MR. HERMON'S

THE PREVENTION OF ACCIDENTS IN MINES.

PRIZE ESSAYS.

The Hermon Prize Essays.

ESSAYS

ON THE

PREVENTION OF EXPLOSIONS

AND

ACCIDENTS IN COAL MINES,

TO WHICH WERE AWARDED THE FIRST AND SECOND PRIZES GIVEN BY
EDWARD HERMON, ESQ., M.P., PRESTON.

ESSAY I. BY WILFRED CRESWICK, OF SHEFFIELD.
ESSAY II. BY WILLIAM GALLOWAY, OF LONDON.
ESSAY III. BY WILLIAM HOPTON, OF ST. HELENS.

LONDON:
W. M. HUTCHINGS, 5, BOUVERIE STREET, FLEET STREET, E.C.
1874.

ERRATA.

Page 22, last two lines.—Omit the words enclosed in parentheses.

Page 26, line 20.—For "4·220 lbs. per square foot," read "3·220;" and for "5·080," in the Total, read "4·080."

Page 30.—The folding plan inserted opposite this page illustrates the writer's meaning more distinctly and fully than the smaller plan inserted in the page itself.

Page 33, line 12.—For "passed" read "piped."

INTRODUCTION.

In the latter part of the year 1871, Edward Hermon, Esq., Member of Parliament for Preston, deeply lamenting the frequency of explosions and other accidents in coal mines, and the terrible loss of human life resulting therefrom, determined to offer prizes for the best essays on the means of preventing such calamities. This intention he communicated to the Mayor of Preston, Miles Myres, Esq., as follows :—

"I have felt deeply the terrible calamities that have befallen our mining population of late, and have considered whether anything could be done to prevent these catastrophes. With this object in view, I propose to give a premium of £200 for the best essays on the subject, to be competed for by practical miners in the coalfields of Lancashire and Yorkshire—say, £150 for a first prize, and £50 for a second. In your official capacity as Mayor and Coroner, I am sure you will assist in gaining the attention of those concerned to the subject. I have no doubt we shall find three able and impartial judges to decide on the merits of the pamphlets, one of the conditions being that phraseology and spelling shall not influence the decision, but the prize to be awarded for the most useful and life-preserving suggestions."

The Mayor of Preston readily responded to the call made upon him, and announcements were issued and invitations given to practical men to compete for the prizes. Alexander Staveley Hill, Esq., M.P., Thomas Hughes, Esq., M.P., and Rupert Kettle, Esq., were appointed judges, and, in June, 1873, they gave the following

AWARD.

June, 1873.

We have perused the essays forwarded to us on the subject of the best means of preventing accidents in mines, especially with regard to explosions; and we have agreed upon bracketing as of equal merit for the first prize the essays of "Mr. Robert Eloin," * of 63, West-street, Sheffield; and Mr. William Galloway, of 3, Duke-street, Portland-place, London. These essays are both of very high merit. We place as next to these an essay by Mr. Hopton, of St. Helens; and we are of opinion that the essay by Mr. Bainbridge, of the Duke of Norfolk's Colliery Office, Sheffield, is entitled to high commendation.

Several of the other essays show a great amount of practical knowledge of mining, and we desire to express our gratification at the high order of ability and accurate knowledge of their duties which the essays show to exist among those who manage mining operations, and our sense of the great service rendered by Mr. Hermon in offering this prize, in inducing the writers of these essays to bring their minds to a careful consideration of the subject.

Alex. Staveley Hill.
Thomas Hughes.
Rupert Kettle.

* This was the *nom de guerre* adopted by Mr. Wilfred Creswick, now of 8, George-street, Sheffield.

Upon receiving the award, Mr. Hermon resolved to increase the amount he had originally offered in prizes, and to so re-arrange the amounts as to meet the case of the two essays declared to be of equal merit, and to be entitled to the first prize. He, therefore, wrote again to the Mayor of Preston (Mr. Myres still holding that office) as follows :—

TO MILES MYRES, ESQ., MAYOR OF PRESTON.

"My dear Sir,—'Essays on Prevention of Explosions and Accidents in Coal Mines.' You were kind enough to call the attention of the mining population to my offer of prizes in this matter. Finding you still occupying the same honourable position, I venture to ask you in your official capacity to distribute the enclosed cheques to the parties indicated in the next award. You will remember that I named £200 for this purpose, allotting £150 for the first and £50 for the second prize; but the judges, you will observe, place two as equally deserving a first prize. They then select one as second, and, further, highly commend another essay. I have, therefore, with much pleasure increased the amount to be distributed to £275, that is to say—Two first prizes at £100 each, £200; one second prize, £50; one third prize, £25; total, £275. I hope this will be satisfactory to all concerned. I have only further to express my acknowledgments to you, and my deep obligation to the judges for the labour, care, and time they have bestowed upon the consideration of these essays.—Yours sincerely,

"EDWARD HERMON.

