mr. Thomas Richards, M.P., Messrs. Alfred Onions, James Winstone, Hubert Jenkins, and D. Watts Morgan.

The General Association of Firemen and Deputies :—By Mr. E. Williams.

Witnesses called.

(5) The following witnesses were summoned and examined at the Inquiry :—

1. Edward Shaw (Agent and Manager of the Colliery).
2. Griffith Morgan (Surveyor).
3. Benjamin Price (Fanman).
4. William Henry Chidsey (Fireman).
5. James Opie (Fireman).
   William Henry Chidsey (recalled).
6. Richard Davies (Fireman).
7. David John Morris (Under-manager).
   Richard Davies (recalled).
   David John Morris (recalled).
8. William Williams (Overman).
9. D. R. Thomas (Overman).
10. Charles Waddon (Electrician).
11. H. W. Schielbach (Consulting Electrical Engineer).
12. Charles P. Sparks (Consulting Electrical Engineer).
13. Dr. W. M. Thornton (Professor of Electrical Engineering at the Armstrong College, Newcastle-on-Tyne).
14. Robert Nelson (His Majesty's Electrical Inspector of Mines).
    H. W. Schielbach (recalled).
    D. R. Thomas (recalled).
15. William Morse (Lampman).
16. Richard Davies (Deputy).
17. Morris Roberts (Fireman).

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18. John Skym (Fireman).
19. Ben Thomas (Fireman).
20. Richard Howells (Fireman).
21. Ernest Moses (Shackler).
22. Dr. Philip James (Medical practitioner).
23. William Thornton (Collier).
24. James Winstone (Vice-President, South Wales Miners' Federation).
25. William Henry Lasbury (Assistant Timberman).
26. Benjamin Thomas Davies (Collier).
27. Archibald Dean (Collier).
28. Ben Hill (Collier).
29. Thomas Jones (Collier).
    James Winstone (recalled).
30. Richard William Evans (Overman, Lletty Shenkin Colliery).
31. Joseph Lloyd (Fireman, Lletty Shenkin Colliery).
32. John Henry Thorne (Superintendent, Rhondda Rescue Station).
    James Winstone (recalled).
33. James Hill (Collier's boy).
    James Winstone (recalled).
34. Hubert Jenkins (Miners' Agent).
35. George Barker (Miners' Agent).
36. D. Watts Morgan (Miners' Agent).
37. Edward Gill (Collier).
38. John Powell (Collier).
39. T. A. Southern (Principal, The Universal Mining (Correspondence) School).
40. Frank Llewellin Jacob (Colliery Agent).
41. Thomas Griffiths (Mining Engineer).
42. John Kane (Colliery Agent).
43. David Hannah (Mining Engineer).
44. John Phillip Gibbon (Colliery Agent).
45. Edward Edwards (Timberman).
46. James Williams (Collier).
47. Griffiths Humphreys (Ripper).
48. William James (Repairer).
    Charles Waddon (recalled).
49. Dr. W. N. Atkinson (His Majesty's Inspector of Mines, South Wales Division).
50. J. Dyer Lewis (His Majesty's Senior Inspector of Mines, South Wales Division).
51. T. Greenland Davies (His Majesty's Junior Inspector of Mines, South Wales Division).
52. J. M. Carey (His Majesty's Junior Inspector of Mines, South Wales Division).

I. Description of the Colliery.

Situation and History of the Colliery.

(6) The Senghenydd, or as it is sometimes called, the Universal Colliery, is situated at the head of the Aber Valley, Glamorganshire, about 12 miles as the crow flies N.N.W. of Cardiff.

The sinking of the shafts was commenced about twenty-three years ago, and coal has been worked since 1896.

This is not the first occasion upon which an explosion has occurred at this mine. On May 21st, 1901, a disastrous explosion, by which 81 persons lost their lives, devastated the whole of the mine, only one man being saved alive. Three reports were made to the Secretary of State for the Home Department on the circumstances attending that explosion, viz., by Professor W. Galloway, Mr. S. T. Evans, K.C., M.P. (now Sir Samuel Evans, one of His Majesty's Judges), and Mr. J T. Robson, one of His Majesty's Inspectors of Mines.*

In view of the various theories which have been put forward to account for the recent disaster it is of interest to note that in respect of the first explosion no definite

* Reports on the circumstances attending an explosion which occurred at the Universal Colliery, Glamorganshire, on May 24th, 1901, by W. Galloway, F.G.S.; S. T. Evans, K.C., M.P., and J. T. Robson, one of His Majesty's Inspectors of Mines. London, 1902. [Cd. 947.] Price 11*d.*

conclusion was arrived at. Professor Galloway thought it probable that "the initial impulse was given by a blasting shot," but nothing positive transpired as to the firing of a shot at the instant the explosion took place. Mr. J. T. Robson did not think that a case against shot firing, or any other case, had been made out, and Mr. S. T. Evans came to the conclusion that the cause was entirely problematical.

All three gentlemen emphasised the danger of coal dust, and made definite suggestions in respect thereof.

Mr. S. T. Evans, in concluding his report, pointed out that it was of especial importance " that provisions should be made for preventing the accumulation of coal " dust, and for the regular and efficient watering of the roads, roofs, and sides in the " main haulage and travelling ways in mines which are dry and dusty."

The workings of the Mine. Seams worked and system of working.

(7) The seams worked are the Four Feet, the Universal, and the Nine Feet. The underground workings are divided into two main divisions, viz., the West side and the East side. The seam being worked on the West side is the Four Feet, those worked on the East Side are the Four Feet, the Universal, and the Nine Feet, but all these workings are connected to one level by means of drifts.*

The seams worked are won by two shafts, viz., the Lancaster (downcast) and the York (upcast), both of which are 18 feet 6 inches in diameter, the depth from the surface to the landing in the Six Feet, the landing to which the coal is chiefly brought, being 535 yards, but both shafts are sunk to a depth of 650 yards or thereabouts, and the York pit has also a landing in the Nine Feet seam. Coal is wound from both shafts, but the larger quantity is drawn up the Lancaster shaft.

The pit bottom of each shaft is arched with stone masonry, the arching on the west side in the Six Feet landing extending for a distance of 124 yards from the shaft. The block of coal left for the support of the shafts is 500 yards in diameter, and comprises an area of $42\frac{3}{4}$ acres.

The explosion of October 14th, 1913, was confined to the West side, only passing for a few yards into the East side. I am concerned, therefore, more particularly with the conditions prevailing in the West side, which is divided into six districts, viz., the West York, Pretoria, Mafeking, Kimberley, Ladysmith, and Bottanic, all of which branch away from the main intake known as the Main West Level. They were not ventilating districts in the sense that each was ventilated by a " split " from a main intake airway, nor were they separate inspection districts, for they were either further sub-divided or added to for this purpose. The arrangement of the districts is shown in Fig. 1, which is a plan of those workings on the West side which were actually being advanced at the time of the explosion, the worked out portions of the mine being omitted for the sake of clearness.

(8) The system of working the coal is the longwall system, the width of the stalls being eleven yards " centre to centre." Very little face timber is drawn out and recovered, it being customary in South Wales to leave the timber in the goaf or gob. Where it can be done it is, of course, the best practice, both from the safety and the economic point of view, to take out the timber from the gobs, but under poor roofs where the gobs are stowed with rubbish right across the face, it may be impossible to do this, and Mr. Shaw stated that at Senghenydd the roof always broke immediately behind the face, that the goaf closed tight, and that there was regular settlement, and further that the character of the roof stone is such that little of the timber can be withdrawn. The even settlement of the goaf is desirable in the interests of safety, and the tighter the goaf is, the less unventilated space is there for the accumulation of firedamp.

Shot firing.

(9) No explosives were used for getting the coal, or for the purposes of carrying out the ripping, except when the ground was particularly hard and in driving hard headings (*i.e.*, stone or cross-measure drifts)—a rare occurrence—when Roburite was used, the shots being fired by authorised shot-firers. No blasting was being carried on on the day of the explosion, and no shots had been fired since the previous Sunday, October 12th.

* The position of these seams is shown in section in Fig. 2. It will be observed that the Four Feet seam has, as a matter of fact, a section of 6′ 1″ coal, and one foot of clod.

Output and Haulage.

(10) The output of coal was about 1,800 tons per diem, the coal being filled into wagons or trams of the common Welsh type, that is, open at each end but for a bar, the coal being piled up well above the tops of the trams.

The main haulage from the Mafeking, West York, Bottanic and part of the No. 2 South (Pretoria) Districts was carried out in the return airways. Only the main haulage from the Kimberley and Ladysmith Districts was entirely in the intake air. Mines which were opened before the passing of the Coal Mines Act, 1911, are exempt from the requirements of Section 42 (4), which are to the effect that where the air current in the main return airway is found normally to contain more than one-half per cent. of inflammable gas, that airway shall not be used for the haulage of coal.

Under the requirements of Section 62 (2) of the Coal Mines Act, 1911, no tram for the conveyance of coal can be introduced into a mine after the date of the passing of the Act unless it is so constructed and maintained as to prevent as far as practicable coal dust escaping through the sides, ends or floor of the tram, and after a period of five years from 16th December, 1911 (the date of the passing of the Act), all trams, whether old or new, have to conform to this requirement. The management of the Senghenydd Colliery were gradually carrying this requirement into effect, and before the Act came into force had already ordered a few hundred trams closed at each end. That is to say, a door is substituted for the bar alluded to above.

The empty tram, which runs on a track of 3 feet gauge, weighs about 8 or 9 cwts., the average weight of coal conveyed per wagon being about 26 cwts. The secondary haulage was performed by horses, except in a few cases, where the mechanical haulage roads led right up to the face (some places in the Pretoria and Ladysmith Districts). The width of the secondary haulage roads was generally about seven feet. The main haulage is in nearly all parts of the mine carried out by means of engines actuated by compressed air; there are a large number of these engines, and their position is indicated on the general plan by small squares. In some parts, however, the haulage is worked by gravity, as, for instance, in the Mafeking incline (see Figs. 1 and 6). The rate of haulage was from 4 to 8 miles an hour, and usually 24 trams constituted a " journey " or train.

Electric Signalling.

(11) An electrical system of signalling was in use, and a good deal of attention was drawn to it in the course of the Inquiry. There were a number of sets of signalling apparatus in different parts of the colliery—over a dozen in all—and each set consisted briefly of an electric bell of the trembler pattern, which though protected by a cast-iron cover was not gas-tight, a battery of anything from six to nine dry cells of the " Dania " pattern, giving when new about 1·5 volts per cell, and two bare wires, described as No. 8 galvanised steel wires, supported on insulators, which in turn were secured to the side timbers. The wires were run 12 or 18 inches apart on the same side of the roadway. The bells and batteries were, in general, fixed in engine houses. Electric sparks, which may or may not have been capable of igniting an explosive mixture of firedamp and air (the evidence on this point will be examined later), were undoubtedly, by the very nature of the apparatus in use, of frequent occurrence. Every time the wires separated after having been brought together or bridged across by a knife or file for the purpose of giving short sharp rings of the bell, a spark or sparks would be formed at the instant of break, and every time the bell was rung there would be a rapid succession of sparks at the make and break contacts beneath the iron cover.

Ventilation.

(12) Ventilation of the mine was produced by a fan of the " indestructible " Walker type which was placed at the surface and was steam driven. The fan, which is 24 feet diameter, exhausts from the York shaft, being driven at a speed of 47 revolutions per minute, and inducing a current of over 200,000 cubic feet per minute at a water gauge of 2·3 inches. Of this volume 152,000 cubic feet entered the West side. The Manager informed me that the fan was capable of producing at a higher speed a current of 400,000 cubic feet per minute at a water gauge of 4 inches.

Arrangements for reversing the air current.

(13) Arrangements for reversing the air current of the mine in accordance with the requirements of Section 31 (3) of the Coal Mines Act, 1911, had not been quite completed. The Manager informed me that the arrangements necessary to put the reversal into operation would have occupied a period of two hours. The date upon which this requirement became operative was 1st January, 1913, but in April the owners of the colliery applied for an extension of time to enable them to make certain structural alterations. This extension of time was granted by the Inspector of the Division, in accordance with the powers given him under the Act, and the extended period terminated on 16th September. The termination of the exemption was however postponed later until 30th September. In that adequate means for reversing the ventilation which could be put into " immediate operation " were not provided on the date of the explosion, the owners and Manager, as their counsel, Mr. Trevor Lewis, frankly admitted, were guilty of a contravention of Section 31 (3) of the Coal Mines Act, 1911.

Measurement of Air Currents.

(14) It is required by Section 29 (2) of the Coal Mines Act, 1911, that the quantity of air in the main current and in every split, and at such points as may be determined by the Regulations of the mine, shall, at least once a month be measured, and entered into a book to be kept for the purpose at the mine. General Regulation 77, which came into force on 15th September, 1913, specifies these points as :—

(*a*) In the main intake airways of every seam as near as practicable to the downcast shaft;
(*b*) In every split as near as practicable to the point at which the split commences; and
(*c*) In each ventilating district at or as near as practicable to a point 100 yards back from the first working place at the working face which the air enters.

The points of measurement of the main current and splits are marked on the plan. The latest measurements prior to the explosion were made on the 25th and 26th September, and were :—

Date.	Name of District or Split.		Anemometer Reading.	Sectional Area of Airway at place of Measurement.	Total quantity of Air in cubic feet per minute.
				sq. ft.	
September 25 ...	Ladysmith	West Side.	630	52	32,760
	Pretoria		310	66	20,460
	Kimberley		306	80	24,480
	Mafeking Hard Heading		465	50	23,250
	Bottanic Deeps ...		386	25	9,650
	York West		310	36	11,160
	West Side		1,520	100	152,000
September 26 ...	Lower Nine Feet Seam	East Side.	516	50	25,800
	Six Feet Seam ...		263	51	13,413
	Alexander's		289	33	9,537
	Slope		350	56	19,600
	Glawnant		515	63	32,445
	York East Str. ...		600	63	37,800
	York East Heading ...		480	33	15,840
	East Side		759	70	53,130

(15) The book in which the air measurements were entered was not in the form prescribed by the Secretary of State, and was not countersigned by the Manager and Under-manager. The management had, therefore, contravened Section 24 (1) and (2) of the Coal Mines Act, 1911. The requirement (*c*), contained in General Regulation 77, had not been carried out either in respect of the East or West side prior to the explosion. I am unable, therefore, to say what was the volume of air current which traversed the working faces, and whether or not the leakage of air as between the commencement of the district and the face was heavy. Owing, however, to the relative position of the intake and return airways, I incline to the belief that the leakage was not considerable.

(16) It was advanced by the representatives of the owners and management that as a legal month is a calendar month, there was no infringement of Act or Regulations seeing that the explosion happened on the 14th October and the calendar month did not expire until the 15th. I learned, however, that on the East side, which resumed work on the 26th November, no measurement was made in the district at points about 100 yards from the first working place until 19th January, 1914.

Volume of inflammable gas generated.

(17) That the mine generated large quantities of gas is evidenced by the analysis of samples of air taken by the Mines Inspectors in the return air, as the following results show :—

Seam or Seams.	Name of Inspector who took the Samples.	Date and Hour on which Sample was taken.	Place where Sample was taken.	Height of Barometer.	Sample contained		
					Percentage methane.	Percentage carbon-di-oxide.	Percentage oxygen.
Four Feet, Six Feet, and Nine Feet.	P. T. Jenkins	29 Aug. 1913 10.30 a.m.	Return airway. East side of upcast.	29·59″	1·44	0·51	—
Four Feet ...	do.	29 Aug. 1913 10.45 a.m.	Return airway. West side of upcast.	29·50″	0·81	0·34	—
Upcast Pit, all the air.	J. M. Carey ...	29 Sept. 1913 12.30 p.m.	Upcast Pit, all the air.	29·40″	0·59	0·28	20·37
Upcast Pit ...	do.	29 Sept. 1913 12.25 p.m.	Upcast Pit, from Nine Feet Seam only below Six Feet landing.	29·40″	0·40	0·09	20·87
Main West Return.	do.	29 Sept. 1913 12.40 p.m.	Airway at Six Feet landing.	29·40″	0·60	0·26	20·48

That is to say, the amount of inflammable gas generated in the mine amounted to about 1,200 cubic feet per minute.

The mine was in this respect typical of the more " fiery " mines in the steam coal area of the South Wales coalfield. It was, therefore, a mine in which the best method of ventilation should be adopted, and as to the carrying out of which the greatest care should be exercised.

(18) It will be observed from the ventilation plan that the West side was ventilated by four splits. To one of these I am desirous of directing special attention, viz., that passing into the Lancaster Level. The air current, passing round the Kimberley workings, joined a split of fresh air coming through Baker's heading, so that the West side of the Mafeking District was ventilated partly by return and partly by intake air. The air in the Mafeking Hard Heading would contain the whole of the firedamp generated in the Kimberley and Mafeking Districts, as well as part of that generated in the Pretoria District. I do not think that the best practice was adopted in ventilating this portion of the mine, for though the total quantity of air drawn through the mine was sufficient if properly distributed, and, therefore, under *normal conditions*, the mine was probably adequately ventilated, yet seeing that the mine was of a gassy character, and one liable to outbursts of gas, I think it would have been better practice to have carried out a scheme whereby the Mafeking and Kimberley Districts had each its own separate intake and return, so that each district would have been in fact a separate ventilating district.

(19) That the mine was in places liable to sudden outbursts of gas is evidenced by the fact that in October, 1910, on the occurrence of a large fall on the Mafeking Level in the neighbourhood of some faults—the place is indicated on the plan, Fig. 1—there was a heavy discharge of gas which continued to be delivered for four days after the fall was cleared. On this occasion the men were withdrawn from the mine.

Safety Lamps.

(20) The safety lamp used at the mine was the Cambrian, with lead rivet locking device, and the lamps were supplied by Messrs. Thomas and Williams. The Manager was under the impression that both the lamp and glass had received the approval of the Secretary of State in the terms of Section 33 of the Coal Mines Act, 1911, and the Order under the Act. In this, however, he was mistaken; the lamp had been approved, but the lamps in use were fitted with unapproved glasses.

Lamps were lighted, locked, and issued to the workmen and officials at the surface, and were again examined underground at places termed " locking stations." These were cabins—one on the West and another on the East side—situated a little distance from the shaft, and just off the main intake airway. The lamps were examined by the firemen at this place when meeting the incoming shifts. If anyone lost his light when at work he had to come outbye to the lamp cabin to have it relit. This was done by men known as the lamp lockers, who, though authorised by the Manager to perform this work, had not been appointed in writing for the purpose. I am, however, satisfied that they were competent to perform the work which devolved upon them. The fact of their not being appointed in writing constitutes a technical breach of Section 34 (iii) of the Coal Mines Act, 1911, a fact acknowledged by Mr. Trevor Lewis, representing the owners and management.

I shall have occasion to return to the consideration of the West side lamp station, which was situate 440 yards inbye from the shaft, as it was put forward by several of the witnesses called by the management as the site of the origin of the explosion.

Coal Dust.

(21) The screens being about 80 yards from the top of the downcast shaft, little coal dust was carried down the shaft from the surface, but some would be blown off the full tubs ascending the shaft.

(22) The open character of many of the trams, and the fact that in all the trams the coal was piled high above the top (the coal piled above the top of each tram would weigh about half a ton), were fruitful sources for the formation of coal dust. The mechanical haulage was at the rate of from four to eight miles an hour, and sets of trams coming out of the Kimberley, Ladysmith and a part of the No. 2 South (Pretoria) Districts, would be hauled against the air current.

(23) The only parts of the mechanical haulage roads of the mine which were naturally wet was a stretch of the Main West Level (in the Kimberley District) and a stretch—about 28 yards—of the Ladysmith intake; these parts are indicated on the plan, Fig. 1. It was noticeable, however, that for a long distance outbye from the wet place in Ladysmith fungoid growths on the timber pointed to a certain amount of dampness. The general character of the mine was, however, dry and dusty, though not so dusty as many mines in the South Wales coalfield.

(24) The means adopted for dealing with the dust on the roads was as follows :—

Every afternoon and night men were engaged in shovelling up the dust from the floor. As far as the Manager could remember eight men were engaged on this work, viz., two men on the Lancaster Level from shaft to the Kimberley face, two in Ladysmith, two in Mafeking, and two in Pretoria. It must be understood, however, that the whole length of these roads was not cleaned every twenty-four hours. The roof and sides were not cleaned at all. Efforts had been made at one time to clean the roof and sides, but I was informed that it was found impracticable to remove the dust. We were told that when it was brushed down, or compressed air was applied to remove it, the dust was carried away by the air current and deposited elsewhere, but I am not satisfied that serious efforts were, in fact, made towards removing the side and top dust, nor do I consider that its removal was impracticable. I think that, consequently, the requirements of Section 62 (3) of the Coal Mines Act, 1911, were not fully observed.

