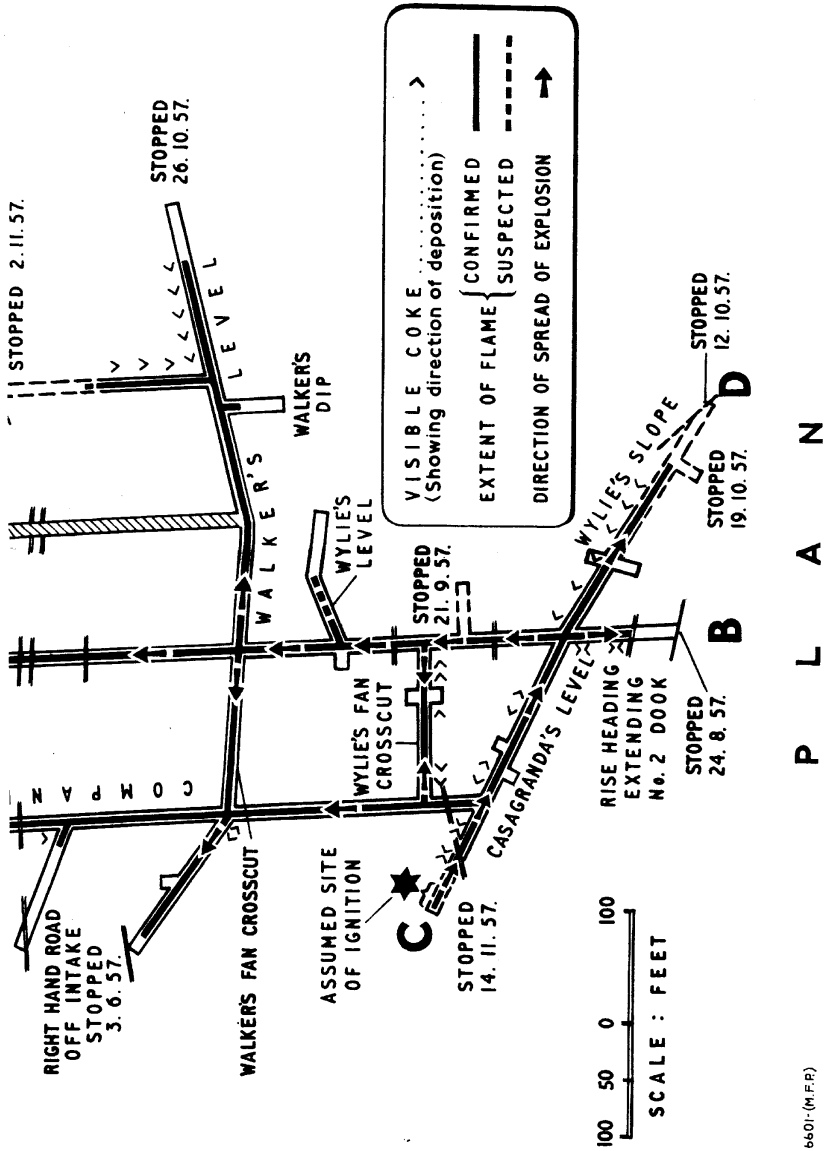

MINISTRY OF POWER

Explosion at Kames Colliery, Ayrshire

REPORT

on the causes of, and circumstances attending, the Explosion which occurred at Kames Colliery, Ayrshire, on 19th November, 1957

BY

SIR HAROLD ROBERTS, C.B.E., M.C., B.Sc.

Presented to Parliament by the Minister of Power by Command of Her Majesty July, 1958

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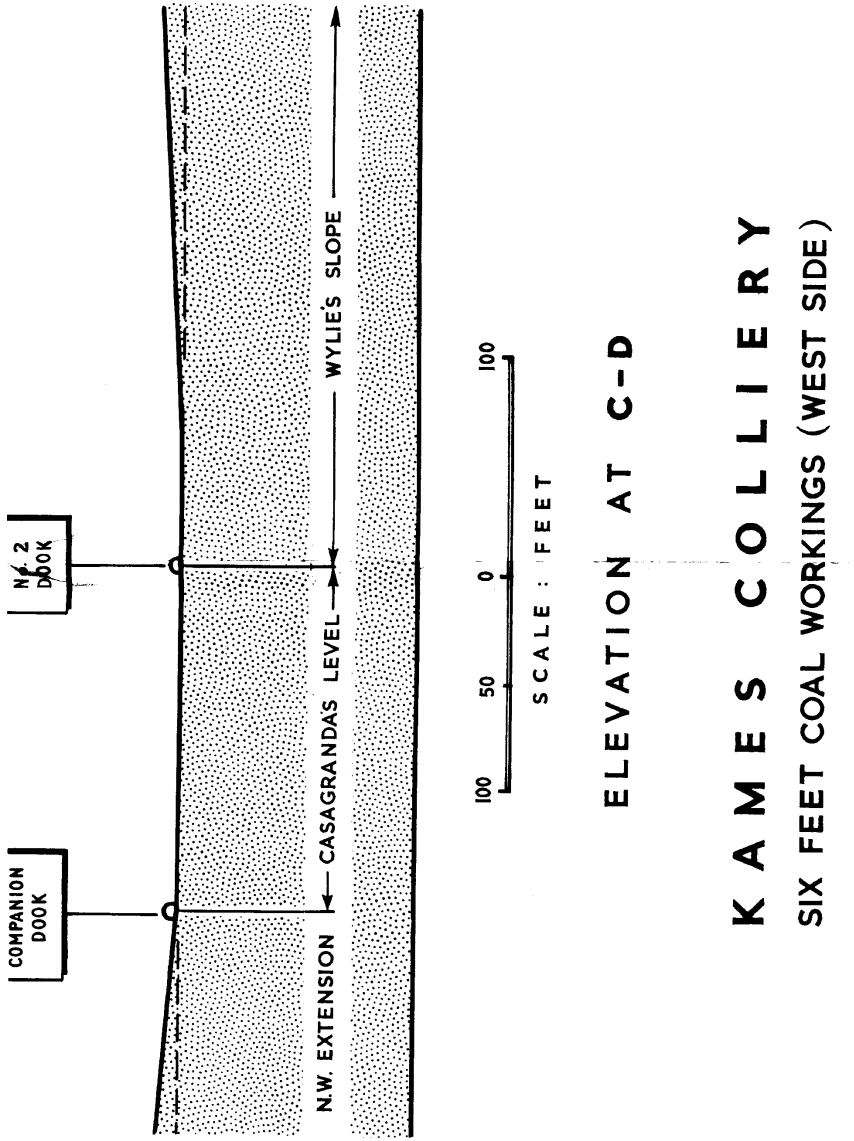