"London, 38, Grosvenor-place, June 12, 1873.

"P. S.—I hope the prize essays may be published, and, perhaps, some of the others, as I entertain a strong expectation that ultimately the mining population will derive the advantage intended by this endeavour to bring out from practical experience the best means for the prevention of explosions and other accidents in coal mines.—E. H."

In accordance with Mr. Hermon's expressed wish the two essays by Messrs. Creswick and Galloway were published in several newspapers, and, together with that of Mr. Hopton, they were published at length in the *Colliery Guardian.* They excited considerable public interest, and as the numbers of the *Colliery Guardian* in which they originally appeared are now out of print, the essays have been reproduced in the present volume in the hope that thus they may be found of service to those engaged in mining enterprise, and contribute in some degree to the economy of human life in underground operations.

Colliery Guardian Office,
5, Bouverie-street, London, E.C.
January, 1874.

Mr. Hermon's Prize Essays.

THE PREVENTION OF ACCIDENTS IN MINES.

MR. WILFRED CRESWICK'S ESSAY,

(Signed "Robert Eloin.")

TO WHICH A FIRST PRIZE WAS AWARDED.

PRELUDE.

An essay on the Prevention of Accidents in Mines would be very incomplete unless referring to the General Rules of the Acts of Parliament, and the Special Rules which are framed with the approval of her Majesty's Secretary of State, and her Majesty's Inspectors of Mines. As each rule is intended to prevent accidents, therefore I subjoin them in their usually printed form (with my remarks on the margin); for the same reason I refer to the number of rules relating to suggestions I make in the course of this essay, it being understood that, as I approve of the subjoined rules, excepting where it is *expressly stated to the contrary, or an explanation is given,* no reference on the margin of any rule signifies my approval of that rule. This essay will also treat on subjects not mentioned in the subjoined rules.

The Laws affecting Coal Mines and Ironstone Mines now require that—

The owner of the mine shall establish such Special Rules for the conduct and guidance of the persons acting in the management of the mine, and of all persons employed in or about the same, as shall be approved by the Secretary of State.

The owner or agent of the mine shall cause the General Rules and Special Rules to be painted or posted on a board, and hung up at the principal office, and at the place where the workmen are paid; and a printed copy of the General Rules and Special Rules shall be supplied to all persons employed in and about the mine who shall apply for such copy. The General Rules and Special Rules so painted, or posted, or printed, shall be renewed and restored as often as the same, or any part thereof, may be changed, defaced, or destroyed. A person who pulls down, injures, or defaces any notice hung up or affixed as required by the Mines Regulation and Inspection Act, will be liable to a penalty of not exceeding forty shillings.

The owner or agent of the mine shall provide accurate maps of the underground workings; and shall in all respects manage the mine, and conduct the proceedings thereof, in accordance with the requirements of the Act 23 and 24 Vict., c. 151, and of the Act 5 and 6 Vict., c. 99.

A

The Mines Regulation and Inspection Act recites that every person employed in or about a mine, who neglects or wilfully violates any of the Special Rules established for such mine, shall, for every such offence, be liable to a penalty not exceeding two pounds, or to be imprisoned, with or without hard labour, for any period not exceeding three calendar months.

The same Act of Parliament also recites that, after the 1st of July, 1861, *a boy above ten years and under twelve years of age* can only be employed in a mine on either of the following conditions, namely:—The owner of the mine shall obtain a certificate from a competent schoolmaster that such boy is able to read and write; or, that in the second and every subsequent lunar month during which such boy is employed, the owner shall obtain a certificate from a competent schoolmaster that such boy has attended school for not less than three hours a day for two days in each week during the lunar month immediately preceding, exclusive of any attendance on *Sundays*.

General Rules, according to the Act 23 *and* 24 *Vict., c.* 151.

The following General Rules shall be observed by the owner and agent:—

See page 29. Explanation.

1. An adequate amount of ventilation shall be constantly produced in all coal mines or collieries and ironstone mines, to dilute and render harmless noxious gases to such an extent that the working places of the pits, levels, and workings of every such colliery and mine, and the travelling roads to and from such working places, shall, under ordinary circumstances, be in a fit state for working and passing therein.

2. All entrances to any place not in actual course of working and extension, and suspected to contain dangerous gas of any kind, shall be properly fenced off, so as to prevent access thereto.

See page 32.

3. Whenever safety lamps are required to be used, they shall be first examined and securely locked by a person or persons duly authorised for this purpose.

4. Every shaft or pit which is out of use, or used only as an airpit, shall be securely fenced.

Drop gates would ensure this in a drawing shaft. See page 37.