(25) No Regulations have as yet been laid down in respect of the means to be taken to prevent explosions of coal dust occurring or being carried along the roadways of mines. The matter is still the subject of experimental and research work

which is being carried out at the Home Office Testing Station at Eskmeals in Cumberland.

Arrangements for watering the mine.

(26) Water from the surface was conveyed down the shafts by two columns of 2-inch diameter pipes, one column in each shaft. These were joined to pipes 1½ inches in diameter laid along the main haulage roads, fitted every 30 to 40 yards with taps to which hose-pipes were connected, and the floors of the roadway were watered every night. The roof and sides were not watered; I was informed that it was impracticable to do this, as if practised it would have so disturbed the roof and sides as to bring on a "squeeze" and cause the roadway to collapse, and I was satisfied owing to the character of the roof on this point. The position of the water-pipes on the roadways is shown on the plan, Fig. 1, being indicated by a blue line. Beyond the end of these pipes watering of the floor was done by means of water-carts occasionally brought in by the haulage. That the watering of the floors was well done was proved by the damp state of the mine when inspected early in December, nearly two months after the explosion.

(27) In addition to these efforts towards laying the dust means were also taken to prevent its accumulation by sprinkling the trams with water. Sprinklers were placed, one at the double parting in Ladysmith, one at the entrance to the storage in Mafeking, and one just outbye the double parting in No. 2 south. The sprinklers consisted of an upright pipe five to six feet in height connected to the line of water-pipes, at the top of which was a right-angle piece passing across the roadway to the opposite side. This was perforated to allow of the playing of jets of water on the set of trams as it passed. The sprinklers were not placed at the spot where the mechanical haulage of the trams commenced, but a considerable distance outbye thereof. For instance, in the case of Ladysmith, the haulage had proceeded 700 yards before reaching the sprinkler, and the sprinkler for trams coming out of the Kimberley and Mafeking Districts was situated just outbye of the Mafeking Storage. It will be seen therefore that these sprinklers, owing to their situation, would not prevent a great deal of dust from being formed. From my inspection of the mine, subsequent to the explosion, I have no doubt whatever that coal dust existed on the roof, sides and timber in dangerous quantity.

(28) The water supply at the colliery was not great, but sufficient for general purposes under normal conditions. There was a reservoir at the colliery, another one some distance away at Caermoil, and a third one—not drawn upon for colliery purposes, but used as a domestic supply—at Maesdivol. The water used for watering the roads, &c., was in part derived from the Lancaster Pit (60 gallons per hour), from the York Pit (80 gallons per hour), and from the sump (558 gallons per hour). The last was pumped up to a large wooden tank on the surface, which also contained water from the water jackets and coolers of the air compressor engine. A pipe connected with the Caermoil Reservoir gave an additional 1,000 gallons an hour. This large tank, which held 8,000 gallons, gave in all a supply of about 4,360 gallons per hour. The water was used along the roadways in the manner described, under pressure.

(29) Later I shall have to consider the question of water supply in relation to extinguishing the fire caused by the explosion. The limiting factor in this connection was, of course, the size of the pipe columns in the shaft.

Management.

(30) The total number of persons employed underground in the mine was about 950, there being about 440 in the West side.

Mr. Edward Shaw, was the agent and manager of the colliery. He had been the manager for 12 years, the last four of which he had been agent also, and he had under him two under-managers—one for the East and one for the West side. Considering the West side alone there were acting under the under-manager three overmen, viz., one for the Ladysmith and Kimberley Districts, another for Mafeking and one for Pretoria. Under them again were fourteen firemen. The firemen's districts are indicated on plan, Fig. 1, and their names and the extent of their respective charges

in respect of the number of working places and persons in their districts are given in tabular form below:—

DAY SHIFT.

FIREMEN.	DISTRICTS.	Number of Places.	Number of Colliers.	Hauliers.	Wallers.	Repairers.	Others.	Total Men with each Fireman.
Edward Jones...	Pretoria ...	27	42	15	8	7	7	79
D. T. Richards...	East Ladysmith	20	14	—	4	3	2	23
Rees Thomas ...	West Ladysmith	28	56	15	6	4	8	89
Evan Jones ...	Kimberley ...	18	25	10	6	4	5	50
W. H. Chidsey...	West Mafeking	46	86	15	4	8	12	125
Fred Williams...	Ditto ...	11	23	5	—	3	—	31
John Jones ...	Bottanic ...	17	42	8	5	4	5	64

NIGHT SHIFT.

Richard Davies	Pretoria ..	6	10	6	10	23	6	55
John Skym ...	East Ladysmith	13	14	3	4	6	2	29
Morris Roberts	West Ladysmith	3	4	8	8	19	7	46
Ben Thomas ...	Kimberley ...	4	7	4	6	16	4	37
Rd. Davies ...	West Mafeking	2	3	3	4	8	—	18
James Opie ...	Ditto ...	9	13	8	5	15	7	48
Nic Sands ...	Bottanic ...	7	11	3	3	15	4	36

The times of commencement of descent and ascent of the various shifts were as follows:—

	Descent.	Ascent.
Day firemen	3.30 a.m.	1.0 p.m.
Colliers and others	5.10-6 a.m.	2.0 p.m.

Coal drawing was carried on from 6 a.m. to 2 p.m.

Repairing shifts ... ...* { 2.0 p.m.–10.0 p.m. / 9.0 p.m.– 5.0 a.m.

(31) The firemen descended the mine at 3.30 a.m., two hours in advance of the colliers, and, having made the statutory examination of their districts, came outbye again to meet their men at the lamp locking station, the men having descended at 5.30 a.m. I have been at some pains to determine whether or not the amount of travelling which the firemen had to do in some cases was too great to allow of the thorough examination of the workings. The workings have to be inspected "within such time not exceeding two hours immediately before the commencement "of work in a shift as may be fixed by the regulations of the mine" [Section 64 (1)], and, by General Regulation 50, the examination has to be "commenced and completed "within the two hours immediately preceding the *commencement of work in the "district*." That is to say, within two hours before the workmen enter the working places. At most collieries throughout the United Kingdom a meeting station is provided in each district, usually only a short distance back from the face. At Senghenydd, however, there was but one meeting station for the whole of the west side of the mine, and that only 440 yards from the bottom of the downcast shaft. In the majority of instances the distance from the meeting station to the first working place was 1,300 yards or more.

(32) The evidence of the firemen called at the Inquiry was to the effect that they arrived at the meeting station about the same time as, or a few minutes before, the workmen. Thus, William Chidsey, a fireman in the Mafeking District, informed me that it took him at the outside twenty minutes to get from the lamp station to the working face of his district, say about forty minutes to travel in and out again, leaving 1 hour and 20 minutes for the examination of the workings of his district. He said that he usually had 44 stalls to examine, and claimed that he could do this in 1 hour 20 minutes. I doubt very much whether he could even under ordinary conditions, but he certainly could not if anything out of the ordinary occurred necessitating a lengthened stopping in any of the stalls. Nor even under ordinary conditions would any margin of time be available within which to give directions to the workmen respecting their working places.

* The firemen in charge of these shifts descend with the men and remain with them during the shift.

(33) I have had the distances travelled by the firemen, starting from and finishing at the lamp locking station, measured on the plan, as well as the distance from the station to the first working place, and find them to be about as follows :—

DISTRICT.	From Lamp Station to District, round District and back to Lamp Station.	From Lamp Station to first working place.
	yds.	*yds.*
Pretoria	4,800	1,300
Mafeking, East portion	3,500	1,300
Mafeking, West portion	5,300 *	1,500
Kimberley	4,000	1,300
Ladysmith, East portion	5,200	1,300
Ladysmith, West portion	4,000	1,400
	From Lancaster pit bottom to districts, round districts and back to pit bottom.	From Lancaster pit bottom to first working place.
	yds.	*yds.*
Bottanic and West York	3,900	Bottanic ... 530 West York ... 730

It is doubtful, therefore, whether the requirements of Section 64 (1) were complied with in that the inspection of each district was not begun and completed within two hours of the men commencing work in the district. Had a meeting station been provided in each district within a reasonable distance of the face, I am of opinion that the districts would not have been too large to allow of thorough inspection before the commencement of work.

(34) I am inclined to think that, as it was, in some cases the firemen were hard pressed to get round their districts and be at the locking station within the two hours, and so be in time to meet the incoming men at the locking station. Colour would appear to be given to this suspicion by the fact that one of the night shift firemen, Morris Roberts, constantly reported the commencement of his examination as taking place at 6.30 p.m. (the firemen in most cases regarded the locking station as the commencing point of their examination), and the completion at 9.0 p.m. He said he thought that he had two and a half hours in which to make the examination, but that he actually completed it within the two hours. The management never drew his attention to the fact that he had entered up his report incorrectly.

This same fireman had not for a long time—" for as long as he could remember " —travelled the return airway of his district—the West Ladysmith—thus committing a breach of General Regulation 60. He stated that he had never been instructed by the Manager as to his duties.

John Skym, another fireman in the Ladysmith District, followed the same practice. He said that he did not take more than two hours over his inspection, but thought the statutory period was two and half hours.

At the same time the men impressed me as honest and intelligent, and when two of them stated that as the old Special Rule in force at the colliery allowed two and a half hours as the period within which the inspection had to be made, they were still under this impression. The Manager and Under-Manager were at fault in not drawing their attention to the inaccurate manner of entering their reports.

Examination for gas.

(35) During the Inquiry a good deal of attention was directed to determining whether or not the examinations for gas made by the firemen were, in fact, thorough examinations.

Owing to the unstable nature of the strata immediately above the Four Feet seam heavy falls took place at times, forming cavities which were timbered up by what is known as " open cogging," constituting places where gas would accumulate if it was being given off in the vicinity. All the firemen were interrogated, but in this connection it should be remembered that all the " day shift " firemen but one had been killed, so that evidence from those directly concerned was limited to the

* The fireman in this case travelled in by a longer route than that travelled by the workmen.

night shift firemen with one exception (Chidsey), to whose evidence I have already alluded. He was off owing to illness on the day of the explosion, and the other firemen called did not go down the mine until 6.30 p.m. All the firemen maintained that they made an examination of the cavities with their lamps, but not in the first instance with a lowered flame. The practice was to elevate the lamp by means of a stick five feet long, observe whether there was any elongation of the flame indicative of the presence of gas, and, if there was, to go up into the cavity holding the lamp in the hand and make a second test with a lowered flame to determine the percentage of gas present. I do not regard the elevation of a safety lamp on a five-feet stick as a proper mode of testing. I think that not only would it be difficult to determine the existence of gas when present in small quantities, but that when the stick was elevated above the holder at a high angle the flame itself would be obscured. I was astonished to learn that this mode of testing for gas is frequently practised at other collieries in South Wales.

Manner of Reporting.

(36) The manner, too, of reporting the presence of gas was unsatisfactory in some instances. Thus, Richard Davies, a night shift fireman in the Pretoria District, stated in examination by Mr. Smillie that, so far as his reports were concerned, the Manager would not be able to distinguish therefrom whether in any place he had found gas present to the extent of 2 per cent. only or an explosive mixture. If he reported a place as " crossed off " it might contain 2½ per cent. of gas or upwards.

This man also committed a breach of the Act in that, on the day preceding the explosion, owing to the day fireman not putting in an appearance, he failed to report his third inspection made in compliance with Section 65 of the Act. He was on his way outbye to do so, when he was ordered back to take the day fireman's place. He made the statutory inspection before work, and this he reported, stating in his evidence that the conditions were the same as those observed during his third inspection.

The firemen, in compliance with Section 14 (1) of the Act, recorded the number of persons in their districts, but entered the figures in a separate time book and not in their Statutory Report Book, as required by General Regulation 50.

Deputy Firemen.

(37) I found that it was the practice at the colliery at the completion of the fireman's shift, but before the completion of the workman's shift, for the management to put a workman—usually a bratticeman—in charge of the district; that is to say, to take charge of the shift during the balance of the shift.

Q. (*By the Commissioner*) : Then he is partly a workman and partly a fireman?—A. (*Mr. Ben Thomas, fireman in the Kimberley district*) : Yes.

Q. : Does he go on repairing after you leave?—A. : Well, no, I don't suppose he does much after I leave.

Q. : He does not carry out any statutory inspection?—A. : No.

It was argued by the owners that these men were not firemen within the meaning of the Act (though, in fact, they held firemen's certificates), as, during the period of their charge it was not necessary to have firemen in charge of the district.

I agree that it is not incumbent on the owners under the Act to have firemen in charge of a district during the whole time that men are engaged in working in the district, provided that sufficient provision is made for the discharge by the firemen of all the duties imposed on them by the Act and Regulations, but think it would have been better practice to have carried out an arrangement which is in force in some other collieries in South Wales and elsewhere, namely, to have three shifts of firemen overlapping, so that the district is in charge of a regular fireman during the whole time the pit is at work.

Another fact relating to the firemen which emerged at the Inquiry was one regarding the mode of filling up the place of a fireman who, through sickness or other cause, omitted to put in an appearance at the mine. On such occasions it was customary to requisition one of the spare firemen. There was nothing wrong in this, always provided he remained there during the whole of his shift and did

not engage in other work, but it is most desirable that the same fireman should, as far as possible, remain in charge of a district throughout the shift instead of having different firemen undertaking the different inspections during the same shift.

The Act requires that a definite district shall be assigned to a fireman, who "shall be required to devote his whole time to such duties as aforesaid (hereinafter "referred to as his statutory duties)" [Section 14 (2)]. Were it otherwise it would be possible for a very loose state of management to creep in.

II.—The condition of the Mine precedent to and at the time of the Explosion.

(38) With a view to arriving at a proper conclusion as to the origin of the explosion, I have given much consideration to the state of the West side of the mine in respect of the presence of inflammable gas, the existence of coal dust, the liability to heavy falls with outbursts of gas, and the state of the electrical apparatus, for I have satisfied myself that the explosion was not due to shot firing; and as the section of the Act relating to search of workmen for matches, &c., was being rigorously carried out I have eliminated this contingency also. I now proceed to pass these matters in review.

State of the Atmosphere.

(39) I was unable to obtain any barometric record from the colliery, as, though it was stated in evidence that the fireman used to read the barometer before commencing work, no one at the colliery recorded the readings.

It is required by Section 71 (2) of the Act that the barometer and hygrometer shall be read and recorded at such intervals and by such persons as may be prescribed by General Regulations, and General Regulation 104 states that persons who have duties connected with the ventilation shall read the barometer.

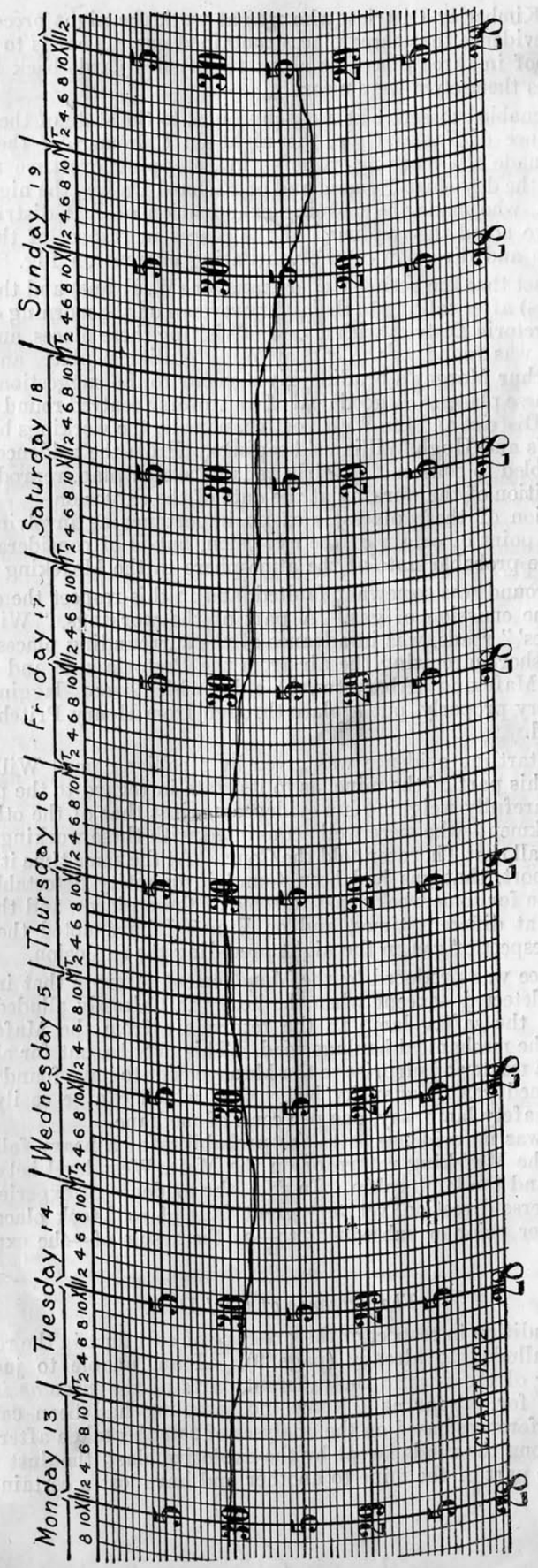
I have, however, obtained, through the courtesy of the owners of the colliery, a barograph taken at the Bute Offices, Aberdare, and reproduce this on the opposite page. From this it will be seen that on the day of the explosion and for the day prior thereto there was no abnormal atmospheric depression. There was no such diminution in atmospheric pressure as would account for abnormal emissions of gas from the waste or coal of the mine.

Occurrence of Gas.

(40) I have endeavoured to discover what was the state of the mine at the time of the explosion and for a few days prior thereto in so far as the presence of inflammable gas is concerned, but, owing to nearly all the persons who were employed on the West side during the "morning" shift having been killed by the explosion, it is very difficult to determine definitely what was the state of that side of the mine on the morning of the 14th October. The evidence, however, of W. H. Chidsey (day-shift fireman in the Mafeking District—off work ill on the day of the explosion), J. Opie (night-shift fireman in the same district), R. Davies (night-shift fireman in East Mafeking District, *i.e.*, "Aberystwyth"), David J. Morris (Under-manager of the West side of the mine—on holiday at time of accident, and for ten days previous thereto), William Williams (day overman in the "Aberystwyth" and Pretoria Districts—off work owing to illness on the day of the explosion), D. R. Thomas (night-shift overman of the whole pit), R. Howells (night-shift overman of the whole pit—off work since October 10th), E. Edwards (timberman), and some of the workmen who had been employed a short while previously in the Mafeking District, as well as that of some of the survivors from the Bottanic District, enables me to draw what I think is a fair inference in this respect.

(41) In respect of the presence of gas, I shall concern myself only with the probable condition of the Mafeking District, for though there is a difference of opinion as to whether the explosion originated in the Mafeking District or not, all the experts are unanimous in thinking that it did *not* commence in either the West York, East side of Pretoria, Kimberley, Ladysmith or Bottanic Districts.

(42) It has been stated that the ventilating current from the Kimberley District, after leaving that district and passing through old workings, with the fresh air from Baker's heading, ventilated that part of the Mafeking District known as the West Mafeking (it is in reality the northern portion). Ben Thomas, the night-shift



fireman of the Kimberley District, who was at work the night preceding the explosion, stated in evidence that three places contained gas. That is to say, he detected gas near the roof in three places at about twenty-five yards back from the face—though the faces themselves were clear.

(43) I am enabled to arrive at a conclusion as to the state of these places chiefly from the evidence of James Opie, the night-shift fireman of the East Pretoria District, who made the morning examination, stopping overtime to do so, owing to the illness of the day-shift fireman, and of Richard Davies, the night-shift fireman of Aberystwyth, who made the morning examination of that district for the same reason, and have noted the condition of the places in respect of the occurrence of inflammable gas and direction of the ventilating current on Fig. 8.