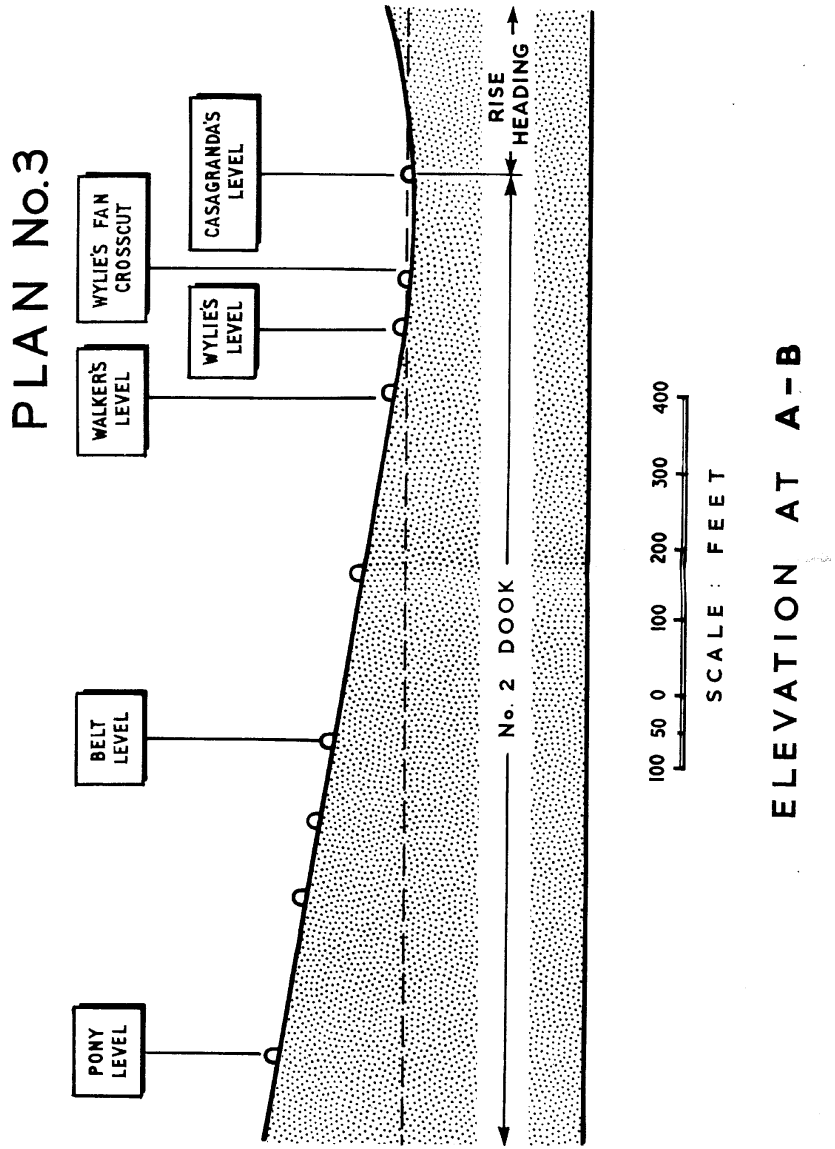

Report on the causes of, and circumstances attending, the Explosion which occurred at Kames Colliery, Ayrshire, on 19th November, 1957

12*th June*, 1958.

The Right Honourable Lord Mills, K.B.E.,
Minister of Power.

MY LORD,

INTRODUCTORY

1. In accordance with your direction under Section 122 of the Mines and Quarries Act, 1954, I held a Public Inquiry into the causes and circumstances of the explosion which occurred at Kames Colliery, Ayrshire, on 19th November, 1957. I now have the honour to submit my report.

2. After full consideration of the evidence given and the submissions made at the Inquiry I have reached the conclusion that a mixture of firedamp and air near the face of an unventilated heading in the Six Feet Section of the West Mine area of the colliery was ignited by a match ; that this caused an explosion sufficiently violent to raise an inflammable cloud of coal dust, and that the explosion continued thereafter as a coal dust explosion. The primary cause of the explosion was failure to ventilate and to make thorough inspections for gas in the heading. Seventeen persons were killed and twelve others injured. A list of the persons killed is given in Appendix I.

3. By kind permission of the Ayr County Council the Inquiry was held in the Council Chamber of the County Buildings, Ayr, from 5th to 11th February, 1958, and submissions were made in the Sheriff Court on the following day. Evidence was taken from 61 witnesses ; a list of them is given in Appendix II.

4. The appearances at the Inquiry were :—

(a) *For Ministry of Power*
Mr. W. Widdas, H.M. Divisional Inspector of Mines and Quarries.
Mr. J. Cowan, H.M. Principal Electrical Inspector of Mines and Quarries.
Mr. H. T. Ramsay, Director, Safety in Mines Research Establishment.

(b) *For National Coal Board*
Mr. G. C. Emslie, Q.C.
Mr. A. J. Mackenzie Stuart.
Dr. H. L. Willett.

(c) *For National Union of Mineworkers*
Mr. Abe Moffat, President, Scottish Area.
Mr. Alex. Moffat, Vice-President, Scottish Area.
Mr. J. Wood, General Secretary, Scottish Area.

(d) *For National Association of Colliery Overmen, Deputies and Shotfirers*

Mr. B. Walsh, Secretary.
Mr. J. Houston, President, Scottish Area.
Mr. W. Derby, Secretary, Scottish Area.

(e) *For National Association of Colliery Managers*

Mr. A. S. Lockhart.
Mr. A. W. K. Stewart, Secretary, Scottish Branch.
Mr. A. Dewar.

(f) *For British Association of Colliery Management*

Mr. A. S. Lockhart.
Mr. J. Bullock, President.
Mr. M. J. Fairnie, Organising Secretary.

I. DESCRIPTION OF THE COLLIERY

General

5. Kames Nos. 1 and 2 Colliery is situated at Muirkirk, some 22 miles east of Ayr. The shafts date from 1870 and are sunk to a depth of 840 feet. There were 510 employees below ground and 130 on the surface. At the time of the explosion the daily output was 650 tons, of which 400 tons came from the West Mine area.

Management

6. The colliery is in the East Ayr Area of the Scottish Division of the National Coal Board. The principal officials were:—

Area General Manager	Mr. G. W. Kirkwood.
Area Production Manager ...	Mr. A. Gardner.
Deputy Area Production Manager (Operations).	Mr. P. Milligan.
Group Manager	Mr. A. H. Walker.
Manager	Mr. T. W. Turner.
Under-manager	Mr. D. B. Hill.

Mr. Turner was ill when the explosion occurred and had been so for some time previously. From 26th September, 1957, Mr. A. Harley, Manager of Douglas Castle Colliery in the same group, had acted as manager.

Seams worked and method of working

7. The seams, in descending order, are the Ell, Seven Feet, Nine Feet, Thirty Inch, and Six Feet, but at the time of the explosion the Ell Seam was not being worked. The colliery was worked by the Stoop and Room method. Coal was produced on the day and afternoon shifts and places advanced about 40 feet a week. Repair work was done on the night shift.

Explosives

8. Coal was got by "grunching"—i.e. by blasting off the solid. At the time of the explosion both capped fuses, ignited by "Fusee" matches, and short-delay detonators, fired electrically by Beethoven exploders, were in use. The explosives used were "Unigel Eq.S" and sometimes, in the bottom of the seam, "Polar Ammon Gelignite".

Villagers gather at the Pithead awaiting news from underground.

Rescue Workers on the night of the Disaster.