5. Every working and pumping pit or shaft shall be properly fenced when operations shall have ceased or been suspended.

All shafts should be lined, unless the inspector directs otherwise. See page 37.

6. Every working and pumping pit or shaft where the natural strata, under ordinary circumstances, are not safe, shall be securely cased or lined, or otherwise made secure.

7. Every working pit or shaft shall be provided with some proper means of communicating distinct and definite signals from the bottom of the shaft to the surface, and from the surface to the bottom of the shaft.

8. All underground, self-acting, and engine planes, on which persons travel, are to be provided with some proper means of signalling between the stopping places and the ends of the planes, and with sufficient places of refuge at the sides of such planes at intervals of not more than twenty yards.

It may, in some cases, be found desirable to have a separate road for persons to travel on. These cases should be left to the inspector, who can decide when such is needful.

9. A sufficient cover overhead shall be used when lowering or raising persons in every working pit or shaft where required by the Inspectors.

See page 36.

10. No single-linked chain shall be used for lowering or raising persons in any working pit or shaft, except the short coupling chain attached to the cage or load.

11. Flanges or horns of sufficient length or diameter shall be attached to the drum of every machine used for lowering or raising persons.

12. A proper indicator, to show the position of the load in the pit or shaft, and also an adequate brake, shall be attached to every machine worked by steam or water power used for lowering or raising persons.

A brake should be fixed to the drum. See page 36.

13. Every steam boiler shall be provided with a proper steam gauge, water gauge, and safety valve.

14. The fly wheel of every engine shall be securely fenced.

15. Sufficient boreholes shall be kept in advance, and, if necessary, on both sides, to prevent inundations in every working approaching a place likely to contain a dangerous accumulation of water.

See pages 33, 34, 35.

Special Rules.

The following special rules shall be observed by the agent, underground viewer, deputies, miners, and workpeople:—

1. The agent and underground viewer shall see that competent deputies are appointed to superintend the underground works and workpeople; that qualified enginemen, banksmen, and hangers-on *(above the age of eighteen years)* are employed to attend the engines and pits; and shall be responsible for the general safety of the works, machinery, ropes, and tackle, and for the adequate ventilation of the mines; and shall *at least once a week* measure with an anemometer the several air currents, and examine the workings of each mine, and see that the air is circulating in a proper manner, and in sufficient quantities to dilute and render harmless noxious gases to such an extent that the shafts, levels, and working places of the mines, and the travelling roads to and from such working

As to the age, see pages 36, 37; for adequate ventilation, see page 29.

places shall, under ordinary circumstances, be in a fit state for working and passing therein; and shall further see that all entrances to any place not in actual course of working and extension, and suspected to contain dangerous gas of any kind, shall be properly fenced off so as to prevent access thereto.

See page 32; also page 22.

2. The agent and the underground viewer shall see that careful and steady men are employed every day and night at the ventilating furnaces or other ventilating apparatus; that an adequate stock of proper safety lamps is provided and maintained; that lampkeepers are appointed to examine and lock them; and shall not allow a safety lamp to be used that has fewer than twenty-eight parallel wires in an inch, or which is not furnished with a lock, shield, and wire picker.

See page 36 about cover.

3. The agent and the underground viewer shall see that an ample stock of good timber, props, bricks, lime, ropes, brattices, air-pipes, and other requisite materials, is always on the premises; and that a sufficient cover overhead is provided for use when lowering or raising persons in a working pit or shaft.

4. The agent and the underground viewer must provide the signals mentioned in General Rule 7, and in Special Rules 49 and 50; and must see that all *underground* self-acting and engine planes on which persons travel are provided with some proper means of signalling between the stopping places and the ends of the planes, and with sufficient places of refuge at the sides of such planes at intervals of not more than twenty yards; and with suitable "*backstays*" or "*drags*" to fix behind the trains going up the planes.

5. The agent and the underground viewer must supply to every person employed in and about the mines a printed copy of the General Rules and Special Rules.

See page 37.

6. The underground viewer shall see that all underground shafts, and openings into the sides of shafts, are securely fenced when practicable. Wherever there is a sump at the bottom of a working pit, the underground viewer must have it safely covered with a scaffold, and see that there is adequate ventilation beneath all scaffolds in shafts.

Tight stoppings, &c. See pages 22, 28.

Roof supports, &c. See page 35.

7. The underground viewer or his deputy shall see that the aircourses and air crossings are kept properly open; that regulators, tight stoppings, doors, and sheets are fixed where needful; that air-pipes, brattices, danger signals, fire boards, packwalls, props, bars, and "sprags" are put where required; that the ventilating furnaces or other ventilating apparatus are constantly attended to; and that the various roads are well

propped and in good repair. The underground viewer or his deputy must remain underground until the day's work is finished, and see that the doors and sheets are closed, *and everything left safe.*

8. The underground viewer or his deputy shall inspect the drawing shaft every morning before any other person goes down; and see that stays, conductors, walling, tubbing, sheeting, and signal apparatus are in safe condition; and shall, on discovering anything wrong, immediately warn the banksman, and order all necessary repairs to be made as soon as possible.