(44) The fact that the acting Under-manager (W. Evans) and the day-shift fireman (Ben Davies) after talking to the night overman on the morning of the explosion went into the Pretoria District with a view of visiting these places, and that the lamp of one of them was found at the end of Wm. Williams' place, and the bodies of both men in Arthur Morgan's heading gives colour to the suggestion that they were anxious about these places. A good deal of controversy centred round a portion of the East Mafeking District and the West portion, namely, the workings branching out of Arthur Morgan's and Hugh Williams' headings. From the evidence which I heard I have been enabled to construct a fairly reliable sketch plan, reproduced in Fig. 8, showing the position of the working at the date of the explosion.

The condition of these places is of no importance as involving this part of the mine as the point of origin of the explosion, but is of considerable importance as indicating the probable state of the atmosphere in the Mafeking return.

(45) The ground was somewhat faulted, and in this respect the conditions were favourable to the emission of gas. A part of the workings, "William Davies'" and "Jim Davies'" roads, was in advance of the surrounding places, and evidently with a view of short circuiting the air from the Pretoria side and ventilating the places on the Mafeking (Aberystwyth) side, which were lagging behind, the Management, very properly, put a place through from Henry Pritchard's stall into Jim Davies' road.

(46) Very startling evidence was given by a collier named William Thornton, who worked in this part of the mine, as to its state in regard to the presence of gas, but after very carefully weighing his evidence against that of the other witnesses—officials and workmen—who were well acquainted with these workings, I find myself unable to accept all that Thornton told the Court. At the same time it is proved from the firemen's report, that gas had been found in quantity detectable by the lamp from time to time for some weeks past in some of these places, and that one or more were fenced off at different times, and on Fig. 8 I have noted the conditions of these places in respect of gas on the night preceding the explosion.

(47) Evidence was produced by the Management to prove that inflammable gas had never been detected—except when the heavy fall already alluded to took place (*see* p. 8)—with the safety lamp in the return air from the Mafeking District, which was also the mechanical haulage road. This may be, but for all that it could never have been a matter of surprise to the Management to have found that the air in this road contained gas in quantity below that which can be easily detectable in the flame of the safety lamp, say, one per cent. of methane.

(48) There was no evidence as to the probability of a heavy fall having taken place either in the Mafeking return or on the Main West level between the No. 1 North way end and the lamp cabin. In fact, the evidence of experienced witnesses pointed in a reverse direction, yet very great falls of roof took place at both these spots, but whether prior or subsequent to—as the result of—the explosion I shall shortly debate.

The presence of Coal Dust.

(49) The condition in respect of the presence of coal dust in the roadways of the mine has been alluded to already (page 9). I am unable to judge as to the precise character of the dust in the different parts of the mine *as it existed prior to the explosion*, for, so far as I know, no sampling had been carried out. I can only make inferences based on the analyses of samples taken after the explosion, and although, along the roads swept by the explosive blast, the dust will have been carried from one part of the mine to another and have lost a certain amount of its

volatile constituents, the analyses are still of value in determining the character of the dust in the area of the explosion, and, to some extent, whether certain parts of the mine have been traversed by flame or not. In that part of the mine not characterised by burning or explosive violence the analyses are of the greatest value as affording an explanation of the cessation of explosive violence.

(50) Lists of the analyses made by Dr. Wheeler of samples taken by Dr. Atkinson, and of samples taken and analysed by M. J. Taffanel, are given in Appendix C, and Fig. 1 is a plan on which are marked the positions at which the samples were taken. These analyses indicate the extent of the incombustible matter in the dust, and I have added to them the results of the samples taken by Sir Arthur Markham in No. 1 North, Ladysmith Return, and the back of the shaft on the East side and handed to me by the owners.

(51) The plan (Fig. 1) shows at a glance the nature of the dust in point of incombustible contents at different points along the roadways. It might be stated generally that where the dust contains a comparatively low percentage of incombustible matter, there the explosive violence was greatest, and where it was highest the explosive violence was least. In some parts it died out entirely.

Thus, in the No. 1 North, where the percentage of incombustible matter in the dust ranged between 50 and 90, there was no explosive violence. In that part of the Ladysmith Return in which the incombustible matter constituted from 63 to 71 per cent. of the dust there was little exhibition of force, but where the flame of the explosion reached the old haulage road (Jenkin's dip), where the incombustible matter in the dust was much less—where, indeed, there was almost pure coal dust in places—there was evidence of a recrudescence of explosive violence.

One point that impresses me, considering the dust as a whole, is the high percentage of incombustible matter contained in it as compared with what I have observed in respect of the dust collected at other mines after explosions, and I consider that this is a very probable explanation for the, comparatively speaking, small amount of violence exhibited.

Inspection by the Representatives of the Workmen.

(52) The last inspection of the mine by the representatives of the workmen of the colliery was made on August 18, 1913, and the report signed by them was as follows:—

> We, the undersigned, examined the new 6 feet, York East. Found these districts free from gas and headings; manholes in good order; engines well fenced; airways in good condition.
>
> *Ladysmith.*—We examined this district; found Ladysmith in good order with the exception of diluted blower in Martin's Road; main wanted a little cleaning and watering. Airways in good condition, also manholes and engines well fenced; main wants dusting and watering.
>
> *Kimberley.*—Diluted blower in Down's Road 12 feet from rail; airway and returns in good condition; manholes and engines well fenced; ventilation good.
>
> *Mafeking*—Aberystwyth District.—Diluted blower in William Thornton's Road and in William Jones' Road.
>
> *East Mafeking*—Bottanic.—Diluted blower in old road on right hand, also in road near Ben Davies Barry; but we all stopped until Ben Hill gets hole from No. 1 North, from there to York West. Manholes of the above two districts in good order, also the engines well fenced. Ventilation good also. Returns in good condition.
>
> *York West.*—Examined this district; all in perfect condition, airways and returns in good condition, also manholes and engines well fenced.
>
> *Glawnant and East Side.*—Examined this district; found diluted blower in Dd. Griffiths' Road, also in Richard Owen's Road, also in Evan Jones Road, everything in good order with the exception of these three places. Ventilation very good; airways and returns in good condition, also manholes and engines well fenced.
>
> *Slope.*—Examined this district; found everything in good order. Ventilation not perfect; roads and airways in good condition, also returns; manholes in good condition, also engines well fenced.
>
> *Lower 9 feet left hand.*—Found this district in very good condition, free from gas, also roads very good except one part of straight wanted water and cleaning.
>
> *Straight.*—Found this district very good with the exception of Pikes Road; diluted blower on this road, also in Dd. Hollands Road and Randall's Road, roads very dusty and sides wanted cleaning; airways and returns in very good condition, also manholes.
>
> *Pretoria*—District No. 2, South 9 feet.—Examined this district; found everything in perfect condition, airways and returns, also manholes.
>
> *Pretoria 4 feet.*—We examined this district; found every place free from gas, well ventilated airways, and returns in good condition.
>
> (Signed) THOMAS LEWIS.
> REES REES.

The condition of the Electrical Signalling Apparatus prior to the Explosion.

(53) Mr. Nelson, the Electrical Inspector of Mines, has made a careful investigation into this question on my behalf, and I am much indebted to him for his help in the matter.

(54) The evidence of the witnesses called to speak as to the electric signalling apparatus as it existed before the explosion was clear and complete except on one material point, namely, the limit of pressure used on the signalling circuits in the mine. On this point the evidence was, in my opinion, too definite to be perfectly convincing, having regard (*a*) to the fact that the voltage of each individual cell in a battery in daily use appears to depend upon the time at which it is measured, whether in the morning or late in the day (as will be seen hereafter); (*b*) to the number of measurements that had to be made to ascertain the exact figure; and (*c*) to the character of the instrument with which the measurements were made.

(55) The men whose duty it was to keep the signalling apparatus in working order were Charles Watton, Senior, and Charles Watton, Junior, father and son, but both were under the general supervision of Mr. H. W. Schielbach, consulting electrical engineer of the Lewis Merthyr Consolidated Collieries, Limited. The actual work fell to Mr. Watton, Junior, but Mr. Watton, Senior, his father, was responsible to the management of the colliery for its proper performance. In the course of the evidence given by the Messrs. Watton, attention was mainly directed to the electrical apparatus in the Mafeking hard heading; and, on one simple point, the number of cells in use at the top of the heading, the two appeared not to agree. Mr. Watton, Senior, who was first examined, said :—

Q. (*By Mr. Evan Williams*) : How many cells would you have in at the top of the Mafeking Hard Heading before the explosion?—A. : Eight coupled up, sir.

Q. : And one stand by?—A. : Yes, sir.

Q. : That was immediately before the explosion?—A. : Yes.

Mr. Watton, Junior, gave evidence on the same point, as follows :—

Q. (*By the Commissioner*) : Now just go a little further up again?—A. : Nine there, sir.

Q. : Where?—A. : The drum. (That is at the top of the hard heading.) There were ten cells there—nine connected and one.

Q. : Unconnected?—A. : Yes.

Evidence was given by other witnesses which left no doubt that, on this point, Mr. Watton, Junior, was right (as one would expect, for it was almost his sole duty to attend to the signalling apparatus), and that at the time of the explosion, though only eight cells were connected at the bottom of the Mafeking hard heading, there were ten in the battery box at the top, one being disconnected and out of use.

(56) On the material point as to what pressure was obtained from the eight cells at the bottom and the nine cells at the top of the heading, Mr. Watton, Senior, said :—

Q. (*By the Commissioner*) : Did you ever test the voltage in those circuits in which there were nine cells?—A. : Yes, sir.

Q. : What did you find it?—A. : Nine volts, sir, exactly.

Q. : Never more?—A. : Never more; we never allowed any more to be put on.

Q. : Where did you test at the top of the Mafeking hard heading, for instance?—A. : In the box.

Q. : Whereabouts?—A. : At the drum.

Q. : And never found it more than nine volts?—A. : No, sir.

And Mr. Watton, Junior, closely confirmed his father as follows (speaking of the battery at the top of the heading) :—

Q. (*By Mr. Evan Williams*) : When you put in a new cell two months before the explosion, what was the voltage of the battery then?—A. : About $6\frac{1}{2}$ to 7.

Q. : That was the total voltage?—A. : Yes.

Q. : Then you put in one new cell?—A. : Yes.

Q. : Did you test the new cell?—A. : Yes.

Q. : What was the total voltage then?—A. : About $8\frac{1}{2}$.

Mr. Schielbach, the Messrs. Watton's superior, also gave evidence on this point :—

Q. (*By the Commissioner*) : In your capacity of adviser on electrical matters to the Senghenydd Colliery Company, did you ever test the voltage of the signalling circuit?—A. : Yes.

Q. : Before the explosion—recently before the explosion?—A. : No, not before the explosion—not recently before the explosion.

Q. : About how long before?—A. : Underground you mean? No.

Q. : Never?—A. : No.

Q. : You never did?—A. : Well, some twelve months before, perhaps.

Q. : What was the highest voltage there?—A. : About, well, not more than nine.

(57) These three witnesses all agreed in placing the voltage in use on signalling circuits definitely at, or below, 9 volts. Mr. Charles P. Sparks, who was called by the owners, gave evidence to the effect that he had had the pressure of the battery at the foot of the hard heading measured two months after the explosion, after the individual cells had been got together and reconnected. The pressure obtained on open circuit was 10·34 volts. Mr. Shielbach, later, gave the pressure of the battery at the top of the heading, taken also two months after the explosion, as 11·45 volts. Both voltages dropped very rapidly on closed circuit, to 6·9 and 3·79 volts, respectively, after a short time, indicating that though the individual cells had recovered their pressure somewhat, they were, in fact, approaching exhaustion.

(58) In explanation of the high voltage obtained on open circuit (in view of the Messrs. Watton's evidence) it must be said that cells do recover if left to themselves unused. No one seemed able to give definite information on this point in the course of the Inquiry, and, by my instructions, therefore, Mr. Nelson communicated with the makers of the Dania Cell. He made a general inquiry as to the performance with respect to recovery of "type C" cells, such as were in use in the mine, and he received in reply a curve which is reproduced in Fig. 9. This curve seems to indicate that recovery is fairly rapid, and that, due to such recovery, the pressure of a battery measured in the late afternoon, after a day's use, might be quite appreciably less than the pressure of the same battery measured the following morning. The makers' curve may be referred to for more exact information, though it must be allowed that the curve is not one obtained under ordinary working conditions in a mine. The cell from which the curve was obtained was closed through an external resistance for six hours and allowed to rest for eighteen hours daily during the course of a month's trial, which is not the same as a series of short rings and short rests. The latter would certainly give less drop in voltage over the same length of trial. The curve is only introduced to show that there might be in the course of a working shift in a mine an appreciable drop in pressure and a recovery to almost the original pressure in the night or during a prolonged rest, and hence the statement made above that the pressure of a battery unless taken right at the beginning of a working shift would not be the maximum pressure of that battery. There was no evidence that this point received attention or consideration from any of the people concerned. In fact none of the witnesses seemed to have any useful information as to the extent to which a primary battery will "recover" after ordinary daily use.

(59) Mr. Watton, Junior, was asked as to the method of testing the pressure of cells. He produced a linesman's detector, and gave in evidence that 10 divisions on the detector scale represented one volt. I have since had the instrument tested, and the test sheet (which forms Appendix D) confirms Mr. Watton's statement. The Board of Trade found that as nearly as possible 11 divisions on the detector scale represented one volt and that 19 divisions represented 1·5 volts. The useful part of the scale, however, only measures a length of about $\frac{3}{8}$ inch, and there are four divisions marked on it : 5, 10, 15, and 20. To read accurately on such a scale requires considerable care and some method. It is comparatively easy to see whether 1 volt is exceeded or not, and even to read 1·25 volts or 1·5 volts, if the equivalent scale readings are accurately known, but it is not easy to read intermediate figures. The limitations of the method are such that an error of as much as 1 volt in the aggregate, in either direction, might readily have been made in the final result after adding together nine different readings each in itself likely

to be inaccurate. A proper instrument to use for such a purpose would be a low reading voltmeter recording, say, from 0–25 volts, and giving a wide scale reading throughout.

(60) There is, first, the fact that the pressure of the cells in use does not appear to be a fixed quantity, or even a very slowly diminishing quantity, but, within limits which are fairly wide, a variable quantity, that is, one which diminishes following use of the cells and then increases almost to its former value in a few hours if the cells are left unused. Secondly the fact that the pressure of the battery at the top of the hard heading was 11·45 volts and that of the battery at the foot of the heading 10·3 volts measured two months after the accident. Thirdly, the fact that the method of computing the pressure was not likely to give a very accurate result. From these facts I conclude that the witnesses called by the Company were more definite in their evidence as to the pressure in use than was warranted, and that it is possible that the pressure of the batteries in use in the mine was sometimes, and possibly not infrequently, in the early mornings and after week-ends, in excess of 9 volts, though the Messrs. Watton may have honestly believed this not to be so. What the precise pressure may have been I cannot say.

(61) To sum up, the only evidence available is that to the best of the Messrs. Watton's judgment and belief the battery pressure never exceeded nine volts, but I think it is not an unfair conclusion that sometimes, unknown to the Messrs. Watton, that pressure may have been exceeded. Whether to a great or a small exent, I had no evidence to show.

III.—Narrative of the Explosion and of the Rescue Operations.

I pass now to a review of the events of the morning of Tuesday the 14th October.

(62) When the explosion occurred, Mr. Shaw, the Manager, was in the lamp room at the surface. At ten minutes past eight o'clock he heard a report and at once went over to the Lancaster pit and saw that the surface in the immediate vicinity was wrecked, that the banksman was killed and the assistant banksman injured. After visiting the fan and finding everything right there, and having given orders to a mechanic about taking out the broken cage at the top of the downcast shaft and repairing the planking over the pit head, he was joined by D. R. Thomas, the overman, and together they got into the cage at the top of the upcast shaft, examined the air for a distance of fifty yards and found it foul with smoke and fumes. Signals were being sent up from below, so, being joined by others, they descended the shaft. When half-way down they saw the body of a man in a tram in the upcoming cage with his legs hanging on the crossbars. This man had been practically blown into the tub in the cage at the pit bottom. They signalled to stop the cage, crossed into the other and pulled in the body and then continued their descent. At the Six Feet Seam landing the cage jammed in the girders. Shouting down to the Nine Feet landing they found the men from the East side were all right.

(63) On their arrival at the bottom they found much smoke coming out of the return. They tried to get through the first cross-cut on the East side, but the doors were on fire and burning fiercely, so they went to the West side. There, again, in the cross-cut there was a fire raging, the doors were blown out towards the return, and the timbering and other matter was burning, but there being less woodwork than in the East side cross-cut the fire was not so severe. They extinguished the fire and got through and round to the Lancaster pit, found a man, Ernest Moses (a shackler) alive behind some empty trams about four yards to the West of the shaft

(64) Crossing the pit they found five or six men lying down full length, but all of them died later. These men were hitchers and worked on the West side, but when there was no coal to wind they used to go over to the East side, as there was a place for them to sit therein.

It seems odd that these men should have died, that the banksman on the surface should have been killed, and yet Moses' life should have been saved. Moses must have been protected by the tubs from the full effect of the explosion, and no doubt the explosion gained considerable force in its passage up the shaft, which would contain a good deal of coal dust blown off the tubs in the process of being wound against a current of air.

(65) The overman, D. R. Thomas, who gave a clear and graphic account of his movements, said that when he got into the Main West Level and worked along towards the West, "it was exactly like looking into a furnace." There were no stones lying about on the road, a point of importance when discussing the probable point of origin of the explosion. Thomas was then told by the Manager to go to the East side with a party of men, whilst he, with one other man, remained on the West side.

(66) Mr. Shaw proceeded along the Main West Level for a distance of forty yards to where the hauling engine was situated, and found the planking of the engine beginning to blaze. He and the man with him knocked down the planking and extinguished the fire. Then they went on to the crab engine, and the timber there was on fire "and all the timber, so far as I could see from there on was all ablaze. " . . . Every collar I could see ahead from the arch was ablaze then. . . . "I could see every collar blazing in front of me for twenty or thirty yards." No falls of any magnitude had as yet taken place there and for a distance of thirty or forty yards, "but the laggings were just beginning to break down."

(67) Mr. Shaw then retraced his steps and rejoined Thomas and his party, helping them to extinguish the fire in the East side cross-cut. After this he tried to get to the "Six Feet Universal seam," but was stopped by a fall, so he came back to the East York Level, "and there I found out that the men from the East side were "all right, as the explosion had not gone in there." The overman informed him that he had withdrawn all the men from the East side workings. "I told him to "keep them where they were and to bring them on within 100 yards of the pit, "and that as soon as I had the York Pit shaft right for travelling in I would send "for the men and let them go up." The ventilation was, of course, now "short "circuiting" to a considerable extent—a strong current from the intake passing into the return through the West side cross-cut. The shaft was cleared, all the injured men collected and placed in the cage and sent to the surface, and the East side men sent up also—28 at a time.

Leaving Mr. Shaw and his companions for the moment, I pass to the movements of one of the persons who was rescued alive.

(68) W. H. Lasbury, an assistant timberman, employed before the explosion by a contractor, descended the York shaft on the morning of the explosion at about 7.50 a.m., went into the West York by the return, and had proceeded to a point about twenty or thirty yards below the engine on the York West incline when he heard a dull report. He was enveloped in a cloud of dust, which travelled in from behind him, lost his light—it being blown out by the force of the blast—and fell forward. He then called to the engineman asking "if he was all right, and he "said 'Yes.'" He then turned back to the pit and groped his way out. As he drew near to the cross-cut he heard a "sound as of air rushing through the doors "in its ordinary course"; that is to say, the leakage through the doors when shut. As he drew nearer "the doors crashed open," and he heard "a splintering sound," and staggered back. The sound was of splintering and crashing, and there was a great rush of air; he staggered back just on the inbye side of the doors, righted himself and proceeded to the bottom of the York shaft, where he dropped. I have made a careful estimate of the time that elapsed between the occurrence of the report and the crashing and splintering sound which he heard, and put this at ten minutes. This, therefore, would be before Mr. Shaw and his party got down the pit.

(69) I see no reason to doubt the man's statement. It is quite possible that there was a first explosion which did not reach the surface (the Whitehaven and Cadeby Colliery explosions have only to be instanced as pointing to the fact that disastrous explosions may occur in a mine, not known to those on the surface) and for a second and more disastrous one to have occurred a little later. In support of this possibility I would draw attention to the evidence of Thomas Jones, who, when working in the Nine Feet Seam (which is about 27 yards below the Six Feet seam) at a point marked on the plan (in the neighbourhood of Mafeking "Storage") heard "a roar "or rumble . . . coming from some distance" and then a terrific and distinct "bang." Then the roar went on, "but more vigorously than previously." On the other hand, the second sound and force may have been due to a heavy fall taking place somewhere between the No. 1 North way end and a point some twenty or thirty yards outbye the lamp cabin on the Main West Level—where the ground is very heavily fallen—owing to the timber supports having been shifted

by the first explosion or partially burned through by the subsequent fire. I do not think it was due to the "back lash" after an explosion, as the lapse of time—ten minutes—was too long an interval to account for a back lash. If the doors were not blown out by a first explosion the force at this point cannot have been great.