Lighting

9. The mine had always been a naked light mine, and before the explosion there were, so far as can be ascertained, no recorded reports of firedamp having been detected other than as traces in samples. Until December, 1956, open lights were used. Electric cap lamps were then introduced in accordance with National Coal Board policy and an agreement with the National Union of Mineworkers to provide free lights for workmen. These lamps (Edison L and L.5) were of types approved by the Minister and had they conformed in all respects with the approvals, they would have been " safety lamps " for the purposes of the Coal Mines Act, 1911, and regulations made thereunder, which were then still in force. The mine would, therefore, have been subject to all the other provisions of that Act and regulations (and subsequently to similar provisions under the Mines and Quarries Act, 1954) applicable to safety lamp mines ; for example smoking, which was freely indulged in, would have been prohibited and only permitted explosives could have been used. To obviate this the management, after consultation with H.M. District Inspector, deliberately omitted to fill the shrouds of the head screws in the headpiece locks with hard wax compound, as specified in the Minister's approval, in the lamps to be issued to workmen. This is an accepted practice and results in the lamps not being " *locked* safety lamps " within the meaning of the Act. I have more to say on this later.

10. Locked flame safety lamps were issued to deputies for the purposes of their statutory inspections and I understand that this was the practice even before the law was changed in 1951 to require it at mines in which inflammable gas was unknown. Deputies also used cap lamps in which the wax seal had been retained.

Ventilation

11. Ventilation for the mine was produced by an axial flow forcing fan designed for an initial capacity of 120,000 cubic feet a minute, situated at the surface at No. 1 Downcast Shaft. Because of leakage at the airlock the actual amount of air produced in the fan drift was 160,000 cubic feet a minute at a water gauge of 2·6 inches, of which only about 73,000 cubic feet a minute was delivered down No. 1 Shaft. The upcast was by way of both No. 2 Shaft and a surface drift known as the East Moor Heading.

Precautions agains coal dust

12. Normally only 12 dust samples were collected each month for compliance with the Coal Mines (Precautions against Inflammable Dust) Regulations, 1956. All were collected in the West Mine, six in the Pony Level of the Six Feet Section and six further inbye in the Nine Feet Seam adjacent to the junction with West Mine haulage road. The first-named place was not shown as a dust zone on a plan kept in accordance with the Regulations. The analysis of the samples collected in the Pony Level during the six months prior to the explosion showed that they varied in incombustible matter from 75 to 98 per cent. Stone-dust, where applied, was limestone dust. For October and for some months previously there had also been entered in the record book the word " wet " in respect of the West Mine haulage road and the outbye end of the West Mine Intake.

13. Precautions against airborne dust comprised water sprays at certain loading and transfer points and the taking of samples by thermal precipitator.

Air sampling

14. Although firedamp determinations in accordance with the Coal and Other Mines (Ventilation) Regulations, 1956, were not required, Kames being a naked light mine prior to the explosion, samples were in fact taken in the Six Feet Section, (*a*) 100 yards from the first working place, and (*b*) 100 yards from the last working place. Between 23rd January, 1957, and the date of the explosion firedamp was found in these samples on three occasions only—0·02 per cent. at point (*a*) on 27th February, and 0·06 and 0·03 per cent. at point (*b*) on 15th April and 21st May, respectively.

II. THE WEST MINE AREA

General

15. Plan No. 1 shows the West Mine area in relation to the shafts. It was served by an endless under-rope haulage which near its inbye end passed along a drift known as Connor's Dook, and then by an endless over-rope haulage which extended into the Nine Feet Seam. The haulage road was known as the West Mine haulage road and it formed the main return airway for all the workings in the West Mine area. At a point 2,183 yards inbye it struck the Six Feet Seam at the Six Feet Bench, and 30 yards further inbye the Thirty Inch Seam.

16. The main intake airway ran to the north-west of and roughly parallel with the West Mine haulage road. At a point 2,053 yards from the shaft there was a booster fan with a capacity of 32,000 cubic feet a minute at a water gauge of 2·5 inches which had been installed following a ventilation survey at the end of 1950. Beyond the booster fan the air split to the Six Feet and Nine Feet Seams, the latter split being subsequently sub-divided to provide ventilation for the No. 2 Thirty Inch Section. The return air from the Nine Feet Seam and the No. 2 Thirty Inch Section joined the West Mine haulage road just inbye the Six Feet Bench, and that from the Six Feet Seam joined it just outbye that point. Further outbye along the haulage road a small section known as the No. 1 Thirty Inch was ventilated by a shunt split.

17. There were three deputies' districts in the West Mine :—

(i) Nine Feet.

(ii) Six Feet and No. 2 Thirty Inch.

(iii) No. 1 Thirty Inch (which also included the Pit Bottoms, and Bell's Mine Loco. Road in the East Mine).

On the day shift there was an overman for the Nine Feet and No. 1 Thirty Inch districts, and another for the Six Feet and No. 2 Thirty Inch district. On the afternoon and night shifts there was only one overman for the whole colliery.

The Six Feet Section

18. The explosion occurred in the Six Feet Section to which the effects of flame and blast were confined. The seam here was 9 feet 6 inches thick. In Rooms the top 2 feet 8 inches of coal was left up and recovered, where possible, during Stooping operations ; in main roads, which were supported by steel arched girders, only the top 8 inches of coal was left. It will be seen from Plan No. 2 that the main haulage and return airway

Workmates wait for news of their comrades.

Disaster victims being brought to the surface

Morris, William Alexander	Area Ventilation Engineer
Milne, John Alexander	Senior Pathologist
Hill, David Black	Under-manager
Turner, Thomas Watson	Manager
Harley, Andrew	Acting Manager
Walker, Adam Hamilton	Group Manager
Milligan, Peter	Deputy Area Production Manager (Operations).
Gardner, Alexander	Area Production Manager
Kirkwood, George Wallace	Area General Manager
Williams, William Gordon	H.M. Inspector of Mechanical Engineering in Mines.
Hislop, William	H.M. District Inspector of Mines and Quarries.
Baker, Francis Henry	H.M. District Inspector of Mines and Quarries.
Tideswell, Frederick Vincent	Safety in Mines Research Establishment.
James, Lynden Reece	Safety Officer—National Union of Mineworkers.
Poole, Granville	Professor of Mining
Hibberd, George Herbert	Professor of Mining
McAdam, Robert	Professor of Mining

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for the Section was No. 2 Dook which dipped in a southerly direction at a gradient of 1 in 5 from the Pony Level. The intake airway, known as the Companion Dook, ran parallel with and to the west of No. 2 Dook.

19. At the time of the explosion there were three open connections between the two dooks—Walker's Fan Crosscut, Wylie's Fan Crosscut and Casagranda's Level. The only places where coal was then being worked were those described on Plan No. 2 as the Stooping Section, Walker's Dip and Wylie's Level, but there were several places standing open which had been discontinued or abandoned within the previous six months and which had no means provided for conducting air into them. From west to east these were (i) an old heading running north-westwards from the Companion Dook opposite Walker's Fan Crosscut, known as the Right Hand Road off Intake, which stopped on 3rd June; (ii) a north-westerly extension of Casagranda's Level which was stopped at a fault on 14th November; (iii) a southerly extension of No. 2 Dook which rose to a fault at which it was stopped on 24th August; (iv) a south-easterly extension of Casagranda's Level beyond No. 2 Dook, known as Wylie's Slope, which was stopped at a fault on 12th October; (v) a heading running southwards from Wylie's Slope which was stopped on 19th October; (vi) a heading running eastwards from No. 2 Dook between Wylie's Slope and Wylie's Fan Crosscut which was stopped on 21st September; (vii) Walker's Level, running eastwards from No. 2 Dook opposite Walker's Fan Crosscut, which was stopped on 26th October; and (viii) the second place running northwards from Walker's Level, known as Walker's Rise, which was stopped on 2nd November.