See page 36. Sheeting. See page 37.

9. The underground viewer or his deputy shall *(with a safety lamp)* daily examine every travelling road and working place before the miners and boys descend; and, if he finds the roads and works well ventilated and in other respects *safe,* he shall give a signal to the banksman; but if danger from gas or from any other source be apprehended, he shall not allow a miner or a boy to go there until the danger is removed. No person shall descend the pit (except the agent, underground viewer, deputies, hanger-on, furnace man, and horsekeeper), until it has been signalled from the bottom that *the underground works have been examined.*

See pages 22, 23.

10. Should the underground viewer or his deputy find any part of the works *unsafe,* he shall immediately take up two rails *(as a danger signal)* and put them across each other in the entrances to such place; and all other persons (except deputies) are forbidden to go beyond the crossed rails. The underground viewer or his deputy must also personally warn the workpeople concerning the danger.

See pages 22, 23.

11. The underground viewer or his deputy (in addition to the daily examination mentioned in Special Rule 9) shall, *at least on every alternate day,* visit the ventilating furnaces or other ventilating apparatus; and inspect *with a safety lamp* the places not working, the goaves, abandoned roads, air courses, regulators and air crossings; and if at any time any part be found "*fiery,*" he must personally warn men and boys not to enter it, and fix bars across the entrances, and hang boards with the word "*fire*" painted thereon.

See page 23, about air which has passed over this "fiery" part of mine.

12. The underground viewer or his deputy must see that *locked safety lamps* are used and naked lights excluded whensoever and wheresoever danger from firedamp may reasonably be expected.

See pages 22, 23.

13. The underground viewer shall appoint at least two experienced deputies in each pit when working "*double shift*" —one during the night, the other during the day. The

See pages 22, 23.

deputy on the night shift must examine the roads and works before the miners and boys descend in a morning (as per Special Rule 9); and before leaving the pit he must see the deputy coming on the day shift, and report to him whatever may require attention. The deputy on the day shift must examine the drawing shaft every morning (as per Special Rule 8); and he or some other person appointed by the underground viewer must remain in the mine until the day's work is finished, and see that the doors and sheets are closed, *and everything left safe.*

See pages 22, 23; and page 27.

14. The underground viewer or his deputy must see that all aircourses and air crossings are made and maintained not less than—[the size varies according to different mines]—sectional area; and that air pipes and brattices are not more than ten feet from the face, and brattices not less than eighteen inches from the side.

See pages 22, 23, also page 28.

15. The underground viewer or his deputy must see that the permanent stoppages are well built with stone or bricks and lime, and plastered on one side, and supported by packing or stowing.

See pages 22, 23. See page 31.

16. The underground viewer or his deputy must see that the doors in the main airways are either checked or doubled; that doors which are only used occasionally by himself or deputy are *securely locked;* and that all doors are hung so that they will fall to of themselves.

See pages 22, 23. See page 31.

17. The underground viewer or his deputy must see that doorkeepers are appointed (where needful) to open and shut the doors; and he must not allow a doorkeeper to leave a door until the day's work or night's work is finished, or until another person is appointed to take care of the door.

See page 33.

18. The underground viewer or his deputy must see that sufficient boreholes are kept in advance, and, if necessary, on both sides to prevent inundations in every working approaching a place likely to contain a dangerous accumulation of water.

See pages 22, 23; also page 32, about powder; also about the air passing over this working place.

19. When a working place is approaching "*old hollows,*" the underground viewer or the deputy must see that *locked safety lamps* are used and naked lights are excluded, so as to guard against an influx of firedamp.

See pages 22, 23.

20. The underground viewer or his deputy must see that when a workman is using a safety lamp, a boy or other person does not use a *naked light* in or near to the same place.

It would be well if, in all cases of neglect of rules, the offender were

21. The agent, underground viewer, and deputies shall have control over all persons employed, and the latter must obey their *lawful commands.* The deputies must report to the

agent or the underground viewer any violation of rules or orders, so that steps may be taken to insure discipline throughout the works. taken before the magistrates, not having the option of a fine.

22. A person descending and ascending the drawing pit shall do so in a covered cage and without corf, and under the direction of the banksman or the hanger-on. Any person disobeying their directions, or without authority giving a signal, may be fined or otherwise punished.

23. No person shall go into any other part of the mine than where he works, except by an order of the underground viewer or the deputy, or under the circumstances mentioned in Special Rule 24.