(70) The very heavy falls which took place on the Main West Level between a point a few yards outbye of the No. 1 North Cross-cut way end and the lamp cabin blocking the intake, which had afterwards to be "bashed" (dammed off) with sand bags, &c., because of the fire beneath them, must have occurred after the explosion for the following reasons:—

(i.) Had a heavy fall occurred, before the explosion, blocking the airway, one would have supposed its effect would have been shown by the fan, but Benjamin Price, the fanman, said he had not observed anything. If there had been any variation in the speed of the fan he would have noticed it at once, but he had observed no variation.*

(ii.) The fire after the falls were observed was beneath the fallen ground, the roof having evidently collapsed, and, indeed, was still falling, for a man was killed by a fall on the day after the explosion when working at No. 1 North Cross-cut way end on top of the burning timber.

(iii.) It would be difficult, if not impossible, to account for the ignition of the timber below the fall on the supposition that the fall occurred first.

(iv.) Even if it were possible to account for the fire beneath the fall on the supposition that the fall preceded the fire, I am at a loss to account for the fire not spreading inbye beyond the fall.

(v.) If the fall occurred first, I should have thought that either (*a*) the fall would have blocked the explosion and prevented its reaching the shaft, or (*b*) the explosion would have swept a shower of stones from the fall and strewn them along the road from the fall to the shaft, but all the witnesses agreed in stating that there was no evidence of this.

(vi.) Had heavy falls taken place prior to the explosion at the spot under consideration, I should have thought that the man Moses, or Lasbury, would have heard them, but neither of them did so.

I am forced, therefore, to the conclusion that the fall or falls in question took place subsequent to the occurrence of the explosion. This consideration has a most important bearing on the determination of the point of origin of the explosion.

(71) I am in some doubt as to whether the crash and splintering which Lasbury says he heard were due to the smashing of the separation doors in the cross-cut or due, as I have said, to the falls taking place in the Main West Level, as otherwise I am in some difficulty to account for the force which knocked him down and the cloud of dust which enveloped him when he was in the West York return, unless this came by way of the Klondike stables or over the air crossing. Certainly the doors might have been blown open and fallen to again, but it seems hardly likely.

(72) I return now to Mr. Shaw and his party of explorers. Shortly after we left him (*see* paragraph 67) he went to the surface to arrange for further assistance. It was an hour from the time of Mr. Shaw's first descent to the bottom of the pit before a commencement was made with putting the water pipes in order to deal with the fire in the Main West Level. The fire in the cross-cut on the East side had been extinguished by breaking a pipe on the East side leading from the column in the upcast, which, though broken, was not so badly damaged that water was prevented from flowing through it into the East water pipe. The column in the downcast was completely severed.

(73) Mr. Shaw stated that within the hour he had men at work connecting the pipes to the column in the downcast shaft and bringing water through the first cross-cut on the West side, but that they were greatly hindered in their work by smoke and fumes, and that it was not until the arrival of breathing apparatus from the Porth Rescue Station—about eight miles distant—that a proper connection was made. As this was not until 11 o'clock—word not having been received at the Rescue Station until 10 o'clock—much valuable time was lost. There were trained rescue brigade men at the colliery, but no breathing apparatus was kept on the premises.

* The effect of restricting the airway in a mine is to reduce momentarily the speed of the fan. The governor would then operate and the normal speed would quickly be resumed.

(74) According to Mr. Shaw the temporary connection which had been made before this time was not a good one. The pipes in the cross-cut were so badly broken that a new line of pipes had to be laid through the cross-cut; and there was a breakage in the shaft column 20 yards up from the bottom of the York shaft which had to be repaired. The column in the Lancaster pit did not convey water from the surface. Eventually two lines of pipes were fed from the column in the York shaft, one line coming along the return and through the West side cross-cut, the other from the East side of the York shaft through the East side cross-cut and across the Lancaster shaft bottom. The fire was fought with the water conveyed by these two lines of pipes. This brings us to midday. Mr. Shaw said: "It would be getting on for twelve or one o'clock then. Possibly it may have been "a little later, I could not say for certain." Mr. Shaw was of the opinion that even if they had had a better supply of water within one hour of the occurrence of the explosion the fire could not have been extinguished. I cannot, however, accept this view. Mr. Greenland Davies, who saw the fire at about twelve o'clock, said it might have been extinguished then but it would have taken a great deal of water. The following day it was confidently anticipated that the fire would be got under control, and the fire which spread into No. 1 North was successfully fought. At the time of the arrival of Dr. Atkinson and myself at the colliery I urged Mr. Rees. the late Agent of the Colliery, who was superintending operations, to secure a better supply of water, and about midday on the 15th October it was decided by some mining engineers, in consultation with the management, to put a second column of 2-inch pipes down the Lancaster pit. This work was completed the same night, the pipes being ready for use the following morning.

(75) In my opinion the insufficiency of the water supply was a most regrettable incident. Of course, there is always the risk of pipes in shafts or underground being broken by the force of an explosion, but the time lost in repairing them would be much less than that absorbed by having to instal a complete column.

(76) At the Inquiry I asked Mr. Shaw whether, in view of the previous disaster—though, as a matter of fact, there was no fire on that occasion—he did not think it would have been advisable to have made arrangements for conveying more water into the mine to meet the case of a possible fire in the future, and he replied, "Well, "looking back on what has happened I agree it would have been advisable." At that we must leave it. It may, however, be asked why not have made use of the 6-inch diameter column of pipes, which conveyed the compressed air down the shaft, for carrying water underground; or, if the strength of these pipes was insufficient to withstand the pressure resulting from a full head of water, to have kept the column filled to a height which would have given a less head. That is to say, to have filled up the 6-inch column to a certain height by a pipe from the surface and drawn away the water at the bottom by one or more 2-inch pipes? The answer given to me when I put the proposition before the management was that the compressed air plant was being kept at work in case some of the entombed miners might be subsisting on the fresh air supplied thereby.

(77) When Dr. Atkinson and myself arrived on the scene on Tuesday afternoon at 5.30 p.m., the fire was being fought with water and fire extinguishers. No actual fire was then visible, it being buried beneath falls, and it was arranged to fill away and send to the surface as much of the heated *débris* as possible, and so advance against the fire. Shifts were arranged to carry out this work, each shift acting under a colliery official or mining engineer, and each shift working for six hours.

(78) The speed of the fan was slackened the day after the explosion.

(79) A Committee of mining engineers and others was appointed on Wednesday midday to control the rescue operations.

(80) That the mining engineers and management anticipated successfully combatting the fire within a short time is supported by the fact that when a suggestion was made that sand could be used for this purpose it was overruled as unnecessary. Ultimately, but not until October 17th, sandbags were procured from Cardiff. Mr. Clement Edwards put the following question to Mr. T. Greenland Davies, Junior Inspector of Mines: "I think you were present at an earlier stage when the "Chief Inspector asked if there was a shortage of a supply of water, and they "seriously considered the question of using sand, and Mr. Leonard Llewellyn said "it was not a sandy district, and I said if it were a question of sand I could get a "hundred volunteers, get the railway company to run a train, and we could have "sand in a few hours from Penarth, and Mr. Llewellyn said they would have the

" fire out before they could get back," answered, " My impression is that that " happened the next day " [Wednesday]. Mr. Edwards : " You do remember what " I have described ? " Answer : " Yes."

(81) Anxiety was caused by the appearance of gas over the fall on the inbye side of the No. 1 North way end. The gas had somewhat increased on the Thursday night, but by the end of the night shift it had materially diminished again, so that at a conference held in the Colliery offices at 11.15 a.m., Mr. L. Llewellyn, one of the Committee of Mining Engineers in control of the rescue operations, reported " That it was a pocket of gas—a maximum of fifteen inches running " out to nothing on the face side." If they would agree he said that he could clear the gas himself in a very short time. Mr. Griffiths also stated that it could be done with perfect safety (Notes compiled by Mr. Rees and put in as evidence). This accumulation of gas was due to the curtailing of the air current passing along the Main West Level over the fall, as in the minds of many of the engineers present a fear existed that the air playing into the heated mass would cause the fire to spread. Various schemes were tried to overcome the fire, but all were successively abandoned. Work on the fall ceased, and the bashing on the outbye side of the fire was commenced on the 8th November.

(82) When the fire was dammed off by the bashings of sandbags and walling (*see* note on plan, Fig. 1), and the state of the ventilation allowed of it, exploration of the workings was undertaken.

Should the air current have been reversed?

(83) The question naturally suggests itself, why was not the reversal of the air current effected so as to carry the smoke and fumes up the Lancaster shaft and prevent their circulating through the workings? I have devoted much time to the consideration of this problem, and have put two questions to myself for answer, viz.: first, was it possible at once to reverse the air current, and, secondly, if the reversal had been carried out would it have been the means of saving life?

In reply to the first question I have the Manager's own confession that, owing to his not having fully carried out the requirements of Section 31 of the Coal Act, 1911, it would have taken two hours to have put the means of reversal into operation, but had the means at the surface been available for *immediate* reversal it would not have taken long to have effectively stopped off the West side cross-cut and so carried the reversal of the air current underground. I think it probable that as a result of this the men in the West York District would have been saved, but that those in the Bottanic District would have been adversely affected by the reversal. In fact, I incline to the belief that it would in all probability have resulted in the death of these persons. We know from the stories of survivors in that District, in particular that of the boy James Hill, whose story was very clear and connected, that for some little time, at any rate, after the explosion —for about fifty minutes—the air in the District, as far along the haulage road as the engine beyond the second parting (reckoning from inbye), was breathable, but that he and his companions could not get beyond that point as " it was too thick " —as it was he was beginning to get faint. I believe that afterdamp was sucked into the Bottanic Return from the Mafeking Return by a momentary reversal of the air due to the explosion, and that on the re-assertion of the ventilation it was forced out again, but that by that time the road leading to the West York was full of afterdamp, which on reversal of the main ventilating current would have been carried into the Bottanic District with fatal results to the persons there, eighteen of whom were ultimately rescued alive. So that, even had the means for reversal been ready to hand, I think it would have been a rash act to have reversed the air, on account of the risk of driving the afterdamp on to possible survivors, though it had not, of course, been discovered that there were persons alive in the Bottanic District when the question of reversal first came up for consideration.

(84) This is a notable instance in which the existence of a second intake would have been invaluable in enabling the fire at once to have been built off.

The Use of Breathing Apparatus.

(85) It has been stated that the breathing apparatus from the Porth Central Rescue Station arrived at the colliery nearly three hours after the explosion. At a conference of mining engineers and others summoned by Lord Merthyr at the colliery

office about 4 p.m., at which were present Messrs. T. Griffiths, D. Hannah, Leonard Llewellyn, W. Routledge, E. Shaw, Howell Jones (mining engineers), Messrs. Pearson, Carey and Davies (Inspector of Mines), and Messrs. H. Hughes, A. Onions, J. Winstone and W. Jones (representatives of the miners), it was stated that " H.M. Inspectors " of Mines do not think any useful purpose will be served by sending rescue men " into the workings," and those present concurred in the view (Notes of Mr. Rees). I quite agree that at this stage no useful end would have been served, but think that if at a much earlier stage—within an hour of the occurrence of the explosion—apparatus had been available and men had gone into the return from the West York District carrying with them light breathing dresses such as are provided for the purpose, some persons might have been saved in this part. I was told that the heat was too great, but when I had the temperature taken in the return it registered only 75 degrees Fah., and this was at 7.30 or 8 o'clock at night. The body of a man was found only a few yards further along the return from the West cross-cut—a few yards from safety. But no apparatus was kept at the colliery.

(86) Smoke helmets, supplied with air by flexible tube and bellows, were used for building the bashing on the inbye side of the fire and the concrete wall at Klondike stables, the smoke helmets being found very useful for this particular purpose, more so indeed than the self-contained apparatus. The difficulties with which the men engaged upon this work had to contend were the heat and fumes coming out overhead, and the smoke helmets kept them cooler and freer to work than if they had been wearing self-contained apparatus; but it must be borne in mind that in both these cases the men were close to fresh air, being never more than a few yards away from it.

The Rescue of Survivors from the Bottanic District.

(87) It was not until 10 o'clock on Tuesday night that an attempt was made to enter the Bottanic District.

(88) On the arrival of Dr. Atkinson and myself at the colliery at 5.30 on Tuesday afternoon, we were informed that the air current on the East side was short circuited near the pit bottom. We pointed out that gas might back from that side of the pit and pass on to the fire, and it was arranged, therefore, that that side should be carefully watched and that the East roads leading to the West side should be examined. Messrs. T. G. Davies and P. T. Jenkins, Inspectors of Mines, with two other persons, proceeded about 9 p.m. to do this, which resulted in their discovering that the air, instead of coming in by the No. 1 North was passing into the Bottanic from the East side. Mr. Davies stated in evidence " We started out about 9.15 p.m. We came back and met Professor " Redmayne and Mr. Clement Edwards coming towards the upcast shaft from the " West side. We reported the matter, and they thought Dr. Atkinson and Mr. Rees " should be at once informed of what we had discovered." The result of what they had discovered led to an exploring party being sent into the Bottanic District at 10 p.m. It was 11.30 p.m. when the first man was discovered, alive but unconscious. By the early hours of Wednesday morning 18 in all had been rescued alive.

(89) I am of opinion that these men might have been rescued sooner, but whether, if the attempts had been made, more lives would have been saved is problematical, as I am unable to say whether any of the eighteen who lost their lives died immediately after the explosion or lingered for some hours. Those of the bodies, however, which were examined by Mr. Davies were quite cold.

(90) When the No. 1 North was first examined by Mr. Shaw's orders, viz., at 9 a.m., and again at 1 p.m. on the day of the explosion, it was impassable to men equipped with breathing apparatus, so the Court was informed. If this had been so the air must at that time have been passing to the Bottanic by way of the Main West Level, and such indeed was the presumption in the mind of the management and of others associated with the management in combatting the fire. But if this was so I fail to understand how it was that any persons at all were left alive in the Bottanic District. I think it is more reasonable to suppose that the current from the East side gradually became stronger. The falls on the Main West Level outbye end of the No. 1 North, would act as a check on the air entering the Bottanic via that Level.

IV.—The Point of Origin and Cause of the Explosion.

The different theories put forward to account for the Explosion.

(91) As to the point of origin the opinions expressed placed it at two fairly widely separated points : (1) on the Main West Level at a spot somewhere between the end of the No. 1 North Road end and the No. 2 South Road end; and (2) somewhere on the Mafeking Incline.

(92) The first is supported by the mining engineers called by those representing the owners and management, by the representatives of the men who gave evidence, and by Mr. Carey. The second is supported by Dr. Atkinson, Mr. Dyer Lewis and Mr. T. Greenland Davies.

(93) The Manager, Mr. Shaw, while uncertain as to the exact spot, put forward several possible theories to account for the ignition of the gas : (i) On the Main West Level at a spot twenty to thirty yards inbye of the entrance to No. 1 North; his idea being that a heavy fall took place blocking, or nearly blocking, the road, and liberating gas which was ignited by a spark caused by the falling stones; or (ii) The gas liberated at the fall was carried inbye to the locking station and there ignited by an open lamp; or (iii) The gas proceeded still further inbye and exploded at a damaged lamp that was found by the entrance to the Mafeking Storage parting.

(94) It will be seen that a heavy fall liberating gas and blocking, or partially blocking, the roadway is required in order to bear out this theory.

(95) The mining engineers also required a like occurrence. Thus Mr. F. L. Jacob put the ignition at the lamp station. Mr. T. Griffiths put it somewhere between the lamp station and No. 1 North road end. He thought the theory that the ignition took place at the lamp cabin a " very plausible and a very feasible one," but was not " wedded " to it.

Mr. John Kane put the fall as occurring between No. 1 North and No. 2 South. Otherwise he agreed with Mr. Jacob, as did Mr. D. Hannah and Mr. J. P. Gibbon.

(96) The representatives of the miners, with the exception of Mr. Watts Morgan, differed somewhat from the mining engineers.

Mr. J. Winstone considered the probability of gas existing in a cavity in the Main West Level at the arch end, and that friction caused by a haulage rope rubbing against timbers near the roof may have induced sparks or flame which ignited the gas. He thought, further, that a second explosion, caused by the first, took place in the Mafeking District on the Hard Heading.

Mr. Hubert Jenkins thought that a rope rubbing against timber on the Main West Level at No. 1 North road end set up a fire which brought about a fall, causing a cloud of coal-dust, which, igniting, caused the explosion.

Mr. Barker required for his theory a cavity in the roof containing gas at a spot some yards outbye side of the No. 1 North road end, and friction of the haulage rope against timber setting up a fire.

Mr. Watts Morgan, who was called by the Commission owing to the prominent part he took in the work of exploration, and as a member of the committee of control which was established on the day after that on which the explosion occurred advanced the theory that gas was liberated by a fall at a point on the Main West Level somewhere near to the Klondike stables, possibly occasioned by the journey getting off the track and drawing out the timber supports, and that the sparks produced by the fall ignited the gas.

(97) Dr. Atkinson, in putting forward his theory, did so not as a positive conclusion, but as the most probable explanation of the disaster. He said :—

> " From a consideration of the indications there appears to be a division of force somewhere on the Mafeking Incline, and I think a preponderance of all the indications points to that place as a possible point of origin of the explosion.
>
> " The only indications against it are those on Mafeking Storage, and here there were indications of force in both directions, some of which must have been caused by a reverse force, or back lash, succeeding the original blast. I incline to the opinion that the first blast was outward, because of the outward indications at the sprayer on the Main Level just outbye of the Storage, and at the first engine further out on the Main Level.
>
> " If the explosion originated on Mafeking incline, the question is how it was caused. There were very large falls on the road, exposing seams of coal, and beds of hard rock, and an outburst of gas may have come away with one of these falls. If this occurred, the only apparent means of ignition would be a spark from the electric signal wire, or sparks from rocks brought down by the fall.
>
> " This theory is not advanced as a positive conclusion. Neither sparks from signal wires nor sparks from falling stones are very probable means of ignition, although I have no doubt that some explosions have been initiated by both these causes; and if the explosion commenced on Mafeking Incline these are the only means of ignition I can suggest.
>
> " Although the experiments with electric signals did not prove that sparks at the voltage said to be in use on the incline would ignite firedamp, the margin is too small to convince me that it was impossible."

Mr. Dyer Lewis concurred with Dr. Atkinson, and Mr. Greenland Davies was of like opinion.

Consideration of the theories.

(98) I cannot, for reasons already discussed (*see* page 22), accept the suggestion that a fall took place immediately prior to the explosion on the Main West Level between the No. 1 North road end and the lamp station, blocking, or nearly blocking, the airway, and short of such a fall I am unable to account for the enormous quantity of gas which would be necessary to cause an explosion at the lamp station. The gas would have to be borne a distance of anything between 160 and 246 yards according to whether a point just inbye side of the No. 1 North road end or a point opposite to the Klondike stables is taken as the point of the efflux of the gas, before arriving at the lamp station, and it would have to be discharged at the rate of 9,000 cubic feet per minute to give even the lowest explosive mixture.

(99) There are several features which are opposed to the lamp station as being the point of ignition. The cabin had been whitewashed only two months previous to the explosion, and yet, on being entered a few days subsequent thereto, it was so discoloured as to present the appearance of having been swept by an explosive blast carrying coal dust and smoke, whereas if an explosion of gas had originated in the cabin one would not have expected discolouration. The three separation doors were blown into the return and smashed to bits. The doors of the cabin itself were blown outwards. A red lamp which hung at the corner of the turning off the Main West Level into the lamp station was found in a shattered condition some little distance outbye. These three last-named facts at first sight seem to favour the lamp station theory, but I think they do not. It is contrary to experience to find indications of the development of great force at the originating point of colliery explosions. The position in which the lamp-cabin doors and the red lamp were found would be compatible with a projection of force from inbye. Curiously enough an underground lamp was found lying on the table of the lamp cabin with unburnt paper inside it.