20. The main ventilating current after passing down the Companion Dook, through Casagranda's Level and up No. 2 Dook, then travelled the Belt Level to ventilate the Stooping Section, and reached the main return airway (the West Mine haulage road) just outbye the Six Feet Bench. Two screens placed across No. 2 Dook a little way above the Belt Level allowed some leakage to continue up No. 2 Dook to the Pony Level and rejoin the main return airway at the Six Feet Bench. Four auxiliary fans, situated in (i) Walker's Fan Crosscut, (ii) Wylie's Fan Crosscut, (iii) the Companion Dook, and (iv) the Belt Level, were used for ventilating the working places.

21. In general coal was transported from the working places by scraper conveyors to loading points, at which it was transferred to tubs for transport up No. 2 Dook by main rope haulage, and thence along the Pony Level by horse haulage. The only exception was in the Stooping Section where the scraper conveyors from the faces delivered on to a belt conveyor for transport along the Belt Level to the loading point near No. 2 Dook.

III. THE EXPLOSION AND SUBSEQUENT EVENTS

22. The explosion occurred during the afternoon shift on Tuesday, 19th November. The men on that shift descended between 2.30 and 3 o'clock, 34 going to the Six Feet and No 2. Thirty Inch District (deputy: James Brady), 29 to the Nine Feet District (deputy: Hugh Parker) and nine to the No. 1 Thirty Inch District (deputy: David Casagranda). James Marshall, Junior, acting overman, was in charge of the whole colliery below ground.

23. Work in the Six Feet Section seems to have proceeded normally until about 7.30 p.m. when the explosion occurred, killing three men who had been working in the Belt Level and all the 14 men who were in the workings to the south of the Level. At that time deputy Brady was with Scott Davidson, engine driver, at the over-rope haulage engine in the West

Mine haulage road; deputy Parker was adjusting a ventilation door about 50 yards inbye the Nine Feet telephone; R. McLaren, engine driver, was at his engine at the top of No. 2 Dook near its junction with the Pony Level, and A. Smith, rope changer, was at the junction; W. Queen, conveyor-switch attendant, and R. Hannah, collier, were at the Stooping Section conveyor; Henry Casagranda and J. Cook, colliers, and W. Bradford, shot-firer, from the Nine Feet District, were in the Stooping Section; and J. Bennie, pony driver, was at the Six Feet Bench.

24. Brady and Parker both realized that something serious had happened and made their way to the Six Feet Bench. Near the Bench Brady, who was accompanied by Scott Davidson and two others, found Bennie and his pony lost in the dust and fumes. Davidson took the lad through the dust and fumes to the stables, and then went to look for his cousin George Davidson, who worked at the top of Connor's Dook.

25. At the Bench Parker attended to two injured men, A. Smith and McLaren, who had come from the top of No. 2 Dook, assured himself that rescue arrangements had been set in motion and gave instructions for his men in the Nine Feet District to be withdrawn. He then went into the intake airway and blocked off the intake to the Nine Feet and No. 2 Thirty Inch Sections at the overcast over the Pony Level, so as to restrict the flow of air into those sections and increase the amount going into the Six Feet Section. He also arranged for the Six Feet Regulator to be knocked down. Meanwhile, Brady, accompanied by one workman, tried to enter the section by the intake airway, but was stopped by dust and fumes some 30 feet below the junction at the innermost end of the Pony Level and had to return.

26. In the Stooping Section Henry Casagranda thought there had been an explosion and so, with Bradford and Cook, he joined Queen and Hannah in the Belt Level. Queen being elderly, Cook and Hannah took him towards fresh air while Bradford and Casagranda went along the Level to try to reach the men working near the loading point. They were beaten back by fumes and went along the return airway to the Six Feet Bench.

27. The party at the Bench now consisted of Parker, Bradford, Casagranda and Cook. Bradford got in touch with the surface and was instructed to remain at the Nine Feet telephone; the others went to look for Brady and meeting him near the inbye end of the Pony Level they all made their way into the Companion Dook. They were stopped by fumes about 150 feet from the top and returned to the end of the Level. Brady and Casagranda then made another attempt to get into the affected area by going along the Pony Level into No. 2 Dook but again had to retreat. Brady, with others, did manage later to get down No. 3 Dook and through the Belt Level Througher to No. 2 Dook where they saw the bodies of J. Dalziel and A. Findlay. These two bodies had earlier been discovered by Cook who had been joined by Joe Casagranda, a repairer working near the pit bottom who had gone inbye to help. Brady then retraced his steps to the Six Feet Regulator where he met the rescue brigade men and did what he could to help them.

28. James Marshall, Junior, the acting overman, was in the East Mine when the explosion occurred. He was told about it by telephone at the pit bottom and arranged for emergency calls to be made to the surface. Realizing that the men in the No. 1 Thirty Inch Section would be in danger, the section being ventilated by return air from the Six Feet Section, he made his way there and told the deputy, David Casagranda, brother of Henry and Joe, to withdraw his men. He then attempted to reach George Davidson

APPENDIX II

List of Witnesses

Name	*Occupation*
Macauley, Ian Charles	Surveyor
Dempster, Thomas Shields	Overman
Hazle, Thomas	Deputy
Ward, Thomas Paton	Deputy
Campbell, Hugh	Shotfirer
Anderson, Charles	Collier
Logie, George Blyth	Collier
Wylie, William Henderson	Collier
Caldow, John	Collier
Barclay, James	Electrician
Ross, Andrew Welsh	Electrical Engineer
Dempster, John	Safety Officer
Hadden, William John	Head Lamproom Attendant
Graham, Robert	Training Centre Manager
Brady, James	Deputy
Bradford, William	Shotfirer
McLaren, Robert	Haulage Engineman
Casagranda, Henry	Collier
Cook, James	Collier
Smith, Archibald	Rope-changer
Bennie, John	Pony Driver
Davidson, Scott	Haulage Engineman
Davidson, George Logie	Clipper
Peters, Alexander Faulds	Clipper
Mackin, John	Pump Attendant
Marshall, James	Acting Overman
Casagranda, David	Deputy
Dempster, John Smith	Shotfirer
Johnston, Albert	H.M. Electrical Inspector of Mines and Quarries.
Evans, Richard John	H.M. Inspector of Mines and Quarries.
Mackin, Thomas	Collier
Parker, Hugh	Deputy
Gebbie, George	Collier
Hillditch, John	Faceman
Ford, Thomas	Pan man
Shaw, William	Shotfirer
Boland, Richard Michael	Collier
Scott, Richard	Police Sergeant
Gray, William	Police Sergeant
Cooke, William James	Ostler
Morrison, John Hendry Dickson	Deputy Part-time
Moreland, Andrew	Deputy Part-time
Mackin, Martin	Mining Student
Blyth, David Gray	Conveyor Operator

APPENDIX I

List of Killed

Name	*Age*	*Occupation*
Burnside, Thomas	58	Ripper
Casey, Thomas	18	Bencher
Crawford, Alexander Brown ...	37	Shotfirer
Dalziel, John	33	Repairer
Dillon, Timothy	44	Mechanical Maintenance Man
Findlay, Andrew McGarry ...	20	Loaderman
Grant, Ronald Carruthers...	20	Loaderman
Hendry, William Aird	30	Loaderman
Lowe, Robert John Stark	53	Collier
Marshall, James Boston	69	Repairer
McGarry, Donald Morrison ...	18	Bencher
McKay, William	43	Collier
McKean, John	53	Repairer
Samson, James	37	Collier
Smith, Robert Watson Parker ...	33	Loaderman
Smith, William Davidson	47	Ripper
Walker, John Brown	37	Collier

at the top of Connor's Dook, but collapsed into unconsciousness about half way to the Dook. He was rescued later by men wearing apparatus and taken to the pit bottom where, with several others, he was treated by Dr. Weir of Muirkirk.