24. A person discovering any stoppage or derangement of the ventilation, injury to air crossings, regulators, doors, sheets, stoppings, brattices, or airpipes, finding any obstruction in an aircourse, weakness in the roof, deficiency of timber, a dangerous feeder or accumulation of gas or water, or observing wood or mineral on fire, or a naked light where safety lamps are ordered to be used, must immediately give notice to the men and boys in that part of the mine, and to the underground viewer or the deputy, so that speedy measures may be taken to remedy the evil. See pages 22, 23.

25. The miners must build good pack-walls, and set a sufficient quantity of props and bars for safely supporting the roof; and add to them or renew them when necessary, or when told by the underground viewer or the deputy. See page 35.

26. The method of holing or baring the coal or other mineral shall be ordered by the underground viewer or the deputy; and the miners must set a short prop or "*sprag*" *at least every two yards*, to prevent the undermined coal or mineral from falling unexpectedly. See page 35.

27. A person employed in strait work must not leave coal, slack, or other mineral in or near to the face; and must not leave a corf or other obstruction in the air current. See pages 22, 23.

28. A person passing through a door, or a sheet, must see it closed again without delay; and any person injuring a door or a sheet, or leaving either open, breaking down a stopping, or a brattice, interfering with a regulator, air crossing, or airpipe, obstructing an aircourse, or (without authority) going beyond or removing a danger signal or a fireboard, may be fined or otherwise punished. See pages 22, 23. See remark at rule 21.

29. When a person is ordered by the underground viewer or the deputy to put out a naked light and use a safety lamp, he shall immediately do so, and continue to use the lamp until he is ordered otherwise. See pages 22, 23. See page 32.

See pages 22, 23.
See page 32.
30. No person shall try the workings or the goaves for firedamp with a *naked light;* and no person shall smoke tobacco, or take a naked light, match, or candle, where safety lamps are ordered to be used.

See pages 22, 23.
31. No person shall put a naked light in the goaf, or near to the roof, or behind the props; but if it be necessary to shelter a light from wind, a shade must be used. A person, when giving up work, shall not leave his light burning in the mine.

See pages 22, 23.
See page 32; also about the air that has passed over this place.
32. A safety lamp must be frequently noticed; and, if it shows any appearance of firedamp, the person using it must carefully draw down the wick with the picker, cease working, leave the place, and immediately inform the underground viewer or the deputy.

See pages 22, 23.
See page 32.
See remark at rule 21.
33. A person wilfully kindling a feeder of gas, or negligently having the gauze of his safety lamp full of fire, or unlocking or unscrewing the gauze, or blowing out the flame, or lighting tobacco or other substance at the gauze, or damaging or improperly using the lamp, or leaving it in the works when he has ceased using it, may be fined or otherwise punished.

See pages 22, 23.
See page 32.
34. When a safety lamp becomes unfit or unsafe for use, by having oil spilled upon the gauze, or in any other way, the light must be put out by drawing down the wick, and the lamp taken to the lamp-keeper.

See pages 22, 23.
See page 32.
35. No person shall "*blast*" coal or other mineral where safety lamps are used, except by order of the underground viewer.

36. No person shall take blasting powder into the mine in large quantities, or leave it exposed or in a dangerous manner, or use it carelessly. Powder must be enclosed in cartridges, or in a flask or horn; and a "shot" that has missed fire *must not be drilled out.*

37. Persons not authorised by the agent or the underground viewer are forbidden to ride on any underground road.

This question only indirectly affects safety, but I think no boy under 12 years of age should work in a mine.

38. Boys *under twelve years of age* are not to enter the mine except on the conditions mentioned in the Act 23 and 24 Vict., c. 151. A person evading this rule, or misrepresenting the age, may be fined according to Act of Parliament.

39. Females are not to enter the mine, and no person unless employed at the mine shall go therein, or enter the engine-house, or remain on the pit bank, without the permission of the agent or the underground viewer.

40. No intoxicated person shall enter the mine, or remain in or about the premises.

41. The pits are to be ready to draw coal or other mineral at such time as the agent or the underground viewer may appoint.

Enginemen, Banksmen, and Hangers-on.

42. A person *under the age of eighteen years* must not act as banksman or hanger-on, or have the charge of a drawing engine; and persons who desire to learn the working of engines must first obtain the agent's consent. See pages 36, 37

43. Every morning, before the drawing engine is started, the engineman shall see that the engine, boilers, machinery, drums, ropes, brakes, indicators, and signal apparatus in the engine-house, are safe and in good working order. *He shall then run the ropes and loaded cages twice up and down the pit before any person descends or ascends.* Persons are to descend in a covered cage and without corf. See page 36.