(100) Indication of force, taken by itself, is sometimes an uncertain guide to the location of the originating point of a colliery explosion, as often the indications are conflicting. In some instances (*e.g.*, the Hulton Colliery Explosion, 1910*) where there was little or no contradiction in this respect the case is, of course, quite different. At Senghenydd the evidence was conflicting, nor was there general agreement in every instance as to the interpretation to be put upon the evidence. I prefer, therefore, to base my opinion chiefly on the evidence of my own eyes.

Mr. Jacob, who was most assiduous in investigating the various indications which might assist the management in locating the explosion, and in marking them on the plan, was the chief witness put forward by the owners to explain these indications. The other expert witnesses on behalf of the owners who followed Mr. Jacob were in practical agreement with him.

(101) I find myself in general agreement with Mr. Jacob as to the roadways of the mine, with the exception of that part of the Main West Level between the lamp station and the Mafeking Storage, and with the exception of a considerable portion of the Mafeking main haulage road.

There was hardly a demonstration of force on the Main West Level from the bashing at No. 2 South to the Mafeking Storage which, in my opinion, could pro-

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* Reports on the explosion which occurred at the No. 3 Bank Pit, Hulton Colliery, on the 21st December, 1910, by R. A. S. Redmayne, H.M. Chief Inspector of Mines, and Samuel Pope, Barrister-at-Law. London. 1911. [Cd. 5692.] Price 2*s.* 6*d.*

perly be said to be indicative of the explosive blast having travelled in an inbye direction. Dr. Atkinson and Mr. Dyer Lewis could find no indication whatever of inward force. The trams on the double parting opposite Ladysmith entrance had been run into each other by force proceeding in an outbye direction, and the outermost tram was entangled in the signal wires. I agree with Mr. Dyer Lewis that this result may have been produced by the falls at this junction.

At the engine outbye of Mafeking Storage there were indications of force outward. The upright timbers supporting the beams over the engine-house were forced outward, and fencing strips were blown outward. The compressed air-service pipe crossing above the road to the engine was fractured at the base, and forced outward more than three feet. (Fig. 4.)

A little further in, beyond a fall, three trams, part of an empty journey, attached to the rope, showed signs of outward force. One of the trams, containing a piece of wood tightly fitting the whole length of the bottom, was found with the door forced open from an apparent inbye force, but as this tram was close up to a fall the stones could have done the damage to the tram doors.

Just outbye of Mafeking Storage the upright standard pipe supplying a sprayer was fractured at the top and bottom, and was found six feet outbye of its proper position.

At the mouth of Mafeking Storage, on the curve, some timbers and rollers on the turn seemed to have been displaced by a force coming outbye from the storage. The body of a workman, much mutilated, was found lying at the side of the roadway of the Main West Level just opposite to the storage. The body appeared to have been hurled against the side with considerable force, and a piece of shirt sleeve was found on laggings immediately above the body.

Between Mafeking Storage and the second engine on the Lancaster Level the fencing of a return sheave was blown inbye, and at the engine there were numerous signs of force inbye : part of a lamp which hung over the drum was blown to the roof and stuck in the outbye side of a beam. The battery box was smashed and the cells strewn inbye, the bell was broken, and the gong was found 6 yards and the battery box 12 yards inbye, and from this point inward such indications as were seen were all inbye.

Returning to Mafeking Storage, the indications in the storage were conflicting, and there were indications of force in both directions. (Fig. 5.)

I attach considerable importance to the position of bodies as a factor in determining the direction of an explosive blast.

On the main level opposite the storage, were two bodies under a small fall. One of these bodies, it appears from the doctor's report, was terribly mangled, which may have been caused by the man having been blown out of the storage and dashed against the side of the main level. Inside the storage was a body almost naked, lying with his head outward. Near him was the body of a horse lying across the road. About here was a journey of six full trams, and the " racing " on the inbye end of the inside tram was swept off, outward. A journey of six empty trams on the opposite line of rails had the three inbye trams blown across the road. The first door on the storage was altogether blown inward. Between the first and second doors two tool boxes were displaced and one unmoved. The accounts of the original positions of the boxes were confusing, but the balance of probability is that they had been blown inward. About the same place a water-tank stood diagonally across one of the lines of rails, and its inbye side was stove in. Portions of the second door were found on both sides of its original position; but most of the bricking was on the inbye side, and a beam cap, which was said to have been above the door, was found under the body of a horse 17 yards inbye of the door. Further in, on the full journey to which the horse was attached, the " racing " of the two inbye trams was partly swept off the inbye end of the trams. The last two trams of an empty journey were off the rails.

At the third door there was about equal evidence of force in both directions; a door band was found on each side of the door place, and broken door wood was scattered along the road on both sides.

Four out of the five bodies found on this section of road had their heads outbye.

On Mafeking Level the falls were so continuous that little evidence of the direction of force was to be seen.

Just outbye of the bottom of Mafeking hard heading was a tool box in its original position, with a white-washing brush behind it. On the turn going into Mafeking hard heading was a journey of empty trams, some of which were off the

rails, and the inside tram was under a large fall. One of the horizontal sheaves guiding the rope round the curve was forced outbye from its original position and almost turned over. There was a large fall just inside the hard heading with a lot of timber leaning outbye, presenting the appearance of having been blown outbye.

At the engine on the hard heading, one of the beams over the engine was forced outbye; the service pipe and throttle valve were broken off and were found in an outbye direction, and the gong of the bell was found in a battered condition against the outbye end of the engine house.

Further on, at the return wheel, there was a thick coating of coked dust on the outbye side of the upright supports of the wheel.

About half-way up the incline two insulators fixed to a wood block appeared to have been blown 17 yards down the incline; the place from which they came being identified by two nails in the wood block exactly fitting nail holes in a projecting arm where insulators were missing.

Near the brow of the incline there had been a staging for timbering purposes, and seven planks forming the floor of the staging were scattered along the road in in an inbye direction. At the drum a water-tub stage over the drum was moved inbye and two iron guard straps were bent in the same direction.

(102) From a careful review of the facts, viz. : The improbability—an improbability amounting with me to conviction—that a heavy fall liberating gas preceded the explosion, and the negative condition of the exhibitions of force in that portion of the West Level between No. 2 South road end and the Mafeking Storage I find myself unable to accept the theory advanced by the owners to account for the explosion.

(103) With regard to the theories put forward by the representatives of the miners :

I was much impressed by the evidence of the timberman Edwards, a most experienced man, who said he had never seen a rope running in the timbers at or near the places named by Messrs. Winstone and Barker, and that there was plenty of clearance. I think, too, had there actually been smouldering wood at this spot, long before a fire originated its presence would have been detected by the smell. Nor do I consider it at all likely that gas would exist in a cavity in a road in which a current of 152,000 cubic feet of air was passing per minute, though it is not impossible.

(104) As to sparks produced by falling stones providing a possible means of ignition. I am not prepared to rule this out. I give my reasons later (page 30). But wherever the explosion originated I cannot accept the theory that it proceeded in an inbye direction from the neighbourhood of the No. 1 North road end.

(105) Whilst putting forward theories of their own to account for the explosion, Messrs. Winstone and Jenkins did not regard Dr. Atkinson's theory as impracticable. Mr. Nicholas, in addressing the Court at the termination of the Inquiry on behalf of the Miners' Federation of Great Britain, said : " But " Mr. Winstone and Mr. Hubert Jenkins in particular, if you will recollect, were so " impressed by certain of the circumstances at the mouth, I think of the Mafeking " Storage, that, to use Mr. Hubert Jenkins' own words, that is not a theory which " you can exclude from the scope of your Inquiry, and the Court, so far as I am " concerned, is invited very carefully to inquire into the circumstances (otherwise) " we would not have taken the time we did with regard to the condition of things in " ' Aberystwyth '—not as originating up there, but as contributing towards this " working theory."

(106) Dr. Atkinson required for his theory an outburst of gas on the road itself. As a matter of fact there was a very heavy fall, but whether it took place before or after the explosion it is difficult to say. Fig. 7 is a levelling of the fall undertaken by Mr. Greenland Davies and the Colliery Surveyor. It would almost appear that the greater part of the *débris* fell prior to the explosion, owing to the discolouration of the greater part of the sides. The arrangement of the signal wires and the position of the " journeys " on the Mafeking Incline as found when this part of the mine was first explored is indicated on Fig. 6.

(107) Mr. Dyer Lewis thought that " a probable initiation of the explosion may " have been a fall of roof where re-opening was going on and where bashing chains are " visible—some short distance below the brow of the incline," that " the fall of roof

" was followed by gas from the upper seams which was ignited by the grinding of " pieces of rock against each other or by a prop supporting signalling wires, falling " and rubbing the wires together."

(108) If the explosion originated at the spot mentioned by Dr. Atkinson and Mr. Dyer Lewis we have to account for the indications of force gradually dying out beyond to drum and in the direction of " Aberystwyth." Like Dr. Atkinson, I think that this is due to the fact that the dust got stonier towards the faces (*see* analyses and plan, Fig. 1).

(109) In connection with the possibility of a spark from the signalling wires having originated the explosion, there was a conflict of opinion as to whether a spark from nine cells of the Dania type, in conjunction with a bell such as was in use at Senghenydd, would ignite an explosive mixture of fire-damp and air. Some experiments were carried out with the idea of determining this point in the rescue station at New Tredegar on January 1st, and some further experiments on January 29th. Briefly, the result was as follows: An ignition was produced with a pressure of 13½ volts (from 9 Dania cells) applied to a bell taken from Senghenydd Colliery, the ignition being produced by rubbing a knife edge along two signal wires mounted to represent the wires in the mine. No ignition was produced when a pressure below 13½ volts was applied to a Senghenydd bell. But the experiments were not exhaustive in the opinion of Mr. Nelson, who conducted them, with the assistance of the Rescue Station Engineer, in the presence of representatives of the owners and the Miners Federation. On this point Mr. Nelson gave the following evidence:—

Q. (*Mr. Evan Williams*): From all that you say do you think that there is a possibility of the electrical conditions on the Mafeking Hard Heading, either on the top or at the bottom, having caused this explosion? What is your opinion on that point?—A.: I will place it at a bare possibility. We had an ignition at 13½ volts under Senghenydd conditions. We had two ignitions in a quarter of an hour's trial. If we had tried longer perhaps we might have got an ignition with fewer than 13½ volts, but I cannot say. I will not say that 10 or 9 volts or less will cause an ignition. I agree fully that it would be difficult to obtain one at those pressures, but I am not personally satisfied as to what the pressure was in Mafeking Hard Heading. I was satisfied at one time, but my belief was disturbed by Mr. Sparks's evidence.

Q. Do you base your opinion as to the bare possibility on the fact that you are not quite certain as to the voltage there at the time?—A.: Well, I don't know how far we can go down. I know we can ignite gas with 13½ volts. I do not know how much under that pressure.

Q. If you assumed that Mr. Watton's evidence was correct, that the voltage did not exceed nine, what is your opinion as to the possibility—the actual possibility—of an explosion having occurred at that point?—A.: I would go almost the length of closing the door, but I would not close it absolutely.

Q. Even with 9 volts?—A.: No. because, as I say, the experiments were not completely exhaustive.

Q. I just wanted your views.—A.: I think I will put it that way. The experiments go a long way to show that the pressure there was getting in the direction of a safe pressure.

(110) As to the possibility of sparks igniting gas, we have the evidence of Mr. Shaw to the effect that he had frequently seen sparks from falls of ground, and the incident which happened at the Lletty Shenkin Colliery, Cwmbach, on the 27th January last points to the possibility of an explosion of fire-damp being caused by sparks other than electrical. An account of this incident was given in evidence by the overman (R. W. Evans) and a fireman (J. Lloyd) who witnessed it. They and others were engaged in working at a fall which had occurred some days before in the main intake road in the Seven Feet seam. The overman was at the side of the men on the intake side of the fall when, hearing a sound in the roof from which the fall had come, he took them a little way back. " After we had gone some distance " I heard a crack and the whole roof fell, with crashing of timber and all. As " soon as it came to the timber I saw a flame rising three feet in length." The stone fell on some iron tangers (*i.e.*, iron bars to support the roof) which were over a short pair of timbers, but he could not say whether sparks were caused by striking

the iron or stones striking each other. No noise accompanied the flash, which was a " lightish blue." There were no signs of burning.

No gas had been detected above the fall before the incident described, though they had tested for gas with the safety lamp.

Lloyd, the fireman, was on the inbye side of the fall, about fifty yards distant, but was coming towards it when the second fall took place. He saw two sparks—bright yellow. He thought this spark was after the fall had taken place, which caused the men to run back and think it was a second occurrence. He observed " a kind of smoke and a smell." The smell was, as near as he could describe, " a " smell of powder after being burnt," which lasted for ten minutes. He saw no flash, but doubts if he could have seen it from where he was " because our side was " closed up with the timber." He heard no report. The place was very wet. The noise caused by the fall was very great, and may have drowned the sound of the report of exploding gas—if indeed gas had exploded.

(111) The boy Hill said that the sound of the explosion proceeded from Mafeking, and a collier, Thomas Jones (working in the Nine Feet seam, below the Four Feet seam and at a spot between 80 and 90 yards from the storage), said that he heard a roar, a bang and a roar. This variation might be due to a fall or to a recrudescence of force. Such a recrudescence would be likely to occur in the storage. Dr. Atkinson leant rather to this opinion:—

Q. (*By the Commissioner*): You allude to the " back lash " in the storage. Do you think that the effect of the explosion going down there—supposing your theory is right—and the fact that the doors opened in that direction would be to create a mass of coal dust there, and that that might lead to a great recrudescence of force breaking in both directions?—A.: I think that is possible, especially having regard to the great area of the storage, and to several open cogs, where there would be coal dust deposited. Possibly that might cause the back lash. I do not know.

Were it not for the contrary evidence of force on the Mafeking Storage I should have little difficulty in coming to the definite conclusion that the explosion originated at the point suggested by Dr. Atkinson. As it is, the weight of evidence is in favour of his theory.

V.—Summary of Conclusions and Recommendations.

Probable site of origin and possible cause of explosion.

(112) After carefully weighing the facts revealed by the evidence of the various witnesses and from my own personal investigations underground at the Senghenydd Colliery, I have come to the conclusion that there is strong probability of the explosion having originated on the Mafeking Incline, and that it was preceded by an occurrence similar to that which took place further outbye in the Mafeking Return in October, 1910, namely, by heavy falls liberating a large volume of gas. These heavy falls exposed seams of coal and beds of hard rock, and an outburst of gas may have come away at one of them. The only apparent means of ignition would be sparks from the electric signalling apparatus, or from rocks brought down from the fall, and we know that explosions have been originated by both these causes. The only other possible means of ignition were safety lamps or matches. The difficulty in regard to the former is that no lamp was found in the place, and even were a broken lamp found under a fall there would be the inference that it may have been broken by the fall. There were, however, lamps lower down the hard heading, but there is no evidence pointing to any of them having been the igniting cause of the explosion. In respect of matches, as has already been stated, a rigorous search of the persons descending the mine was being carried out daily, and the possibility of a match being the igniting cause is, in my opinion, remote.

(113) General Regulation 132 states that " In any part of a mine in which inflam- " mable gas, although not normally present, is likely to occur in quantity sufficient " to be indicative of danger, the following additional requirements shall be " observed:—

" (i) All cables, apparatus, signalling wires and signalling instruments, shall " be so constructed, installed, protected, worked and maintained, so " that in the normal working thereof there shall be no risk of open " sparking," &c.

and " open sparking " is defined in General Regulation 118 as meaning " sparking

" which owing to the lack of adequate provision for preventing the ignition of " inflammable gas external to apparatus would ignite such inflammable gas."

(114) The signalling wires were carried into the Mafeking District as shown on the plan, and past the places where, in October, 1910, a large outburst of gas had occurred (*see* page 8). The wires were also carried into the West Mafeking District, past the place known as Beck's Old Heading in which the existence of gas had been reported some time previous to the explosion in such quantity as to prevent men working there. Undoubtedly, therefore, electrical signalling was being used in a part of the mine in which there was likely to be inflammable gas in quantity sufficient to be indicative of danger.

(115) It was argued by counsel appearing on behalf of the owners and management, and evidence was called to show, that the sparks caused by bringing the wires together, or in the ringing of the bells, were not of sufficient intensity to ignite gas—in effect that there was no "open sparking." In this connection I can only regret that the safer plan of excluding sparks altogether was not adopted. It is all the more astonishing that the management should have faced the risk that the sparks produced *might* have ignited gas in view of the Bedwas Colliery explosion, which occurred on March 27th, 1912, and which was proved beyond reasonable doubt to have been caused by the sparks from an electric bell. The attention of owners of mines throughout South Wales was called to this explosion in a circular letter sent out by Dr. Atkinson, dated 28th August, 1912, the terms of which are given in Appendix E.

Rescue operations.

(116) I have described in some detail the nature of the operations which followed immediately after the explosion with a view to overcoming the fire and of rescuing the entombed persons. The position of the bodies points to the persons who were working at the face having come out only a comparatively short distance from the face. They were, in all probability, overcome by the afterdamp resulting from the explosion, and not by the fumes generated by the fire, and did not survive long enough for the fumes from the fire to affect them. The persons engaged at work on the haulage roads were killed outright.

(117) I very much doubt whether it would have been possible to have saved any of the persons in the Pretoria, Mafeking, Kimberley and Ladysmith Districts. But I incline to the belief that if rescue apparatus had been kept at the colliery, and men equipped with breathing apparatus and carrying with them a lighter form of apparatus, had at once penetrated the West York by the return and the Bottanic District a few more lives might have been saved. I do not put this forward as a definite conclusion, but from the evidence I think there is strong probability that this would have been the case. Much valuable time was lost, as is so often the case, immediately after the explosion, but it must be remembered that Mr. Shaw had lost a great number of his officials. He was short handed; and he and those who accompanied him in the first descent of the mine certainly did all that was humanly possible *with the means at their disposal* to combat the fires, but I am convinced that had there been available at that time an adequate water supply, and had brigades of rescuers attacked the three fires (*i.e.*, at the two cross-cuts and that on the Main West Level) simultaneously, the fires might have been extinguished in a comparatively short time. I should have thought, in view of the fact that the colliery was such a gassy one, and as it had already been devastated by an explosion, that the management would have made arrangements for a supply of water adequate to meet an emergency of the kind that actually occurred.

(118) I think that arrangements should be made—they need only be of a very simple nature—whereby on the occurrence of an explosion or fire, an agreed upon signal should be given at the earliest possible moment, *e.g.*, by blowing the colliery whistle ("horn," "hooter," or "buzzer") a certain number of times—as is done in some pits to intimate to the men that the pit will lie idle on the succeeding day, or to make known the meal hours to the surface hands—and that on the sounding of this signal rescue hands should at once assemble, secure the necessary apparatus, and proceed upon their allotted tasks, just as fire drill is carried out on board ship. For this purpose collieries might be formed into groups and practices be carried out at different collieries of a group from time to time.

(119) I have considered the question as to whether the reversal of the air current, if carried out immediately after the occurrence of the disaster, would have resulted

in the saving of life. I think it would not, for reasons which I have given at some length on page 24. The mine was so laid out that the reversal of the air current would have resulted in driving the afterdamp back on to the faces, in some districts, *e.g.*, Mafeking, if the explosion had originated on the return of the Mafeking District.

(120) I would like to repeat (*see* page 25) that had this colliery been provided with a double main intake the task of dealing with the fire on the Main West Level would have been a comparatively simple matter, as it could have been stopped off at both ends and so isolated, always assuming that there was not a fire in both intakes.

The state of the mine prior to the explosion.

(121) In the course of this Report I have dealt at some length with the state of the Mafeking and West side of Pretoria Districts in respect to the presence of inflammable gas, and evidence was taken as to the state of other Districts on the West side. The conditions, in my opinion, were such as might be expected to exist in a fiery colliery, and I am not prepared to state that the ventilation was inadequate under normal conditions of the mine.

(122) In respect of the presence of coal dust, the mine was not in a satisfactory condition. Whilst I am satisfied that the floor of the roadways of the mine was adequately watered, the dust on the roof and sides was practically disregarded. I found a misapprehension to exist in the minds of the management as to the interpretation of Section 62 (3) of the Coal Mines Act, 1911. It was argued that the meaning of the Sub-section was that the *clearing* of dust from the floor, roof, and sides should be carried out as far as practicable. I think, and informed counsel of my opinion, that the Sub-section requires the *systematic clearing* of the floor, roof, and sides, and that the words " as far as practicable " relate to the latter part of the sentence only, namely to the prevention of the *accumulation* of coal dust.