29. Meantime, while David and Joe Casagranda had gone inbye to see what they could do, John Dempster, shotfirer in the No. 1 Thirty Inch District, tried to help J. Frew and T. Mackin, two workmen from the district, through the fumes in the main return airway to the pit bottom. They had only travelled about 150 yards when Frew collapsed. Dempster tried unsuccessfully to revive him and then, in spite of being greatly distressed himself, first dragged and then carried and finally threw him into a tub and pushed him as far as the airlock where he too collapsed. Mackin had also collapsed, but all three were rescued by willing helpers.

30. While these events were happening below ground, people at the surface had not been idle. The first intimation that a serious accident had occurred was received there at about 7.50 p.m. Mr. Harley, the acting manager, and a doctor and ambulance from Muirkirk were promptly summoned, and the Rescue Station at Kilmarnock was asked to stand by for instructions. At 8.30 p.m. Mr. Dick, the Superintendent, received a call for action from T. Dempster, the dayshift overman. He despatched a rescue van immediately with the Assistant Superintendent, Mr. Morran, and asked Dempster to call out the Kames Brigade. He also arranged with the Superintendent of Auchinleck Rescue Station to call out the Highhouse Colliery Brigade and with Coatbridge Rescue Station to send two brigades.

31. Morran arrived at the mine at 9.40 p.m. and, with two members of the Kames Brigade, descended at 9.45 p.m. Others followed and a fresh-air base was established in No. 3 Dook, just above its junction with the Belt Level Througher, some two miles from the shaft at 11.05 p.m. At 11.15 p.m. a brigade, comprising W. Shaw and R. M. Boland of Kames Colliery and three men from Coatbridge, was sent in to the affected area from the fresh-air base ; they returned at midnight and reported that they had found 16 bodies but no sign of life. Later it was learned that one other person was not accounted for. Steps were taken to restore the ventilation and by 3.0 a.m. it was possible to undertake a more thorough inspection. This was made by a party which included Mr. P. Milligan, Deputy Area Production Manager (Operations), Mr. F. H. Baker, H.M. District Inspector, Mr. R. J. Evans, H.M. Inspector, and at a later stage Mr. W. Widdas, H.M. Divisional Inspector. Except for the north-westerly extension of Casagranda's Level, where a rescue team which included Mr. Evans found the bodies of two men, beside one of which was a box of matches, this inspection was made without apparatus. All 17 bodies were located ; they were brought to the surface by 1.20 p.m. on 20th November and taken to Ballochmyle Hospital.

IV. INVESTIGATION OF THE EXPLOSION

32. The positions at which the persons killed were found and the last known places at which they were working before the explosion are shown on Plan No. 2. There were burns on the four bodies found near the junction between No. 2 Dook and the Belt Level, on two in Walker's Level, on three in No. 2 Dook between Wylie's Level and Wylie's Fan Crosscut, and on the two in the north-westerly extension of Casagranda's Level. None of the other bodies was burned possibly because, at the time of the explosion, the men were at the faces of headings to which flame had not penetrated due to compression of the air, a typical explosion effect in dead ends.

33. A detailed investigation of the explosion area was made by H.M. Inspectors and by Dr. F. V. Tideswell, with a number of his colleagues from the Safety in Mines Research Establishment, on the day following the explosion and on subsequent occasions. Dr. Tideswell's team collected some 200 specimens of fibrous fabric and other material likely to indicate exposure to flame, of deposited and impacted dust, and of coke. These were all subjected to laboratory examination.

34. As a result of the investigation it was seen that the explosion had spread over almost the whole of the lower workings in the Six Feet Section. The greatest material damage was in the Belt Level and in Walker's Level. There were local falls, mainly at junctions and in disused roads. The extent of flame, the visible signs of coking, and the direction of the spread of the explosion are indicated on Plan No. 3.

35. Flame had spread over a total distance of between 3,000 and 3,500 feet. It had travelled No. 2 Dook between Casagranda's Level and a junction 120 feet above the Belt Level; the Companion Dook between Casagranda's Level and the througher below the Belt Level Througher; throughout Casagranda's Level and its north-westerly extension; throughout Wylie's and Walker's Fan Crosscuts; and for varying distances into the Right Hand Road off Intake, Wylie's Slope, the rise heading at the foot of No. 2 Dook, Wylie's Level, Walker's Level, Walker's Dip, Walker's Rise, and the Belt Level. Signs of burning visible to the naked eye were most strongly marked in the north-westerly extension of Casagranda's Level, the Right Hand Road off Intake, Walker's Level and Walker's Rise. Few such signs of burning were noticed in No. 2 and Companion Dooks.

36. Deposition of dust was nowhere very heavy, but local deposits of a thickness of from one to three millimetres were observed along the whole of Casagranda's Level and Wylie's Slope, in Wylie's Fan Crosscut, in Walker's Level and in the main intake. There was a little deposited dust in the Belt Level, decreasing towards the Stooping Section; and in No. 2 Dook, from Walker's Level to the Pony Level, explosion dust was consistently impacted on the inbye faces of supports.

37. There were signs of coking visible to the naked eye in the Companion Dook, in Casagranda's Level and Wylie's Slope, in the rise heading at the foot of No. 2 Dook, in Wylie's Fan Crosscut and in Walker's Level and Walker's Rise. The heaviest deposits were in Walker's Level and Walker's Rise. In addition, microscopic examination of samples showed that there were occasional slight deposits of coke in No. 2 Dook inbye of Wylie's Fan Crosscut and from Walker's Level increasingly towards the Belt Level, and in the Belt Level near the loading point.

38. The main blast developed by the explosion was from the foot to the top of No. 2 Dook. There was also evidence of blast from No. 2 Dook towards the Companion Dook through the various connections, in the Belt Level from No. 2 Dook towards the Stooping Section, in Walker's Level and Walker's Rise towards No. 2 Dook, and in Casagranda's Level, from No. 2 Dook towards the Companion Dook.

39. These facts were accepted by all parties.

40. The only source of firedamp discovered immediately after the explosion was in the rise heading at the foot of No. 2 Dook. Because of indications of the possibility of fire this heading and other parts of the lower workings were flooded shortly after the explosion and were not de-watered until mid-January, thus delaying the completion of the investigation.

41. At the end of November, H.M. Inspectors took dust samples in the manner prescribed by the Coal Mines (Precautions against Inflammable Dust)

of this Report. I thank also Mr. F. Porteous, Chief Surveyor for the East Ayr Area of the Scottish Division of the National Coal Board, and his surveyors and draughtsmen for the excellent plans which they prepared.

89. Finally I wish to thank Mr. W. K. McFadyean the Procurator-Fiscal and his staff for their valuable help, the Ayr County Council for placing the Council Chamber and Sheriff Court at my disposal, and their staff who co-operated so willingly.

I have the honour to be, my Lord,

Your Lordship's obedient Servant,

H. C. W. ROBERTS.

82. It should be superfluous for me to say that statutory requirements must be strictly observed at all mines, even when in the light of special circumstances they might seem to be taking precaution unnecessarily far. This obviously does not happen now and more positive measures must be taken to educate everyone engaged at mines to the need for such observance.