44. The engineman shall not allow any person but himself to interfere with the drawing engine or machinery at any time, without leave from the agent or the underground viewer. The engineman must gently lift the cage from the pit bottom, and carefully drive the engine *at a slow speed*, and remain at the handle and at the brake when a person is in the shaft. He must also pay particular attention to the indicator and signals; and if he perceives anything wrong in the pit or the machinery, he must instantly stop the engine, and not proceed until the signal "*to go on*" is given, or until the defect is put right. See page 36.

45. The engineman shall keep the drawing engine clean, and examine and oil the machinery and engine, and attend to the ropes, drums, boilers, steam gauges, water gauges, safety valves, and feed pumps, with a view of keeping them in good and safe working condition; and if he sees anything amiss he must immediately report it to the agent or to the underground viewer, so that it may be put right. He must clean the boilers *at least once a month;* and he shall not alter the weight on a safety valve without leave from the agent. He must see that the ropes are securely attached to the drum, and when either cage is at the bottom of the pit, there must not be less than two rounds of rope upon the drum. See page 36.

46. The engineman must be at the drawing pit at such time as the agent or the underground viewer may appoint, to let down the underground viewer or the deputy. The underground viewer, deputy, and banksman must report to the agent every instance of neglect on the part of the engineman. See pages 36, 37.

47. When the drawing engine ceases working at night, or at any other time, the cages and landing doors must be left so See pages 36, 37.

as not to impede the ventilation. The engineman and banksman are required to obey this rule.

See pages 36, 37.

48. The walling and timbering of the pumping pit, and the engine, boilers, pumping apparatus, stages, cradles, man-loops, ropes, chains, gin, and capstan, shall be examined *at least twice a week* by the pumping engineman, who must report without delay to the agent, or to the underground viewer, any defect or weakness that he may discover. The pumping engineman must clean the boilers *at least once a month*, and he shall not alter the weight on a safety valve without leave from the agent. The engineman must put the fencing round the top of the pumping pit when operations shall have ceased or been suspended.

See pages 36, 37.
It is advisable to have a bell at the pit top, actuated by the same impulse as that in the engine-house, so that the banksman's attention be more particularly called to each signal.

49. There will be two bells *or other signals* in every drawing engine house; one connected with the drum shaft, to denote when the engineman must cut off the steam; the other will be connected with the drawing pit bottom; and the hanger-on and the banksman shall give the following signals, which must also be carefully observed by the engineman:—

When the cage is to be raised from the pit bottom, the hanger-on must strike the signal	ONCE.
When a person is about to ascend... ...	THREE TIMES.
And the banksman must answer (before the person enters the cage) by striking the signal...	TWICE.
When the person is ready, the hanger-on must strike the signal *when to go on* ...	TWICE.
To stop the cage, if in motion	ONCE.
To lower down the cage	TWICE.
To raise up, after being stopped	FOUR TIMES.

Fixed in the pit porch.

See pages 36, 37.

50. There will also be a bell *or other signal* in every drawing pit porch, and connected with the pit-top; and the banksman shall signal to the hanger-on as follows:—

When a person wants to descend, and the hanger-on is to send up the *empty cage*, the banksman must strike the signal ...	THREE TIMES.
And the hanger-on must answer (before the person enters the cage) by striking the signal...	TWICE.

See pages 36, 37.

51. The engineman, banksman, and hanger-on must use great caution and pay particular attention to the signals when a person descends or ascends the shaft; and if they perceive

anything wrong, they must immediately try to rectify it. They must not permit a person to enter a cage after the signal "*to go on*" is given. They must not allow a person to be lowered or raised *without a sufficient cover overhead, or by a hinged or coupled rope.* They must not let a person descend or ascend when an incline rope or chain is working in the shaft, unless such rope or chain is "boxed off."

52. The banksman must be at the drawing shaft at such time as the agent or the underground viewer may appoint, and provide a sufficient number of lights. Before the engine is started he must see that the pulleys, ropes, cages, chains, and landing doors or frames are in safe working condition. He shall not allow a person to descend or ascend the shaft until the *ropes and loaded cages have been twice run up and down;* and if any weakness or defect is found in anything belonging to the shaft, or in the engine, machinery, ropes, or tackle, he must not permit persons (except those employed to repair the damage) to descend or ascend until it is made secure. The banksman shall then signal to the engineman to let down the underground viewer or the deputy; and he must not allow any other person (except the deputies, hanger-on, furnaceman, and horsekeeper) to descend until it has been signalled from the bottom that *the underground works have been examined.* Persons are to descend in a covered cage, and without corf. See pages 36, 37.

53. The banksman must not allow a boy *(under the age of twelve years)* to enter the mine without an order from the agent. See page 37.