(123) As no attempt had been made for a long time to clear the roof and sides of coal dust, a breach of Section 62 (3) of the Act seems clearly to have been committed.

(124) I am of the opinion that the best method of preventing the accumulation of coal dust in the roadways of this and other mines in which it is customary to heap the coal above the level of the top of the trams is either to provide a covering for the top of the tram, or so to wet the coal that from the commencement of its journey outbye from the landings to the shaft it is maintained in a damp state, and I see no practical difficulty in the way of effecting either remedy.

(125) I have stated elsewhere in the Report that the force developed in this explosion was not great as compared with other explosions of which I have had experience, and can only attribute this to the fact that the dust in the Senghenydd mine contained a high percentage of incombustible matter, and it is a noticeable fact that wherever the percentage of incombustible matter in the dust was highest there the explosive force tended to die out. I am of the opinion that this is one of the reasons why the explosion extended such a very short distance past the Lancaster pit into the East side, and that the considerable violence of the blast at the top of the shaft is due to the large quantity of coal dust in the shaft, the explosion gathering violence in its passage up the shafts. These facts have strongly impressed upon me the desirability of stone dusting in mines. I know that apprehension exists in some quarters as to whether such a remedy would not be worse than the disease, the idea being that the introduction of stone dusting might be conducive to miners' phthisis, but I would point to the fact that dust derived from argillaceous shale has existed naturally in many mines in the United Kingdom for long past without, so far as I know, injurious effects resulting to the workmen employed therein. I am aware of the experiments mentioned in the First Report of the Explosions in Mines Committee (*see* pages 12-17), carried out by Professor James M. Beattie on guinea pigs; but if any doubt still exists, I would urge that further experiments be carried out with a view to removing the matter from the realm of doubt.

(126) In respect of the means to be adopted for removing the dust from the roof and sides of roadways, I have been impressed by the experiments which have been carried out by Mr. Benjamin Nicholas at Tirpentwys Collieries, Pontypool. Mr. Nicholas adopts the method of sweeping the sides of the roadways of coal dust by means of a blast pipe of compressed air at a pressure of 80 lbs. to the square inch,

the dust being driven forward in a cloud and passing through perforated zinc screens erected across the roadways, over which water is passed continuously, rendering the dust into mud. Any experiments carried out with the object of the effecting the removal of coal dust from the roadways are to be welcomed, and I mention this particular instance in the hope that it may further stimulate efforts in this direction.

Firemen's Reports and size of Firemen's Districts.

(127) I have stated that in respect of the presence of inflammable gas, the condition of the mine prior to the explosion was not, in my opinion, such as to disquiet unduly the mind of the management, but I regard the system of reporting followed by the firemen—not only at this colliery, for the evidence of Mr. F. L. Jacob, Sub-agent of the Ferndale Collieries and Agent of the Welsh Navigation Collieries, pointed to indefiniteness in this respect at other collieries—as unsatisfactory, in that it was not sufficiently definite—not full enough nor accurate enough—to enable one to judge of the actual state of the working places, and I had to subject several of the witnesses to very close examination before I could arrive at any conclusion as to the actual condition of the working places.

(128) Nor did any of the reports under the heading " Condition of roof and sides " allude to the existence of coal dust. The requirement contained in Section 64 (3) was not, therefore, fully observed. Some of the firemen also, under the heading " Examination," entered 2½ hours as the time taken for the statutory examination of the districts. Several of the witnesses, however, informed us that they did this in error, and that the time actually taken on the inspection was in fact only two hours.

(129) By the last paragraph of General Regulation 50 the fireman is required to check the number of workmen under his charge and to record this number in his report. The firemen did not record the number in their report, but in a separate time book, so that a technical breach of the Regulation in question was committed.

(130) I discovered that there were a number of cases of broken lamp glasses, but in no case could I find that General Regulation 53 had been observed in this respect, for there was no record in the firemen's reports of damage done to any safety lamps.

(131) I am of the opinion that some of the firemen's districts were too large, if the district is regarded as commencing at the lamp-locking station, for, on their own showing, it was not possible for the firemen to have commenced and completed their inspection within the two hours immediately preceding the commencement of work in the districts. This difficulty would have been met by placing the meeting station nearer to the face of each district instead of having one meeting station for the whole of the West side of the pit.

(132) When a fireman was off work through having overslept himself a temporary or spare fireman was put in charge, and did not necessarily remain in charge during the whole shift, but when the regular fireman put in appearance returned to his own work, *e.g.*, as bratticeman, for the remainder of the shift. It will thus be seen that a breach of Section 14 (2) was committed in that the said fireman did not devote the whole of his time to his statutory duties as defined in Section 14 (1) (*see* page 13).

Breaches of the Coal Mines Act, 1911, *and Regulations under the Act.*

(133) I have alluded in the body of the Report to several breaches of the Coal Mines Act, 1911, and the Regulations made under that Act, namely, failure to provide means for the immediate reversal of the air [breach of Section 31 (3)], failure to measure the air in each ventilating district, at, or as near as practicable to, a point 100 yards back from the first working place at the working face which the air enters [breach of General Regulation 77 (*c*)], failure to record the measurements of the air current in a book in the form prescribed by the Secretary of State and omission of manager and under-manager to countersign [breach of Section 24 (1) and (2)], failure by persons on whom responsible duties are imposed with respect to the ventilation underground to record the reading of the barometer immediately before going into the mine and after coming out of the mine [breach of Section 71 (2)] and failure to remove, as far as practicable, coal dust from the roof and sides [breach of Section 62 (3)].

Further breaches of the Coal Mines Act, 1911, referred to in the body of the Report are Section 34 (1) (iii), page 9, Section 64 (1), page 11, and in respect of General Regulation 60, page 12.

(134) Some of these breaches, compared with those to which I have already given especial prominence may appear trivial, but taken in the aggregate they point to a disquieting laxity in the management of the mine.

I regret exceedingly to have to say this because Mr. Shaw impressed me as an honest, industrious, and in many respects, an active manager, and he gave his evidence in a clear and straightforward manner and assisted in the Inquiry to the utmost of his power.

The unlocking and opening of Safety Lamps in Gassy Mines.

(135) Although in my opinion the lamp cabin was not the originating point of the explosion, I am of the opinion that it is inadvisable, to say the least, to permit the opening of a safety lamp in any mine of a gassy nature such as Senghenydd—and there are many mines of a similar character, not only in South Wales, but in other parts of the United Kingdom. It seems to me the only safe rule is that in a mine, seam or part of a seam where safety lamps are required to be used by the Coal Mines Act, 1911, or the Regulations and Orders under that Act, no lamp should be unlocked or opened.

The Use of Electricity for Signalling Purposes.

(136) Reference has already been made to the electric signalling arrangements. This Inquiry has shown quite clearly that the exemption from the requirements of the electricity Regulations which applies at present to electric signalling apparatus that happens to have been in use before 1st June, 1911, and that was in conformity with the code of electricity Regulations then in force, goes too far. The Regulation in the code of 1905 (which code was superseded by the present code in 1912) to which reference is made reads as below :—

> " In any place or part of the mine where General Rule No. 8 of the Coal " Mines Regulation Act, 1887, applies, bare wires shall not be used for " signalling circuits *except* in haulage roads, and the pressure shall not exceed " 15 volts in any one circuit."

This clearly permitted bare signal wires on haulage roads anywhere below ground even in places where inflammable gas might have occurred in quantity such as would have rendered the use of a naked light dangerous (General Rule 8, Coal Mines Regulation Act, 1887) provided the pressure did not exceed 15 volts, and Regulation 137, paragraph (*b*) of the present code allows the continued use of such wires (unless the Inspector of the district raises objection) until June 1st, 1920. It is clear from the evidence given at the Inquiry that a pressure of 15 volts on bare signal wires may be dangerous in the presence of an explosive mixture of firedamp and air, and I think, therefore, that a modification of Regulation 137 is desirable so as to exclude from its operation such signal wires and signalling apparatus as are in use in virtue of the Regulation of the code of 1905 quoted above.

No apparatus other than signal wires was permitted by the code of 1905 to produce external sparks in places where gas might occur in quantity sufficient to be indicative of danger, and my recommendation is that it be made clear that signalling apparatus should be treated in the future as all other apparatus is treated, and that all open visible sparks should be avoided where gas may occur. This will require a slight modification of Regulation 137. I am encouraged to make this recommendation as signalling apparatus which is guaranteed by the makers not to produce an open or visible spark is readily obtainable.

(137) It would be individious, where all the mining engineers and miners engaged in attempted rescue operations worked so hard in endeavouring to get past the fire into the workings with the object of saving life, to commend individuals by name, but I think a particular meed of praise is due to Mr. Shaw and to the small band of workers who accompanied him underground immediately after the explosion.

(138) In concluding this Report I wish to acknowledge the courtesy of the legal and other representatives of the owners and management, of the relatives of the deceased, and of the federations of workmen, and the great assistance they have been in furthering the objects of the Inquiry.

I have the honour to be,

Sir,

Your obedient Servant,

R. A. S. REDMAYNE.

Note on Electrical Signalling Apparatus.

The experiments carried out at New Tredegar with the electric signalling apparatus, the results of which are given in Appendix B, and are commented on in the body of my report were not, to my mind, sufficiently exhaustive and definite to warrant their being regarded as finally settling the question of the safe limit, in respect of electrical pressure and current, for electrical signalling apparatus when used in any part of a mine which is likely to contain inflammable gas in dangerous quantity. I therefore asked Dr. Wheeler to be so good as to carry out some experiments further to elucidate the matter. This he has done with bells of the type and make in use at Senghenydd Colliery, and I attach his report with this covering note as Dr. Wheeler's notes were not received in time to enable me or my colleagues to comment in our reports on his very important findings. There is, however, nothing in my report which is contrary to the results arrived at by Dr. Wheeler, one of which is that with three Dania cells giving a current (on closed circuit) of 0·45 ampères under a pressure (on open circuit) of 4·5 volts it is possible to produce a spark, by short circuiting the current in the signal wires to give a signal, which will explode a mixture of air and methane when methane is present to the extent of 8·2 per cent.

I am much indebted to Dr. Wheeler for this valuable piece of experimental research work, which should receive the close attention of mining engineers.

R. A. S. R.

Dr. Wheeler's Report on Experiments with Signalling Apparatus.

The electrical ignition of methane-air mixtures.

On March 21st there were received at the Experimental Station two signalling bells of the pattern used at Senghenydd Colliery, and a supply of dry cells of the make and size used at that colliery at the time of the explosion. I was instructed to carry out tests to determine the limiting conditions under which the electrical ignition of methane and air mixtures could be effected when using a battery of dry cells connected through a bell so as to form a signalling circuit.

A number of tests have been made, the results of which are given in detail later, using one of the " Senghenydd " bells, and, for comparison, a bell kindly lent to me by Professor Thornton, of Armstrong College, Newcastle-on-Tyne, from whose work our knowledge of the conditions necessary to obtain ignitions of gaseous mixtures by momentary electric arcs is mainly derived.*

The experiments described in this report show, as Professor Thornton's work with higher voltages has also shown:—

(1) That methane-air mixtures vary in their ease of ignition according to the percentage of methane present, being much more difficult to ignite as the " limit mixtures " (lower limit 5·6 and higher limit 14·8 per cent. methane) are approached.

(2) That the inductance of the circuit is of prime importance in determining whether the flash produced on breaking the circuit can ignite an explosive mixture; and

(3) That the ampèrage of the current is of more importance than the voltage.

Before describing the experiments that have been made regarding the general question of the electrical ignition of methane-air mixtures, it will be as well to state the results obtained with the " Senghenydd " bell and cells under conditions comparable with those that would obtain in practice.

The bell was of the usual trembler pattern for continuous current working, with an iron cover (not gas-tight), which was removed during the tests. The bell had a resistance of 10 ohms.

The experiments were carried out in such a manner that either the bell or the signal wires, by the short-circuiting of which the bell could be caused to ring, could be enclosed in a chamber containing an explosive mixture of methane and air. It was found that ignition at the bell, due to the maintained spark at the spring contact, could be obtained with a battery of five cells, the current when the circuit was closed being 0·70 ampères, and the voltage across the terminals of the bell being 7·5.

Of more importance to determine was the number of cells required to cause ignition by the flash produced by short-circuiting the signal wires to give a signal.

* Trans., Inst. Min Eng, Vol. XLV., Part 1, pp. 145–147.

With only the resistance due to the bell (10 ohms) in the circuit, a battery of three cells was sufficient to give a break-flash capable of igniting the most sensitive methane-air mixtures (containing from 8 to 9·5 per cent. of methane).

To allow for the resistance afforded by the long lengths of signalling wire used in practice, non-inductive resistance coils were inserted, as shown in the series of experiments below in which a mixture of methane and air containing 8·2 per cent. of methane was employed.

Resistance in circuit.	Number of cells required for ignition by break-flash.	Current on closed circuit, ampères.	Voltage on open circuit.
Bell only (10 ohms) ...	3	0·45	4·5
Bell + 10 ohms	5	0·40	7·5
Bell + 20 ohms	7	0·35	10·5
Bell + 30 ohms	11	0·40	16·5
Bell + 50 ohms	15	0·35	22·5

A resistance of about 13 ohms is given by one mile of galvanised-iron signalling wire of No. 8 gauge.

The effect of methane-content on ease of ignition.

The series of experiments just described were made, as already stated, with an 8·2 per cent. methane-air mixture, which is one of the mixtures most readily ignited. Mixtures containing smaller percentages of methane are less easily ignited, as the following experiments show.

" SENGHENYDD " BELL IN CIRCUIT.

Percentage of methane in air.	Number of cells required for ignition by break-flash.	Current on closed circuit, ampères.	Voltage on open circuit.
5·6 (" lower-limit.")	8	1·15	12·0
6·3	7	1·05	10·5
7·0	5	·70	7·5
8·0	3	·45	4·5
9·0	3	·45	4·5
9·5	3	·45	4·5
10·2	5	·70	7·5

The effect of methane-content on the ease of ignition is better shown when either the voltage or the ampèrage of the current is kept constant. In the table below are given the voltages required to cause the ignition of different methane-air mixtures by the break-flash when the current passing through the bell was kept constant at 0·60 ampères by the insertion of sufficient (non-inductive) resistance:—

" SENGHENYDD " BELL IN CIRCUIT. CURRENT MAINTAINED AT 0·60 AMPÈRES.

Percentage of methane in air.	Additional resistance inserted to maintain current at 0·60 amps.	Voltage required to cause ignition by break-flash.
5·8	70 ohms	70·5
6·0	31 „	25·5
6·4	13 „	15·0
6·6	9 „	12·0
7·3	2 „	7·5
8·0	nil	4·5
8·2	nil	4·5
8·5	nil	4·5
9·0	nil	4·5
9·4	nil	4·5
10·0	2 ohms	7·5
10·6	9 „	12·0
12·1	63 „	63·0

These results are shown graphically in Fig 1. No ignition up to the highest voltage available (80 volts) could be obtained of either the lower- or the higher-limit mixture of methane and air.

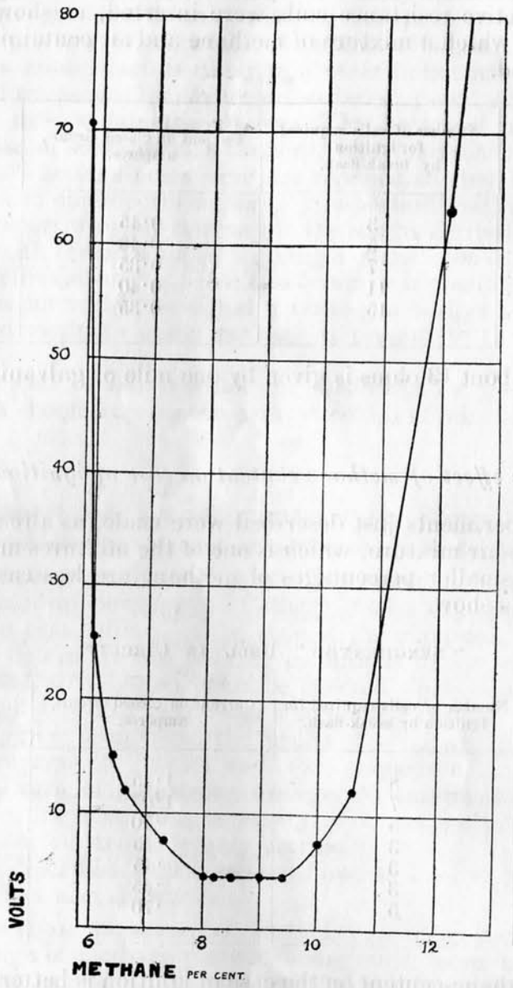

FIG. 1.—THE IGNITION OF METHANE-AIR MIXTURES BY BREAK FLASHES.
"SENGHENYDD" BELL IN CIRCUIT, CURRENT 0·60 AMPERES.

The effect of inductance on the ease of ignition.

As Professor Thornton has pointed out (*loc. cit.*, p. 152) "with low-voltage "apparatus the inductance of the circuit is of the first importance from the point of "view of safety at break."

This is illustrated by comparative tests made with the "Senghenydd" bell and that lent by Professor Thornton (bell "A"), the inductances of which, according to determinations kindly made by Professor Thornton, were:—

"Senghenydd" bell: Mean inductance at all currents 0·344 henry.
Bell "A": " " " 0·135 "

Whereas with the "Senghenydd" bell in circuit a battery of three dry cells was required to cause the ignition of an 8 per cent. methane-air mixture by the break-flash, with bell "A" five cells were required, the currents being 0·45 ampères at 4·5 volts and 0·7 ampères at 7·5 volts respectively. Both bells had the same resistance, namely, 10 ohms.

The influence of ampèrage.

The influence of ampèrage can be appreciated from an examination of the series of experiments with an 8·2 per cent. methane-air mixture, using the "Senghenydd" bell, in which resistances of different values were included in the circuit. It would appear that if the current flowing round the signalling circuit could be reduced below 0·30 ampères by introducing suitable non-inductive resistances, there would be but little risk of ignition by break-flashes below 25 volts pressure. The use of Leclanché cells, therefore, owing to their high internal resistance, should afford greater comparative safety than the use of dry batteries. Comparative experiments illustrative of this were made using an 8·2 per cent. methane-air mixture and the "Senghenydd" bell, the results being as follows:—

	Number of cells required for ignition by break-flash.	Current on closed circuit.	Voltage.
Dry cells	3	0·45	4·5
Leclanché cells	6	0·50	9·0
Whilst with bell "A" the results were:			
Dry cells	5	0·70	7·5
Leclanché cells	9	0·60	13·5

Test of a device intended to prevent sparking.

The opportunity arose of testing a device of Professor Thornton's intended to prevent sparking at the signal wires and at the bell. The bell used was bell "A" already referred to, and the circuit was modified by the addition of two circuits termed respectively "Simplex" and "Duplex," which could be connected to the bell separately or together.

The tests with bell "A" alone have already been given; the effect of adding the special circuits was as follows:—

IGNITION OF AN 8·0 PER CENT. METHANE-AIR MIXTURE.

	Number of cells required for ignition by break-flash.	Current on closed circuit, ampères.	Voltage.
Bell + "simplex" circuits ...	15	2·225	22·5
Bell + "simplex" and "duplex" circuits.	15	2·275	22·5

The above results were obtained when a battery of dry cells was used. When Leclanché cells were employed no ignition of an 8·5 per cent. methane-air mixture could be effected with the maximum number of cells available, namely 24 (current on closed circuit 1·0 ampère, voltage 34·5).

The addition of either the "simplex" or the "duplex" circuit practically eliminated sparking at the bell.

Manner of carrying out the tests.

The preliminary experiments were made with an explosion-chamber of about one cubic foot capacity in which either the bell or the signalling contacts could be placed. The last-named consisted of two steel rods of $\frac{1}{4}$-inch diameter, one fixed firmly in position across the box and the other running parallel with it for a few inches and then turned at right angles. This bent rod could be moved round or backwards and forwards by hand, so that a rubbing contact or a rapid make and break of circuit could be made.