83. The primary responsibility for ensuring that statutory requirements are complied with must always rest with the manager, but he cannot discharge that responsibility effectively without the active co-operation of everybody in the industry. This matter is being investigated by a sub-committee of the Safety and Health Committee of the Coal Industry National Consultative Council, which sits under the chairmanship of Sir Andrew Bryan and of which I am an assessor. I have great hopes that the results of the work of the sub-committee will go a long way towards achieving that co-operation, but I must comment here on the part to be played by the under-officials, particularly the deputies.

84. There must be between the manager and the deputies a two-way system of communication of a more effective kind. A manager must guide and inform his deputies about what is required: they in their turn must see that his requirements are carried out, and keep him informed of what is happening in their districts. Furthermore, they must by their foresight, initiative and meticulous attention to detail ensure that anything unusual in their districts is dealt with before it can become a danger.

85. The task of the deputies is not easy as they often have to exercise authority over and demand obedience from men who are their neighbours and personal friends when off duty. The National Coal Board must therefore ensure that the status and conditions of service are such as will attract men of the highest calibre—men who have the right human touch as well as technical ability—and managers must ensure that districts are not so large that proper attention cannot be given to all safety matters. Most important of all, deputies must have the unstinted support of both management and workmen, and the National Coal Board and the National Union of Mine-workers must see that they get it.

86. I am convinced that it will be by measures such as these, rather than by additional statutory requirements, that progress will be made towards avoiding disasters such as that at Kames. But there must be active co-operation by all concerned—the mere expression of pious hopes will not do.

87. I cannot close this section of the report without referring to the actions of those persons who, although in comparative safety when the explosion occurred, risked their lives to do what they could to help their workmates. When so many behaved so well it would be invidious here to mention anybody by name, but I have in Section III described briefly the movements of those principally concerned. To them, and to others who took an active part but are not mentioned there, I offer my most sincere admiration and thanks.

VII. ACKNOWLEDGMENTS

88. I wish to express my sincere appreciation of the co-operation of the representatives of all parties to the Inquiry. I am particularly indebted to Mr. W. Widdas, H.M. Divisional Inspector of Mines and Quarries, and his staff; to Mr. H. T. Ramsay, Director of the Safety in Mines Research Establishment, and his staff; and to Mr. W. J. Longley of the Ministry of Power, who not only acted as Clerk to the Court but gave me valuable help in the preparation

Regulations, 1956, in all accessible roads in the Six Feet Section. They took 82 samples in all—39 from the floor and 43 from the roof and sides. Eighteen of these were described as "wet"; of the remaining 64, only one from the floor and two from the roof and sides were shown, on analysis, to contain the percentages of incombustible matter required by the Regulations.

42. All the electrical apparatus and lamps from the affected area were examined at the Safety in Mines Research Establishment, but no defect likely to have originated the explosion was discovered.

V. CAUSES AND CIRCUMSTANCES OF THE EXPLOSION

Causes and development

43. It was accepted by all parties represented at the Inquiry that the explosion originated as a firedamp explosion somewhere south of Wylie's Fan Crosscut, and that the firedamp was ignited by a match. There was a divergence of views about the cause of the spread of the explosion and about the precise site of origin.

44. Dr. Tideswell, Mr. Baker, Professor Poole and Mr. James were firmly of the opinion that the ignition of an accumulation of gas in the north-westerly extension of Casagranda's Level, resulting from a slow emission, caused a comparatively small but moderately violent gas explosion which was extended over the whole of the remainder of the affected area by the explosion of coal dust, assisted by the inflammation of firedamp in the Right Hand Road off Intake. Professors Hibberd and McAdam thought that it was essentially a firedamp explosion; that coal dust, although present, played an insignificant part in the propagation or spread; and that the site of origin could not be determined more precisely than somewhere south of Wylie's Fan Crosscut.

45. The theory of a major explosion of firedamp took two forms. Both were seemingly based on calculations of the volume of firedamp theoretically necessary to produce an explosion of this magnitude derived from the well known ratio of flame projection from highly inflammable mixtures of firedamp, i.e. about 7 to 1 with ten per cent. of firedamp, the most inflammable mixture.

46. Professor Hibberd thought there had been a comparatively quick build up of an explosive mixture of the order of 35,000 cubic feet within a period of one to two hours migrating from Wylie's Slope, and the extension of No. 2 Dook, into Casagranda's Level and up No. 2 Dook. Having regard to the path of the ventilation in the area, I find it impossible to visualize how an emission of this kind could have caused gas to be present in explosive proportions, either in the form of a homogeneous mixture or of accumulations in layers and pockets, over such an extent of roads as would be needed to explain the character of this explosion and the area affected by it.

47. Professor McAdam also was unable to accept the idea of a sustained migration, particularly into an area in which men were working and, as smoking was allowed, would obviously be striking matches. He therefore assumed a very sudden emission of from 3,000 to 4,000 cubic feet of neat gas within a period of a minute or so from some "pocket or bursting strata" in Wylie's Slope, the rise heading at the foot of No. 2 Dook, Casagranda's Level, or its north-westerly extension.

48. So far as I am aware it has never been shown that the flame projection ratio on which the calculation seems to be based applies other than to the more imflammable mixtures, and certainly I do not think that it would

apply to the over-rich mixture which must result from a very sudden and heavy emission. Still less do I think that the quantity of firedamp assumed could have become associated with the many times greater quantity of air needed to burn it, in such a way as to cause the spread of flame observed. As I pointed out in my Report* on the Easington explosion this requirement is a crucial one.

49. Neither of these witnesses explained the pattern of flame and coking observed in the north-westerly extension of Casagranda's Level and neither supported his arguments with any factual evidence. I find both forms of the theory equally untenable.

50. Turning to the part played by coal dust, Professors Hibberd and McAdam thought that it could not have played any significant part in the propagation of the explosion because (*a*) the explosion stopped (i) in the Companion Dook near the junction with the throughter below the Belt Level Throughter, (ii) in No. 2 Dook at the junction above the Belt Level, and (iii) in the Belt Level some 100 feet from No. 2 Dook; (*b*) visible signs of coking were not more extensive, especially in No. 2 Dook; (*c*) the damp nature of the workings would create difficulty in raising dust into the air; and (*d*) they considered the normal dust deposition to be too light to allow continued propagation.

51. It is of course difficult to explain precisely why the explosion petered out just where it did, but this is not unusual. The factors affecting extinction of flame are complicated. The advancing flame tends to be pulled back by the cooling of burnt products behind it, causing a serious check if the dust cloud through which it is advancing is not very inflammable. This factor is exaggerated by pulsation due to resonance (for it is known that flame from a weak explosion is liable to be extinguished during a reverse pulse) and also if the explosion is following several paths simultaneously, because extinction of the flame on one path, causing a collapse of pressure within the system, may cause a decisive check leading to nearly simultaneous extinction on the other paths. Probably that is what occurred here.