54. The banksman must not let a stranger go into the mine without an order from the agent or the underground viewer; he shall not allow an intoxicated person to descend; he must not permit any one but himself to give signals at the pit top, or let inexperienced persons land the corves, or put them into the cages. He must listen at the pit top when a person is in the shaft, and instantly signal the engineman *to stop the engine in case of alarm;* and he must remain at the pit top until all the men and boys are drawn out. See page 37.

55. The engineman, banksman, or hanger-on shall not let a boy *(under fifteen years old)* go down or up the pit unless accompanied by a man; and shall not permit more than *three persons to descend or ascend at once* in a single cage, nor more than six persons in a double cage, nor more than two persons in a cage where a gin is used. A person shall not descend when another is ascending, or the contrary; and shall not ascend or descend with or against a corf or a *loaded cage;* and shall not take with him rails, props, tools, or other bulky materials; and shall not get into or out of the cage until it is at rest. See pages 36, 37.

See pages 86, 87. 56. The banksman must frequently look at the pit pulleys, ropes, chains, cages, and landing apparatus during working hours; and, on observing any defect or weakness, he must immediately inform the agent or the underground viewer, so that it may soon be repaired. The banksman must see that wire ropes are coated with oil or grease; and whenever a rope requires "hinging," "capping," or "coupling," it must be done by a fitter, smith, or other competent person.

Drop gate will ensure the top of the drawing shaft always being fenced. See pages 86, 87.

57. The banksman must cause the pulleys and rollers to be oiled daily, and see that materials on the pit bank are placed safely, conveniently, and in order. He must also put the fencing round the top of the drawing pit when operations shall have ceased or been suspended.

See page 87. 58. If a person receives an injury in or about the mine, the banksman must send instantly for a surgeon, or send the injured person to the infirmary.

See page 87. 59. The head banksman shall have the control of the drawing pit top, and of the assistant banksman (subject to the agent), and he must report to the agent any disobedience on the part of the miners or others.

See page 87. 60. The hanger-on shall have the control of the drawing pit porch (subject to the underground viewer). He must be at the pit at such time as the agent or the underground viewer may appoint, and go down before the miners. He must be in the porch and attend carefully to his duty when a person descends or ascends the shaft, and remain there to see all the men and boys safely into the cage and up the pit at the close of the day. He must himself give the signals and also obey Special Rules 49, 50, 51, 55, 61, and 62.

See page 87. 61. The hanger-on must see that persons ascend the shaft in a covered cage and without corf. He must report to the underground viewer every person that gives a signal or disobeys his directions; he must remain at the signal when a person ascends or descends; he must not allow inexperienced persons to put corves into or take them out of the cages; and he must see that coals, or other minerals or materials, do not project over the cage.

See page 87. I think the minimum strength of this cover might well be mentioned here.

62. Wherever there is a sump at the bottom of a drawing shaft, the sump must be securely covered with a scaffold; and when the water is drawn out of the sump, the scaffold must be replaced immediately by the hanger-on, who must see that *the sump is always covered* when the mine is at work, or when a person ascends or descends the shaft.

Furnacemen, Lampkeepers, and Doorkeepers.

63. The ventilating furnaces, or other ventilating apparatus,

must be attended to constantly both day and night; the furnacemen must change at the furnace or other ventilating apparatus; and, in case of sickness or unavoidable absence, they must give early and sufficient notice to the underground viewer, so that a substitute may be provided.

64. The furnacemen must constantly keep clean brisk fires; the fires must not be smothered with fuel; ashes are not to accumulate upon or under the bars, but when cold they must be removed; the passages about the furnace are to be kept clear and in good order by the furnacemen, who must obey the directions of the underground viewer.

65. A lampkeeper must not allow a safety lamp to be used that has fewer than twenty-eight parallel wires in an inch, or which is not furnished with a lock and wire picker. See page 32.

66. The lampkeeper must see that each safety lamp, when given out for use, is in good working order, clean, well trimmed, *securely locked*, and in proper repair; and that each *Davy lamp* is protected by a shield. See page 32; also pages 22, 23, about description of safety lamp.

67. The lampkeeper must inform the agent or the underground viewer whenever he finds that a safety lamp has been wilfully or negligently damaged, or carelessly or ignorantly used. See page 32.

68. A doorkeeper must open his door only when a corf or a person approaches, and instantly close it when the corf or the person has passed through. He must never allow the door to remain open or to be propped or fastened back unless told to do so by the underground viewer or the deputy. See page 31.

69. A doorkeeper must not leave his door until the day's work or night's work is finished, or until another person is appointed (by the underground viewer or the deputy) to take care of the door. See page 31.

Enginemen, Brakesmen, Inclinemen, and Train Boys on Engine Planes and Self-acting Inclines.