For the later comparative experiments a mechanical device for making and breaking circuit in an explosive mixture was employed, as being more convenient and giving greater uniformity of results. The results obtained by the two methods of experiment were the same, but whereas with the hand-breaks some thirty or forty contacts had to be made at the limiting voltages before ignition occurred—the nature

of the break-flash depending greatly on the rapidity with which contact was made and broken, and on whether the break at the signal wires synchronised with the break at the bell—with the mechanical break ignition was obtained at the limiting voltages at the first (or sometimes at the second) break.

The apparatus is shown in the photographs in Figs. 2 and 3. It consisted of a gas-tight wooden box of about half a cubic foot capacity, fitted with a glass window and having one end removed. This end was covered by a sheet of oiled paper and a measured volume of methane was passed in from a gas-holder, displacing air. The mixture was then made by rapidly revolving a small motor-driven fan for a given time, and a sample drawn out over mercury into the glass vessel shown on the right of the photograph, whence it was transferred to an apparatus for explosion-analysis. The methane used was prepared from aluminium carbide and purified by passing through ammoniacal cuprous chloride (to remove traces of acetylene) and over "oxidised" palladium precipitate heated at 212° F. (to remove traces of hydrogen). Analysis showed it to contain 98 per cent. of methane and 2 per cent. of nitrogen.

The mechanical contacts and breaks were made by slowly revolving (by means of a motor and gearing) a turn-table carrying four metal rods each of which just touched the end of a strip of metal fixed at right angles to them. For the majority of the experiments the contacts were steel and steel, but a comparative series was also made with zinc-zinc contacts without any difference being obtained in the results.

I wish to ackowledge the assistance afforded me in carrying out these experiments by Mr. C. B. Platt.

MEMORANDUM BY MR. ROBERT SMILLIE, ASSESSOR.

With the main body of the above report I am in general agreement, but on one or two of the points dealt with, I feel it necessary to offer some observations. The points with which I wish to deal cannot be said to have any bearing on the origin of the explosion, but are, in my opinion, of importance as contributing a higher death roll than might otherwise have been recorded.

Communication Doors.

It will be noticed from the report that the communication doors in the two cross-cuts leading from the Lancaster main in-take to the return at York pit were formed of wood, and that as the result of the explosion the whole of those doors were blown out and ultimately caught fire. The blowing out of those doors caused the short circuiting of the air current, and it will also be found from the evidence that it took some considerable time to put out the fire caused by those doors, and to re-erect a stopping in the east side cross-cut. I am of opinion that communication doors situated as those were, should be strongly built in order that they may be in a position to resist considerable pressure, and also that they should be formed of uninflammable material. The time lost by Mr. Shaw, the manager, and those who accompanied him in the first descent into the pit after the explosion in overcoming the fire at those doors was at the most critical period of the explosion, and had they not been forced to deal with the fire at the doors, they might at once have turned their attention to the most serious fire at the end of the arch way in the Lancaster level. It may be said that had those doors not given way, and thus given vent to the explosion, the fire might have gone into the east side of the mine with more serious results. I do not think that this is so, as the blast found full vent up the Lancaster shaft. In any case I feel that no objection can be taken to the suggestion that communication doors ought to be composed of uninflammable material.

Reversal of the Air Current.

In paragraphs 83 and 119 of the report, the question of the reversal of the air current is dealt with, and on this point I differ most strongly from my two colleagues.

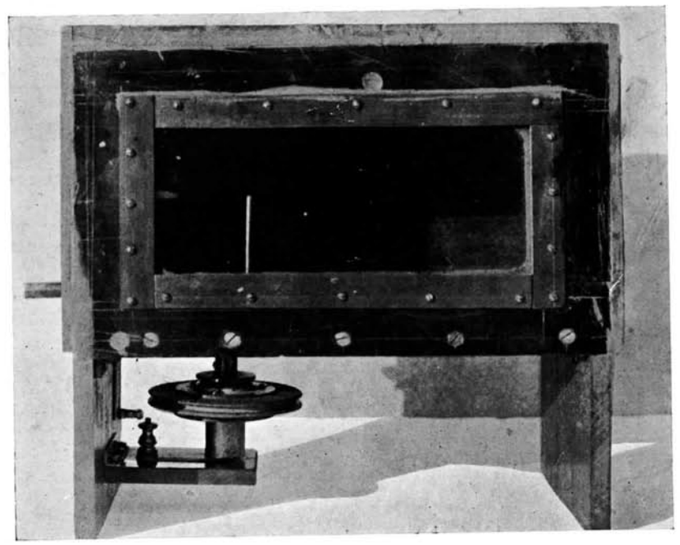

FIG. 2.—SIDE VIEW OF EXPLOSION CHAMBER.

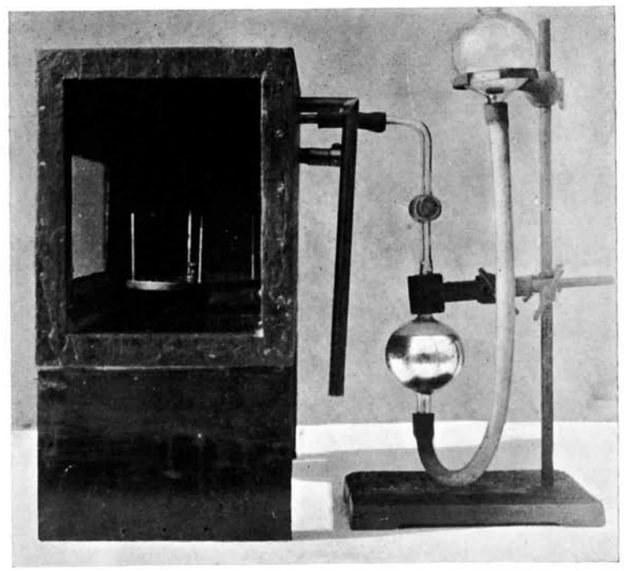

FIG. 3.—END VIEW OF EXPLOSION CHAMBER.

The fact that it was found impossible to reverse the air current would be bad enough standing by itself, but it becomes much worse were it found that the inability to reverse the air current has led to greater loss of life than otherwise would have been the case. As stated in the report, the date upon which this requirement became operative was 1st January, 1913, but up to April nothing seems to have been done, and one is surprised that up to that time no action had evidently been taken by the Inspector of Mines for the Division to have this provision of the Act carried out. It is evident that it was only in April that any application was made by the owners for an extension of time to enable them to make structural alterations with the view to putting themselves in a position to reverse the air current. The extension secured by them ultimately ran out on September 30th, 14 days before the explosion, and I think it is correct to say that at the close of the Inquiry, provision had not even then been made to reverse the air current. It is true that the reversing of the air current of a mine when a great calamity takes place, such as a serious fire or an explosion, is a very serious responsibility on the management of the mine, but in this case, it was discovered almost immediately after the explosion that a large fire existed in the intake air-way, less than 150 yards from the bottom of the downcast shaft. Surely this was a case in which immediate reversing of the air current ought to have taken place, because the manager and those acting with him must have known that all the fumes coming from a very serious fire of the nature described by him were being carried into the workings of the mine. As the Lancaster level was strongly protected by stone arching for a distance of 124 yards from the bottom of the downcast pit, and as the fire was burning within a short distance of the end of this arch, it would spread further in the level so long as the air played on it, but it could not have spread to the bottom through the arch had the air been reversed. From the nature of the fire it was clearly seen that it would be quite impossible to get inside of it into the workings beyond as the fumes would be of a poisonous nature, but the result of the reversing of the air current would have been to bring all the fumes from the fire up the Lancaster shaft, which would then be the upcast, and would at once have sent pure air from the York pit, which would be the downcast, and would have enabled rescuers, even without appliances, to have gone right into the workings on the York pit side. I think it would be admitted by everyone who took part in the Inquiry that the reversing of the air current would have meant the saving of the lives of all of the men in the West York district. Most of those men had found their way to within a short distance of the York pit when they were overcome by the fumes. The three doors at the stables at the bottom of No. 1 north were blown out, and the probability is that the air was going down the Lancaster level from Lancaster pit, short circuiting down No. 1 north, round the stables over the air-crossing, and back up to York pit (upcast). The reversing of the air current would have changed this, and would have led the pure air from York pit right down into West York, and also down into Pretoria district, and also, I believe, right down the return from Bottanic and into Bottanic district, and that within a short time there would have been a circuit of pure air in all of those districts. All the doors in the Mafeking storage were blown out, and with the reversal of the air current all the foul air generated by the explosion would have been brought up through Mafeking storage and up Lancaster Level to Lancaster Pit. There was little, if any, force shown in West York district, in Pretoria district, or in Bottanic district, and the probability is that in those districts there was very little, if any, after-damp. Few of the men were killed by force, and I believe that all of them died from suffocation caused, not by after-damp, but by the smoke from the fire which raged at the top of No. 1 North. To me, it is an amazing thing that for hours and hours those in charge allowed the smoke to continue going down from the fire in Lancaster Level when they must have known that it was finding its way into all of the districts. When an attempt was made to get into West York, the rescue men, who were protected by suitable life-saving apparatus, found that it was impossible to penetrate the smoke as it was so dense that they could not see. This smoke was really the fumes going from the fire at the end of No. 1 North, finding its way round the stables over the crossing, and vast volumes of it coming right back to York Pit. This made it impossible that any person could penetrate that part of the mine, and so every one was helpless. I understand that a discussion took place more than once on the afternoon of the day of the explosion regarding the advisability or otherwise of reversing the air current. I feel that this step was not taken, not because it would not have been wise to have taken it, but because it was found impossible, as provision for reversing the air current had not been made.

William Thornton's evidence.

In paragraph 46 of the report reference is made to evidence of a startling nature which had been given by a miner named Thornton. This witness gave his evidence in a perfectly clear, straightforward manner. He could not be shaken by cross-examination, and I am of opinion that he told the truth, and that the state of this part of the mine had been very bad for several weeks before the explosion.

Duties of Fan-men.

Though it may have no bearing on the cause of the explosion, I would like to call attention to the fact that there were two fan-men at this colliery whose duty was to oil and generally look after the fan-engine. They were supposed to read the water-gauge every ten or fifteen minutes. The hours of these men were 84 per week, the man on the night-shift being on duty 14 hours, and the man on the day-shift 10 hours. Once every fortnight each man required to attend to his duty for a period of 24 hours when changing shifts. I think that it is too much to expect a person to be alert during all the time on a long shift like this, and to examine in an intelligent way every fifteen minutes the water-gauge, or even to pay adequate attention to the fan itself.

Firemen's Districts.

On page 12, paragraph 33, the question of the size of firemen's districts is dealt with. The Inquiry revealed the fact that the districts of some of the firemen at this colliery were extraordinary large, in one case the fireman having 44 stalls to examine. This man had 125 men under his charge. I must express the opinion that the whole of the firemen's districts in the section covered by the explosion were far too large, and that they would still be too large even if the lamp-cabins were removed nearer to the district.

ROBT. SMILLIE.

REPORT BY MR. EVAN WILLIAMS, ASSESSOR.

SIR,

I REGRET I am unable to subscribe to Mr. Redmayne's report owing to my differing from him in greater or less degree upon several material points, and I therefore beg respectfully to submit to you separately my observations and conclusions upon those questions on which I am not in agreement with either or both of my colleagues. In regard to those matters which I do not deal with nor specifically refer to, I beg to say that I am in substantial accord with Mr. Redmayne's views of them, as set forth in his report.

The Senghenydd Colliery is typical of the average steam coal colliery in South Wales. The seams of coal and the strata lying immediately over and sometimes under the seams are more or less charged with gas which exudes, generally imperceptibly, at the face as the coal is worked, and issues, sometimes with force, more often gently, but still perceptibly, from fissures in the roof and floor when they have been exposed by the removal of the coal. These issues of gas are locally called "blowers" and their occurrence is not infrequent in the steam coal collieries of the district. The presence of gas is, therefore, inevitable in the ventilating current after passing through the working faces, as no human effort can possibly prevent the giving off of the gas from the coal and other strata, and the return air must therefore be normally charged with a percentage of firedamp dependent upon the extent of the emission of gas and the quantity of air circulating, and the aim of

good management is to keep this percentage as low as is compatible with the avoidance of other dangers that may arise from the forcing of air at too great a velocity through the workings of the mine. The steam coal collieries of South Wales are also liable to sudden outbursts of gas in very large quantities accompanied by falls of roof. In these cases, more often than not, the gas under pressure, generally coming from an unworked seam of coal lying some distance above, is a contributory cause of the fall which releases it, in volume so great sometimes as completely to block the passage of strong currents of fresh air. Such a fall as this occurred in October, 1910, at Senghenydd, and is a contingency against which no provision can be made.

One of the determining factors in the arrangement of the ventilating districts of a mine is the length of working face that the available quantity of air in the split can pass through without becoming so charged with gas as to cease to be harmless. Judged by this standard, I do not consider that the arrangement of the ventilation in the workings of the west side at this colliery is open to censure or adverse criticism. There may be more efficient ways of dividing and circulating the air currents through these workings, but the length of face and the number of working places traversed by any of the splits are by no means great, nor have we any evidence at all that the condition of the general body of the return air in the Mafeking return any more than in the other districts was otherwise than normal and safe.

As to the statements of the witness Thornton, I entirely concur with Mr. Redmayne's remarks. For instance, his version of the state of his own working place on August 18th is directly contradicted by the report of the workmen's inspection, which agrees exactly with the firemen's report on that date.

That there was an accumulation of gas in Wm. Williams' place prior to the explosion is agreed by all, and that it was not dissipated by turning the current of air into it by hanging a sheet across Wm. Davies' road is, I think, clearly proved, so that the return air from that district into the Mafeking hard heading had not even temporarily been made more charged with gas than usual, and I concur in Mr. Redmayne's view that the condition of the workings in this part of the district can have no bearing upon the origin of the explosion nor even upon its propagation, seeing that from the top of the hard heading into this district the evidences of explosive force or fire were very slight.

As to the actual quantity of air passing through the working faces, there is no information as no measurements had taken place. Amid the bewildering number of new obligations laid upon managers by the Act and General Regulations, this had no doubt been overlooked though no actual breach of the law took place.

The method of timbering known as open cogging was much discussed at the Inquiry, but the weight of evidence, strongly backed by Mr. Dyer Lewis, the Inspector of Mines with the longest experience of South Wales, was emphatically in its favour as being the best and safest for cavities in the roof.

With regard to the management I consider that the colliery was well and efficiently staffed and neither in the number of officials nor in the provision of labour, materials, or any arrangements necessary for the safe working of the mine was there evidence of any expense having been spared, but quite the contrary, and we have it from the evidence of the Inspector of Mines that he found on his visits that the general state of the colliery was excellent.

There was considerable controversy as to the size of the districts allotted to the firemen and to the time occupied in the examinations before the commencement of shift under Section 64 (1) of the Act and General Regulation 50. The station provided under Section 63 of the Act in the west side was at the lamp station, and the travelling roads inbye from this point were included in the "districts" of the firemen and had to be examined before the men passed beyond the station. The time of descent of the day firemen was 3.30 a.m. There is no suggestion that they ever descended before this hour. The station would be reached by 3.40, and the examination begun. The district which necessitated the longest walk is the

Mafeking West, the total distance to be travelled, including up and down each stall road and along the face, being 5,300 yards, and that has the largest number of working places, viz., 46. The actual walking of the distance can easily be done in an hour, so that an hour, at least, would be left for stopping to examine the working parts of the district, and, I am of opinion, confirmed by the evidence of the firemen themselves and the mining engineers called by the Company, and not disputed by the Inspectors of Mines, that an efficient examination could be made in the time, and all the more so in the other districts, with less distance and fewer working places.

Provided the first man was passed into the district by the fireman at 5.40 a.m., and we have no evidence that the men who descended in a regular stream from 5.30 on were kept waiting at the station, it is, I think, evident that no breach of the Act was committed in this respect. For the night shift, the same applies as between 6.40 and 8.40 p.m.

It is true that there was considerable lack of accuracy in the filling in by many of the firemen of the time occupied in their inspections, and in the case of two of them of the time allowed by the Act, and their attention should have been drawn to it by some of the superior officials, but from the nature of the arrangements at the Colliery, it is clear that the examinations must have been made between the hours before mentioned, and I think that work can be said to have commenced in a district when the first man has been admitted into it by the fireman.

With regard to the position of the station it is a question of balance of advantages. It was claimed by Mr. Shaw that by his method the overman and any other superior officials were able to meet and confer with all the firemen of this side of the pit together, and to learn at once its condition, and were thus able to decide what part or parts required their most urgent attention and to give prompt instructions to all.

On the other hand, stations inbye would have the advantage of enabling the inspection of the faces to be made within a shorter interval of the time at which the men actually entered them. No hard and fast rule can be laid down, and it is a question that must be left to the discretion of the individual manager to arrange within the limits laid down by the Act. In this particular instance, it is not suggested that this matter had any bearing upon the explosion.

The method practised at this Colliery of examining cavities in the roof for gas by raising a lamp on the end of a stick has been impugned, and, in my opinion, unjustly. As long as the flame of the lamp is in sight, at distances of 7 feet or 8 feet, it is possible, without difficulty, to detect the presence of gas well below the explosive point upon the ordinary flame of a safety lamp.

At the New Tredegar Rescue Station on January 29th last, Mr. Smillie and I saw a lamp with flame ½-inch high raised into a chamber containing a mixture of 3 per cent. of gas, and at distances exceeding 8 feet away the flame was easily seen to lengthen to over an inch high.

It is very necessary that a fireman should have some indication of the condition of a cavity in the roof before he climbs into it to examine it closely, and there is no method so convenient or safe as that under consideration. There is absolutely no evidence of its being otherwise or that it has ever had undesirable consequences.

With regard to the manner of reporting the presence of gas, I agree that the entries on the report books should be more specific as to the exact condition of the place reported upon. It would be well, when gas is found, if more detailed information were given of its character—if a blower, whether diluted as made or at what distance away; if detectable in the body of the air, the percentage present; if an accumulation, whether explosive or not, and also the extent of it.

But Section 64 (3) of the Act does not require this detailed information to be entered, as it does not specify that the report shall be " full and accurate " as regards gas in respect of anything more than " whether or not, and where, if any, noxious or inflammable gas was found," while as regards roof and sides, a description of the defects found must be given as well.

On the question of the record of the number of men required by General Regulation 50 the words " Statutory Report Book " do not occur in the regulation, and no place has been provided in the prescribed form of firemen's report book for the purpose.

In these circumstances no more blame can be attached to the management for having these figures entered in another book, than to the Home Office for not providing a place for the entry in the firemen's report book.

With regard to the recording of the readings of the barometer, there is one

Statutory Report Book, No. 53, for each mine, in which the daily records of barometer and hygrometer are to be entered, and it can never have been contemplated that all the firemen were to record their readings one after the other at the beginning and end of each shift in this book.

I do not agree that a breach of Regulation 60 had been committed by the fireman of West Ladysmith, in that he had not travelled the return air-way, which was the second means of egress from his district. This Regulation came into force on September 15th, and the requirement is as to once in every quarter, and not a month had elapsed at the time of the explosion.

Of the matters brought under our consideration at the Inquiry, that of dealing with coal dust on the sides and roof of roadways constitutes the most difficult problem. Owing to the natural peculiarities of South Wales coal in deep, dry mines, it is to be feared that no practicable method can be applied to the transport of coal from the faces to the pit that will prevent the production of fine dust in sufficient quantity to propagate an explosion, and up to the present no system has been proved to be efficacious in heavily timbered roads of large area, such as those at Senghenydd, for preventing such accumulation on roof and sides of very fine dust as would carry on a violent explosion, or of removing such accumulation to an extent that would render the remainder harmless.

The only known methods of dealing with dust of this kind in almost impalpable powder were spraying with water, brushing, and blowing by compressed air. Mr. Shaw stated that all three had been tried at Senghenydd. The first necessitated water in such quantity as to have a very deleterious effect upon the roof and sides, and had to be abandoned, otherwise the roads could not be kept open. This was confirmed by all the mining engineers who gave evidence, as being the result in the warm and dry steam coal collieries generally. Brushing is only possible to some extent on the sides of the road, the laggings above the timbers cannot be reached for this purpose, and both brushing and blowing by compressed air were found at Senghenydd to have the result only of transferring the dust in a cloud from one place to be deposited in another without improving the condition of the roads at all.