52. I think it is fair to say that most mining men might have thought before the explosion that there was little fine coal dust in the Six Feet Section, and that what was there was so damp that it could not be raised into the air. But it must be recognized that coal dust does not readily so dampen as to become completely indispersible, and that an explosion can be propagated with a cloud density of as little as 0·05 oz. per cubic foot (equal to a film thickness averaging only three or four thousandths of an inch) and by damp or even wet dust. The position is aggravated when the coal has a volatile content as high as it was at Kames—over 39 per cent. on a dry ash-free basis. Moreover, the blast of an explosion will raise into the air, in a way quite inconceivable by other means, dust from nooks and crannies, from disused roads (especially roads driven in coal), from supports, from spillage, and from conveyors and conveyor structures.

53. That dust was in fact present and was raised follows, I think, from the evidence of Mr. W. Hislop, H.M. District Inspector of Mines and Quarries, about the road dust samples taken after the explosion and from Dr. Tideswell's evidence about the deposition of dust, referred to in paragraph 36, which was I repeat accepted by all parties. That visible signs of coking were not more extensive is quite consistent with this evidence. Clearly, if the concentration of dust is light, perhaps little more than is needed to ensure continued propagation, it will be almost completely consumed and there will be little or no coke residue.

*1951, Cmd. 8646.

booster fan was not provided with an automatic revolution counter, or alternatively an automatic pressure indicator, and it was alleged that certain stoppings and screens were inadequate for the prevention of leakage.

76. Although these matters have not greatly affected my assessment it is only right that they should have been considered.

VI. CONCLUSIONS AND RECOMMENDATIONS

77. As I have said earlier, I am satisfied from the evidence that the explosion originated near the face of the north-westerly extension of Casagranda's Level which for four days had neither been ventilated nor thoroughly inspected; that when two workmen went into it to see what work might be necessary, one of them struck a match in order to smoke, which he was entitled to do, and that this ignited firedamp; and that the resultant explosion was continued by the explosion of coal dust.

78. Kames had always been regarded as free from firedamp and the workings were thought to be so damp that the coal dust present could not be raised into an explosive cloud. Nobody had ever contemplated the possibility of an explosion and, naturally enough, workmen were allowed to smoke. Unfortunately, such was the mistaken feeling of immunity that simple precautions were not observed. The ventilation, particularly of blind ends, was not what it should have been, the sampling of road dust and the application of stone dust were inadequate, and the statutory inspections for gas were either ignored altogether or made in a most perfunctory manner. It was the tragically simple story of a combination of errors and misjudgments, not of great danger individually but together leading to disaster—a story paralleled time and again in mining history, and far too frequently in the last few years.

79. The inescapable conclusion to be derived from this disaster is that no coal mine can be regarded as immune from the danger of an explosion. I therefore recommend that the National Coal Board should, as a matter of policy, forthwith prohibit below ground the presence of naked flame in any form and by 31st December, 1960 (the date from which "mixed light" mines are prohibited by Section 62 (5) of the Act) make all their mines safety lamp mines in every sense. Such a step, to be fully effective, would need the co-operation of the workmen, but I am confident that the National Union of Mineworkers would give it their full support.

80. I also recommend that the Board should instruct managers that the phrase "dust . . . which can be raised into the air" in No. 5 (1) of the Coal Mines (Precautions against Inflammable Dust) Regulations, 1956, must be given the most liberal interpretation. Following from that managers must ensure full compliance with the requirements of the Act and Regulations about dust suppression and the use of incombustible dust and, where appropriate, must provide waterproofed incombustible dust and stone dust barriers.

81. It will be noted from paragraphs 30 and 31 that although it was known at the surface by 7.50 p.m. that an explosion had occurred it was not until 11.15 p.m. that the first rescue brigade left the fresh-air base in No. 3 Dook to explore the affected area. In this instance the delay did not have the slightest effect upon the possibility of saving life, but in other circumstances it might have done. Where permanent rescue corps are maintained it is possible to get a brigade to the scene much more quickly than would otherwise be the case, I therefore recommend that this system should be extended to all central rescue stations, without reducing the present strength of the mine brigades, or that other arrangements having the same effect should be made.

also contended that the argument that the lamps were not safety lamps in a legal sense (to which I have already referred in paragraph 9) was in any event invalid because the wax seal for the headpiece lock had not been omitted from some of the lamps when they were first introduced, and one lamp in such condition was in use at the time of the explosion.

71. There is no legal basis for Mr. Moffat's first contention and little concrete evidence to support the second. Even if there had been I do not think it would have been reasonable to have regarded Kames as a safety lamp mine because of what was at worst an oversight. Nevertheless, I think there is weight in Mr. Moffat's further contention that to the working miner the absence of a wax seal does not turn something which he regards as a safety lamp into a naked light! If he is allowed to smoke in a mine where such lamps are used, he will see no reason why he should not smoke in other mines where " locked safety lamps " in the full meaning of that term are statutorily required to be used.

Standards of supervision

72. The deputies frankly admitted that they rarely carried flame safety lamps during their general inspections and by no means regularly during their pre-shift inspections. I have grave doubts whether, even when they carried them, they made thorough tests for firedamp as they were required to do by Nos. 12 and 15 of the Coal and Other Mines (Managers and Officials) Regulations, 1956. In particular, as I have said before, there was no evidence of an inspection for firedamp having been made near the face in the north-westerly extension of Casagranda's Level for at least four days before the explosion. The heading had not been excluded by a manager's notice under Regulation 15 (2) and consequently full inspections were statutorily required.

73. The attitude of the deputies was epitomized by one of them who said in evidence, " I never dreamed about gas ". It must be said, however, that they were not alone in this respect: their attitude was reflected in the failure of the management to observe good ventilation practice and to take effective measures against coal dust, in spite of the high volatile content of the coal. And here I must add that I am satisfied that these failures were not due in any way to the mine being, at the time of the explosion, in the charge of a temporary manager.

74. Clearly the safety standards at the mine, at least as regards the risk of explosion, were not of a very high order. Having said that, however, it would be quite unrealistic not to recognize that most mining men would have thought the mine immune from such risk because of the general dampness of the roads and the fact that firedamp was unknown in any practical sense. Indeed, so safe was the mine considered to be that it had been used for some time for experimental work in blasting practice. But no coal mine can be regarded as immune, and proper precautions must be taken at all times even if in the minds of some people they are, in the popular phrase of the day, just " bull ".

Comments on matters not related to the explosion

75. In the course of the Inquiry evidence was given about a number of matters not causally connected with the explosion, but which I allowed as being helpful in forming an opinion of the general standard of observance of statutory requirements. Among the more important were the admitted failure to keep an effective check on the return of explosives and the practice of stemming shots with coal dust " gummings ". It was also stated that the

54. Dr. Tideswell's conclusions about the origin and subsequent course of the explosion were reached after an exhaustive survey of the undisputed evidence of signs of flame, dust and coking, and of the effects of blast. In particular he showed convincingly to my mind that the combination of flame pattern and direction of coking in the north-westerly extension of Casagranda's Level could only have been produced by the ignition of firedamp at or near the inbye end of that heading. This view in no way depended on the facts that two bodies and a box of matches were found in the heading, and that it was subsequently found that a slow emission of firedamp did take place ; but they do lend strong support to it. Indeed the hypothesis of the ignition in this unventilated heading of an accumulation of gas resulting from a make of only a fraction of a cubic foot a minute over a period of a few days, leading to a coal dust explosion, can be fully reconciled with all the known facts, including the presence in the heading of the workmen and a box of matches. There was no evidence of an inspection for firedamp having been made, except possibly near the entrance to the heading, for at least four days before the explosion. There could, therefore, quite conceivably have been near the face, as an accumulation bordered by an inflammable fringe, the small quantity of firedamp necessary for initiation.