Since the explosion, Mr. Benj. Nicholas has experimented at Tirpentwys Colliery with the interposition of water screens with promising results, and I endorse Mr. Redmayne's remarks thereon. But in the absence of knowledge of some means of this kind for the interception and collection of the dust, it cannot be said that there was any system that could be adopted that had any practicability at all in preventing coal dust accumulating, and no suggestion to the contrary was made at the Inquiry by any engineer or Inspector of Mines. The limit of practicability was the prevention of coal dust accumulating on the floor, and as this was systematically cleared, I consider that Section 62 (3) was complied with as fully as possible.

These being the conditions in South Wales, the solution of the problem seems to me to lie in spraying the journeys of loaded trams with water at the farthest possible point inbye, and at such intervals as may be necessary to keep the exposed coal damp until it reaches the surface, in clearing as much of the accumulated dust as is practicable, and in adopting means to render the remainder innocuous.

I concur with Mr. Redmayne in the view that the efficacy of stone dust has been supported by the phenomena of this explosion.

The evidence as to the electric signalling in this pit was very instructive though not quite conclusive. Whenever a signal was given, either by pressing the wires together or by drawing a file or other piece of metal across them, sparks easily visible must have been produced, both at the signalling point and at the bell. The question is whether such sparks, as produced at Senghenydd Collieries were capable of igniting an explosive mixture of gas and air. It was made abundantly clear that sparks may be not only visible, but bright and luminous, and still be incapable of firing gas, and that the appearance of a spark was no criterion as to its power in this respect. Nor is the voltage of the battery used as the source of the current in itself a criterion, and it is wrong to say loosely, as is frequently done, that a certain voltage, say, 13½, will fire gas, while another voltage, say 9, will not. This voltage is only one factor, and not the most important one.

The internal resistance of the cells themselves, of the wires, and of the bell, and particularly the inductance of the bell have to be taken into account before the actual voltage that causes the spark can be determined. What is called the voltage of the battery is only the static difference of potential on open circuit, the actual electromotive force when a signal is given is the voltage on closed circuit with the line and bell in series, and may and this does differ very largely between one installation and another even though the voltage of the respective batteries on open circuit may be the same. In one case, it may be very near the voltage on open circuit, and in another it may be as low as one-fourth of it. The self-induction also, which causes by far the most dangerous spark when the contact between the wires is broken, depends upon the construction of the bell that is used.

So that nine volts under one set of conditions of batteries, line and bell, may be more dangerous than 12 volts under another set of conditions, and it cannot be too strongly emphasised, that all the characteristics of the signalling installations must be taken into consideration, and the prevailing impression, that the voltage of the battery is the only thing that matters, corrected.

In face of the knowledge gained in our investigations on this subject, it appears to me most desirable that the Government should at once carry out an exhaustive series of experiments with a view to determining what may and may not be permitted to be used in mines liable to outbursts of gas.

This system of electric signalling with bare wires possesses, in its simplicity, ease and quickness of manipulation and its reliability, so many practical advantages over all others that its prohibition, would, I am convinced, lead to a big increase of accidents upon haulage roads, and the objection to visible sparks incapable of igniting gas is sentimental only.

Dr. Thornton, of Newcastle, showed us a very simple arrangement of byepass, consisting of a short length of thin wire connected across the terminals of the bell, which rendered a signalling installation quite incapable of igniting with a 12-volt battery a mixture of town gas and air, which, without the byepass, was ignited by a 4-volt battery with the same bell and wires. (Town gas, owing to its high hydrogen content, can be exploded by a spark that will not fire pit gas.)

Dr. Thornton, who has made more investigations on this subject than any other man in this country, is firmly of opinion that this simple device will remove all risk from the ordinary signalling installations in mines, and I think this should be brought to the notice of all colliery managers by the Home Office.

Dr. Thornton and Mr. Sparks also agreed that the use of alternating current, within the limit of voltage laid down by the Regulation, viz., 25 volts, in place of direct current, would confer complete immunity from danger upon bare-wire signalling. With this there is no sparking at the bell, and the sparking on the line is very weak.

Turning to the consideration of the apparatus in use at Senghenydd, in trying to arrive at a conclusion as to whether there was a possibility of the ignition of gas from this cause, one can only be guided by the experiments made with the actual bells in use at the colliery, and not by anything done with other bells in other places, or with any gas other than natural pit gas.

It will be observed from the results of these experiments at the New Tredegar Rescue Station, given in an appendix to this report, that with a Senghenydd bell no ignition of gas was obtained in an explosve mixture of pit gas and air until a battery of nine cells, giving 13½ volts on open circuit, was used. With six cells giving nine volts every one present at the station must have been convinced that every possible expedient for producing sparks was tried by Mr. Nelson without result, and that with this combination of bell, line and battery, no spark could be produced that would cause an ignition.

It will be observed also that in these experiments new cells were used and that consequently the voltage on closed circuit was within a decimal point of the open voltage, so that it may be taken that under these conditions an actual E.M.F. of 8·9 volts was not sufficient to fire the explosive mixture.

It is true that the pit gas used was from another colliery, but Dr. Thornton's evidence was quite definite and conclusive that gas taken from Senghenydd or any other pit in South Wales would have behaved in exactly the same way.

Some doubt has been cast upon what was the actual voltage of the batteries in use at Senghenydd, and from Mr. Sparks' evidence it is clear that after a period of rest the pressure on open circuit of some of the batteries composed of eight and nine

cells each may have been over 10 and 11 volts respectively, owing to the recovery of the partly exhausted cells during a week end or, to a less degree, a night. This pressure would fall very rapidly as soon as the bells began to be rung, to what extent is not exactly known, as we have not the information as to the behaviour of old cells that we have for new cells, in the curve reproduced in Fig. 9, but we have it from the electrical experts that it would fall much more rapidly in old than in new cells.

I see no reason, therefore, to discredit the statements of the colliery electricians that when measured by them during working hours, the voltage never exceeded 9 on open circuit, although I think the method of measuring the voltage might have been improved upon by using a voltmeter from which the total voltage of the battery as well as that of the individual cells could be read without calculation. It was, however, clearly shown the voltage on closed circuit in the case of old cells was less than half that on open circuit, so that the comparison to be made between the experiments at New Tredegar and the actual working condition at Senghenydd is as between working pressures of 8·9 volts on the one hand, and something actually below 6 volts on the other, and not between static pressures on open circuit of 9 volts, and a possible 11·45 volts for a short time after a period of rest. To my mind the evidence is quite conclusive that the characteristics of the installation were such that no spark capable of igniting gas could have been produced.

There is another point which seems to me to bear upon this question as far as the signalling apparatus in the Mafeking hard heading is concerned. From my own observations underground, as well as from the evidence, I am satisfied that the positions of the journeys at the top and bottom of the incline were such that no signalling could have been going on when the explosion occurred.

Any sparking that may have taken place could, therefore, be produced only by the accidental contact of the two bare signalling wires.

When two wires are pressed together in any way the surfaces that touch have an area many times larger than the points of contact of a knife edge across them would have, and it is a well-established fact that the current necessary to ignite gas increases in direct proportion to the area of the surfaces in contact. The further comparison must, therefore, be made as between the small area of contact of the knife edges at the Rescue Station experiments, and the larger area of the surfaces in contact of the two wires in the mine, and this strengthens my conviction that the possibility of an electrical cause of the origin of this explosion can be entirely dismissed.

I now come to the consideration of the theories as to the place of origin of the explosion.

When I made my inspection of the colliery, I went through all the roads traversed by the explosion that were not blocked by gas, and made my own observations of the effects of the explosion, so that, like my colleagues, I am not dependent entirely upon the evidence given at the Inquiry for material upon which to base my conclusions. The only two places suggested as possible seats of origin of the explosion are the Mafeking hard heading, and that portion of the Main Lancaster Level between the No. 1 North and the lamp station. Wherever it took place, there must have been an outburst of gas which came into contact with a flame, large, like that of a lamp, or small, such as a spark, but containing sufficient heat energy to ignite it, bringing about a gas explosion which caused the fine dust on the roof and sides to be thrown into suspension in the air, by the firing of which a violent explosion was carried along with enormous force in the directions of propagation, followed by a rebound or backlash of less violence than the forward impulse.

The direction of the original blast, therefore, between the two suggested points of ignition determines the seat of origin, and thus the Mafeking Storage becomes a critical region in this determination. Here the mining engineers called by the Company, and the miners' representatives who gave evidence agree that the great preponderance of indications is in an inward direction, while Dr. Atkinson and Mr. Dyer Lewis agree that there are indications of force in both directions, but incline to the opinion that the first blast was outwards, because the sprayer just outside the storage and a pipe at the engine on the main level had been blown outbye.

This storage parting was closed by two doors, and no explosive blast could have passed through the parting without first breaking through the doors. It would appear, therefore, that the direction in which these doors were blown would indicate

very strongly the direction of the original force. Both these doors are admitted by all witnesses to have been blown inbye, one a distance of 11 yards, and the other 15 yards, and a heavy beam 12 inches square weighing 500 lbs. walled into the brick-work above one of them was carried inbye a distance of 16 yards. The heavy iron hinges of both doors were also bent back, and blown inwards. I find it difficult to conceive that the full violence of an explosion could have passed through these doors without appreciably damaging them, and that the backlash from it could afterwards have developed sufficient force to have caused such destruction in the reverse direction, and it is far more likely that the effects of the backlash are shown by the lighter articles mentioned by Dr. Atkinson and by the coal blown off the trams at the inbye end of the journeys that were standing on the parting. The position of the water-tank, the empty trams at the outbye end, and the stone driven into the outbye sides of the timbers and other indications seemed to me to be more consistent with an inward propagation. The positions of the bodies were mainly heads outbye, but where the violence of the blast is such as to blow the clothes off a body and the skin off a hand like a glove, as happened here, it is impossible to say how many times a body may have tumbled over before coming to rest.

Along the Main Lancaster Level from the inner bashing to the first engine the indications are slight, but such as they are they appear to be inbye. Up to this point the Level is a fine wide high road, but just beyond the engine it suddenly becomes restricted from a sectional area of nearly 180 square feet to one of about 45 square feet, and it is at this point that there are evidences of outbye force. It is a place at which contradictory evidences might at any rate be expected.

Along the other main roads branching off the Lancaster Level just inbye of the inner bashing, viz., the No. 2 South, and the Ladysmith roads, the indications are agreed by all to be inbye, as also in the Main West Level into Kimberley beyond the entrance to the storage, and through Baker's heading and back along the intake to Mafeking up to the point where this runs parallel to the Mafeking hard heading where they die out. On that part of the Mafeking Level between the intake just referred to and the turn into the hard heading there are two doors. These two doors were blown in opposite directions towards each other. From the Mafeking storage inbye to the hard heading indications are slight or obscured by falls, but such as they are, they are agreed by the mining engineers and the miners' agents to be mainly inbye. On the Mafeking hard heading itself the falls were also very heavy, and visible signs of direction of force were not many. The trams at the bottom of the heading had certainly been moved by an inward force, the outer trams, although upon an incline, being close together, having their couplings slack. At the engine, on the right hand side going up, where the road was widened sharply to form the engine house, the indications were outwards, while at the top of the incline it was agreed that all the signs show an inward direction which divides and dies out on the West Mafeking district on one side and towards Pretoria district on the other. The piece of wood with two insulators fastened to it found on the Mafeking incline is supposed to have been blown outwards a distance of 17 yards from its original position, because two holes are to be seen in a post into which the two four-inch nails driven through the piece of wood seem to fit, but, from personal observation, I cannot accept this, as I found the depth of the holes was more than the length of the nails, the edges of the holes showed no signs of having had nails torn violently out and the nails were bent in a vertical direction and not horizontally. So I attach no value to this an an indication of direction.

The two doors above referred to as being blown towards each other on the Mafeking Level between the turn into the hard heading and the intake are significant, as also is the fact that the men in the Mafeking district were able to leave their working places and collect into groups before they were killed. Generally, the great weight of evidence seemed to me to point against the Mafeking hard heading being the point of origin, while I can discover nothing that is inconsistent with the explosion having started in or near to the Main Lancaster Level.

The wonderful escape of the Bottanic haulage road from being traversed by the explosion, with the whole of the return air from the Kimberley, Mafeking, and Pretoria districts passing into the entrance of it, may be accounted for by the many turns in it, and perhaps also by the fact that it runs at an obtuse angle back from the direction in which the explosion travelled. The same may apply to the No. 1 North, which suffered from fire only and not from explosive violence, while the roads into which the explosion travelled with great force, viz., Ladysmith, Pretoria, and Mafeking storage, all branch off at an acute angle forward with its direction.

The consideration also of the probable cause of the explosion dealt with later on, confirms my opinion that the Main Level was the place of origin and not the Mafeking hard heading. In the former we have indisputable proof of the existence of all the elements necessary, while in the latter the theories have to be based purely upon assumption, which there is no evidence to corroborate.

Turning to the cause of the explosion, Mr. Redmayne has dealt in detail with the theories put forward by witnesses, but I regret I am unable to accept his conclusions.

As previously stated, I eliminate the signalling apparatus from the list of possible causes, and the evidence is strong against the probability of sparks or flame from the friction of ropes on timbers, or on sheaves and pulleys having been the means. The only causes that remain are matches, sparks from stones falling against each other or against iron or steel, and the flame of a lamp. Matches can be dismissed as being highly improbable. Sparks from stones are not infrequent, and have been known to cause explosions, and must be entertained as a possible cause in this case, particularly seeing that above the seam there are beds of rock of such a nature as would strike fire, and Mr. Shaw stated that he had often seen such sparks at Senghenydd. The last possible cause is the flame of a lamp, and to me it seems more natural to attribute the explosion to this cause, which we know did exist, than to the other two, of which the most that can be said is that they are merely possible. At the lamp station, 440 yards in from the pit bottom, there was an open lighted lamp. Outbye of this a fall did occur which gave off gas in dangerous quantity for some time after the explosion, which had to be carried away in pipes to the East side crosscut, and though the most obvious is not always the true explanation, it is reasonable to connect these two facts together, and to say that they suggest, at any rate, the most probable cause.

I am inclined to the view that a big fall did take place on the level before the explosion, and that an outburst of gas accompanied it. We had it in evidence that the roadway was being widened by 4 feet to put in side walls on the night before the explosion. This would tend to weaken the roof and bring about a heavy fall particularly where there was gas under great pressure, as there must have been here, the seam above being solid all around this area. The gas liberated in this way would be carried on inbye, but the volume of air passing would be considerably decreased owing to the fall, and the stream of gas along the roof could remain without dilution to a non-explosive point for a considerable distance, until it reached the open light at the lamp cabin, where it would become ignited and flash back as an initial gas explosion along the main road, disturbing the dust, and developing into a coal-dust explosion of great and increasing violence as it passed along the roadways into the workings.

Towards the pit the force could not have been as great, owing to the passage of the explosion over the fall close to its place of origin into a spacious roadway beyond, and through the arching, which was kept watered.

Had the violence been very great it is probable that it would have crossed the pit with much more strength, and passed into the East side workings. Sufficient heat passed through to set fire to woodwork on the pit parting and in the crosscut on that side, but the force was not great. Up the pit, no doubt the violence was increased by the coal dust in the shaft itself. Had the explosion travelled the full distance along the main level from the storage unobstructed by falls, the violence might be expected to have been much greater at the pit bottom, to have shot farther into the East side, and raised the coal dust there into an explosive cloud devastating those workings as well.

I believe that the fall on the main level inside the No. 1 North preceded the explosion, and I do not agree with Mr. Redmayne in the reasons which he gives against this. In the first place, I contend that there would not have been any perceptible rise in the water gauge at the fan. The fall did not completely block the roadway, nor was this the only intake airway, and even had it been, the effect on the fan of such fall would be to lessen the volume of air passing through it, and so reduce the strain upon it. The water gauge would be increased only if the speed of the fan rose in consequence of the smaller volume of air. The fanman had not looked at his water gauge for eight minutes before he heard the " one thunderclap," as he called it. The time required for the fall, the outburst of gas, the carrying of the gas to the lamp station, and the detonation would not be much over a minute. The only points of substance in the fanman's evidence are that immediately after

the explosion there was a greater strain upon the engine, due, of course, to the short circuiting of the air at the pit bottom through the broken separation doors, and that there was only " one thunderclap," both indicating that one explosion only occurred, and that the separation doors were blown in by it instantaneously. On this point, I may say that, without wishing to cast any reflection at all upon Lasbury, I cannot accept what he says—that the doors on the West side were blown in some ten minutes after the explosion when he reached them. I do not think that any man who had had to find his way out in the dark from the West York return in these circumstances, with the fear of death upon him every second, could be in a condition to take accurate note of the state of matters on arriving at the cross cut, through which a huge volume of air was short circuiting. This is confirmed by the fact that a man was blown on to the cage and killed, and trams were blown into the pit at the bottom of the upcast shaft by the explosion, which could only have reached there through the cross cut.

In the second place, the fact of the fire being under the fall, and not having spread inbye, is capable of explanation better on the assumption that the fall took place before the explosion than after. An explosion of this magnitude uses up the oxygen of the air and carries with it its products to such an extent that in its path there is nothing left which can support combustion, and it is only at the end of its course where a supply of fresh air can be obtained that the intensely heated combustible matter can burst into flame. I think, therefore, that the timbers which first caught fire were those just inside the arching, and that the quantity of air which afterwards passed along in spite of the short-circuiting, was sufficient to carry this fire back along the level with great rapidity and that it was probably the fall which prevented its extension further inbye.

The quantity of timber under and projecting from under the fall would be great enough to allow some air to go through, as was found when the efforts to put out the fire failed, and it was in this way that the fire was communicated from the burning timber outside.

In the third place, the absence of stones blown from the fall is not strange. A fall of this height takes the form of a more or less rounded cone projecting up into the cavity above, and any stones blown from the ridge by the explosion would of necessity strike the overhanging side of the cavity in front and not be carried beyond.

Lastly, it is not probable that a fall some 200 yards away would be heard at the pit bottom, and if heard would so resemble the closing of a door or the rumble of a journey as not to be taken notice of.

With regard to the evidence of T. Jones, I cannot agree that the " heavy bang " which he heard in the seam below following the first roar could have been due to a fall in the West level. I am inclined to think that the " roar or rumble " was due to the sound of the explosion transmitted through the intervening strata, and that the following " bang " came through the air, the sound travelling faster through the ground than through the air.

I do not believe that there was more than one explosion, which gained strength in some parts, and lost it in others, but that the whole oscillation of the explosive force was completed in very few seconds.

With regard to the operations after the explosion, the question of reversal of the air is the first that arises, and on this I agree entirely with Mr. Redmayne's remarks. Even had the means been available for immediate operation, the fire in the cross-cut at the pit bottom would first have to be put out and the separation doors repaired, and we know from the evidence that this took over two hours, and by this time it is probable that the men in the West York district had been killed by the afterdamp from the Mafeking return. The stopping of the fan would probably have had a beneficial effect, and it seems to me that in the great majority of cases of explosions it would be wise to stop the fan at once. I cannot think of any case in which harm would be done by this step. The reversal of the ventilation is quite another matter, and should not be done without full knowledge of the conditions after the explosion.

Much was said at the inquiry as to the water supply at the pit bottom, and the opinion of those who first saw the fire was that no quantity of water could have extinguished it. The larger the supply, however, the better the chance, and I think it would be a very wise precaution in all collieries which do not naturally make a sufficient quantity of water at the pit bottom, to instal a column of pipes in each

pit from a water supply on the surface, interconnected at each landing, so that in the case of damage to one pit, the other would be available.

With regard to the use of breathing apparatus for rescue work in the West York district return, the evidence of Mr. Shaw and the experts in the use of apparatus must, I think, be taken as conclusive that the smoke was too thick for any attempt to be made within such time as there might be any chance of bringing men out alive.

Believing as I do that the explosion was caused by the presence of an open light in the lamp cabin, I think that the new lesson to be learnt from this disaster is that in mines which are dry and dusty and liable to, or working seams which are known to be liable to, outbursts of gas, no open light and no unlocking or opening of safety lamps should be permitted underground, and when the classification of mines provided for in Section 30 of the Coal Mines Act, 1911, is made, there should also be a regulation to this effect applicable to mines of the character of the deeper steam coal collieries in South Wales.

I am of opinion that the explosion was not consequent upon any breach of the Act or Regulations, nor due to any lack of precaution of a kind not required by law, other than that which may be attached to the position of the re-lighting station, and while there were some contraventions of the statute, they were all, with the exception of the failure to complete the means for immediately reversing the ventilation, of the nature of neglect to comply with formalities of no importance in themselves.

I have the honour to be,

Sir,

Your obedient Servant,

EVAN WILLIAMS.