55. The two workmen whose bodies were found in the heading were engaged in preparing part of Casagranda's Level as a tub road which was to be continued into the heading. It would be only natural for conscientious workmen to go into the heading to look at the job as a whole, and equally natural, in a naked light mine for one of them to light a match to smoke whilst they were doing so.

56. This, in my considered view, is what occurred.

Comments on causes and development

Method of work

57. The practice of " grunching " was strongly criticised by Mr. Abe Moffat, partly on general grounds but more particularly in regard to the production of coal dust. Obviously some risks may be increased by this practice, but as with so many mining practices it is essential to consider where the balance of risk lies. The relevant issue at Kames was whether " grunching " did in fact increase the explosion risk by causing an excessive quantity of dust. I can see no reason to believe that more dust was made than might have resulted from cutting, shearing and blasting, which is a common alternative in narrow work in Stoop and Room workings.

58. The fact is that the Stoop and Room method of work has its own peculiar difficulties as regards both dust and ventilation. In addition to the considerable degradation inseparable from the actual getting of coal from a narrow face with solid coal on either side, there is a tendency thereafter for coal to " spall " off the side and to be ground to dust underfoot ; and the coal dust is not diluted by incombustible dust created during ripping and packing as it is in Longwall working. If conveyors are used, the make of dust tends to be further increased because of the multiplicity of loading and transfer points.

59. As regards ventilation, there are difficulties in avoiding excessive leakage in the coursing of air across wastes in broken workings, and in the maintenance of constant ventilation in blind headings. If auxiliary fans are used for ventilating such headings, great care is necessary to avoid recirculation and to ensure that ventilation is maintained during weekends and other idle periods.

60. These matters should be carefully considered before deciding upon the method of work to be adopted, and measures for dealing with them should be incorporated in the development scheme. I did not get the impression that such forethought had been exercised at Kames.

Ventilation

61. While the ventilating arrangements at the mine were open to criticism in several respects, the explosion was due to a local ventilating failure rather than a general one. Its primary cause was the failure constantly to maintain adequate ventilation in the north-westerly extension of Casagranda's Level. This heading was approximately 100 feet long and rising towards a fault. When the fault was struck a week to ten days before the explosion, work was temporarily stopped and the air tubes withdrawn. Four days before the explosion a round of shots was fired to bare the fault. From then until the explosion the heading was not thoroughly inspected with a flame safety lamp and no means were provided for coursing air into it. The minimum volume of gas necessary to cause the initial explosion has been calculated at something between 50 and 90 cubic feet. In the time available this would not be inconsistent with the rate of emission found after the explosion.

62. Ventilation should have been maintained in the heading to conform with the requirements of Section 55 of the Act and thorough inspections should have been made, particularly as it was clear from the evidence that work was to be resumed there to prove the fault. Had these steps been taken it is unlikely that the Inquiry would have been needed.

63. I have said that the general ventilating arrangements were open to criticism. The main intake airway into the Six Feet Section included a number of sharp bends and was unnecessarily circuitous. There was a leakage at the surface airlock of over 50 per cent. of the air produced by the fan. A good deal of this was doubtless due to the fact that a new high-efficiency fan had been installed in advance of a new airlock, as part of a major scheme of reconstruction, but even so it seems excessive. In addition, neither the arrangement of the auxiliary fans nor the volume of air reaching them accorded with best practice. The need for special knowledge and careful consideration in the installation and use of auxiliary fans has been stressed on innumerable occasions. It is all the more to be deprecated therefore that the management failed to observe the requirement in No. 26 (2) of the Coal and Other Mines (Ventilation) Regulations, 1956, that a plan showing the general system of ventilation must be sent to the inspector for the district when two or more auxiliary fans draw air from the same air current.

64. On a number of occasions records of air measurements tallied to the last figure. This should have indicated to an alert management the need for investigation of the way in which the official who made them, and who was also responsible for taking dust samples, was carrying out his duties.

Firedamp

65. Kames had been regarded as a mine in which firedamp was unknown. Although this might not be strictly true, as samples referred to in paragraph 14 had shown 0·06 per cent. in the return air (equivalent to a make of about four cubic feet a minute), I am satisfied that it had not been detected with a flame safety lamp within the memory of anybody working in the mine. Evidence was given that a little while before the explosion—no specific date could be fixed—firedamp had been ignited in a shothole in the north-westerly extension of Casagranda's Level and it was alleged that the incident had been reported to the deputy. This was denied by the deputy, and certainly there was nothing to suggest that it was reported to any senior official. It is possible

that firedamp was so ignited ; indeed, this may have been an early indication of some gradual change in physical conditions which, during a comparatively short period before the explosion, caused a slight but significant increase in the rate of firedamp emission, probably by way of the faults. Experience since the explosion confirms this increase ; firedamp has been found in the rise heading at the foot of No. 2 Dook, in the Right Hand Road off Intake and in the north-westerly extension of Casagranda's Level. Although the rate of emission has not been high and there has been nothing to support the suggestion of a sudden large emission, it does appear to be in excess of anything previously experienced.

66. From the flame pattern in these places Dr. Tideswell was convinced that at least the last two had contained firedamp and air in explosive proportions when the explosion occurred, but that the pattern in the two first-mentioned places could not have been produced by an explosion originating in them. On the other hand, the signs of coking and the general development of the explosion in the north-westerly extension of Casagranda's Level were entirely consistent with it having originated there. I am satisfied that this was so and that any accumulations in the other two headings had little effect on the spread of the explosion.

Dust

67. Apart from the cleaning up of spillage, the only steps taken to deal with the dust problem in the Six Feet Section were (a) the installation of water sprays at the two tub loading points in the Belt Level and Walker's Level and at the transfer point in the Belt Level, and (b) the application of inert dust in the Pony Level and in the main intake airway over a length estimated by the Safety Officer to be about 100 yards. Samples were not taken except in the Pony Level, and even this was not indicated as a zone on a Dust Plan.

68. I am satisfied that the officials genuinely believed that there was insufficient dust to propagate an explosion, that the dust present was too damp to be raised into the air, and consequently that it was unnecessary to take any other precautions. It is all the more important therefore that the lessons of this explosion should be brought home to everybody—management, under-officials and workmen alike. And here I think it is necessary to comment on the requirement in No. 5 (1) of the Coal Mines (Precautions against Inflammable Dust) Regulations, 1956, that "*any dust . . . which can be raised into the air* shall contain not less than the minimum percentage of incombustible matter". Whatever the legal interpretation of these words may be, in common sense they must mean that any dust which can be raised, even if the blast of an explosion is needed to raise it, should contain the requisite proportion of incombustible matter—indeed, that is the whole purpose of the Regulations.

69. As I have already said, it is an established fact that very little coal dust is needed to propagate an explosion. More than enough dust to form such a cloud will be made in almost any system of mining and it cannot be stressed too vigorously that there are very few mine roads which are so wet that dust cannot be raised by the blast of an explosion. The logic of this is that whether or not a mine is wet the possibility of a coal dust explosion must be guarded against by dust suppression, by the use of incombustible dust, waterproofed if necessary, and by stone dust barriers where appropriate.

Use of naked lights

70. It was contended by Mr. Abe Moffat that when electric cap lamps were introduced in 1956 the mine automatically became a safety lamp mine subject to all the consequential requirements applicable to such a mine. He