70. The engineman must diligently and carefully attend to the working of the engine and machinery. He must examine the engine, boilers, drums, ropes, chains, shackles, and other apparatus every morning before commencing work, and *at least twice* during the day; and, if he find any weakness or defect, or apprehend any danger, he must immediately inform the agent or the underground viewer. The engineman must clean the boilers *at least once a month;* and he shall not alter the weight on a safety valve without leave from the agent.

71. The brakesman must be cautious in conducting the rolleys or the wagons; and the inclineman must see that the

wheels are sound, the axles greased, and the chains securely coupled.

72. No person shall ride on the rolleys or the wagons without the consent of the agent or the underground viewer. The brakesman and inclineman must see that this rule is obeyed.

73. On all *underground* self-acting inclines and engine planes on which persons travel there will be provided some proper means of signalling between the stopping places and the ends of such inclines or planes; and the following signals must be given by the trainboy or other person appointed by the underground viewer:—

When the train is to be drawn up, the signal is to be struck ... ... THREE TIMES.

When the train is to be lowered down ... TWICE.

When the train is to be stopped ... ... ONCE.

74. The *underground* engineman, brakesman, inclineman, and trainboy must, at all times, pay strict attention to these signals, and to any deviation from the regular course of the train or the machinery; and if they perceive anything wrong *they must immediately try to stop* the train and the machinery until the defect is put right.

75. The trainboy (or other person appointed by the underground viewer) must fix a "*backstay*" or "*drag*" behind every train going up the engine plane.

Concluding Special Rules.

76. No person in a place of trust shall absent himself from duty or appoint another person to do his work without the sanction of the agent or the underground viewer.

77. Wages are to be paid in money at the "*pay office*" of the mine.

78. The agent, underground viewer, deputies, and other officers are particularly enjoined to comply with and to enforce the rules.

Special Rules for Sinking Pits at the [ ] Colliery.

1. The agent and the enginewright will direct and be responsible for the proper and safe ventilation and management of the sinking operations, and for the proper and safe construction and repair of the engines, boilers, capstans, gins, machinery, pumps, drifts, and pits.

Enginewright.

2. The enginewright must see that a proper set of distinct signals, to be strictly observed by the enginemen, banksmen, and sinkers, are painted on a board and placed in the engine-house and at the top of each sinking pit.

3. The sinking tubs, water tubs, ropes, chains, pulleys, bolts, shackles, and hooks, are to be examined daily by the enginewright; and if found defective, he must see that they are immediately made secure.

4. The engines, gins, capstans, machinery and boilers, and all parts connected therewith, are to be examined daily by the enginewright; he must also daily observe the fastening of the ropes to the drums; and whatever is wrong or unsafe in any of the before-mentioned machines or implements or arrangements he must immediately rectify, or stop the whole work.

5. The enginewright must see that the boilers are well cleaned at least once in every three weeks.

Enginemen and Stokers.

6. The engineman must not allow any one but himself to work the engine, except when ordered by the agent or the enginewright.

7. The engineman shall not move the engine, except by an order or a signal from the banksman; nor shall he leave the handles or the brake whilst the engine is in motion; and no other person shall touch the handles or the brake, unless authorised by the agent or the enginewright.

8. When the ropes are properly adjusted, the engineman must run them twice up and down the shaft with a loaded tub, before any person descends or ascends.

9. The engineman must steady the rope before the tub or load leaves the top or bottom of the shaft.

10. The engineman must lower and raise persons and materials in the sinking pit with the greatest possible caution.

11. The stoker must act carefully under the control of the engineman (subject to the agent and the enginewright).

12. The stoker and the engineman must see that the boiler-feed is so regulated as to maintain a sufficient supply of water in the boilers.

13. The steam gauges, water gauges, and safety valves are to be particularly attended to by each stoker and engineman during their shifts, and are not to be interfered with by any other person, without the authority of the agent or the enginewright.

The engineman must not leave his engine whilst men are in the shaft.

Banksmen.

14. The banksman must not leave the pit top while men are in the shaft.

15. The banksman shall give a distinct signal to the sinkers in the shaft when the descending tub is six yards from the bottom; and he shall also give a signal to the engineman regularly and properly.

16. He shall securely tie to the tub-bow all sinking tools or other gear, and shall safely sling timber or other bulky articles.

17. He must always fasten the bridge over the pit top before landing the tubs or materials; and when sending bricks or building materials down the pit, he must load them below the top of the tub.

18. The banksman must also put the fencing round the top of the pits when operations shall have ceased or been suspended.

Chargemen and Sinkers.

19. One man in each shift will have the entire charge of the pit bottom (subject to the agent). This person, called the chargeman, must carefully examine the sides of the pit at the beginning of every shift, and remove all loose pieces; he must also, after the work has been standing or the men have been out of the bottom, examine the ventilation and other arrangements for safety, as directed by the agent.

20. The chargeman must see that the tubs are properly loaded and steadied, and that the outside of them is free from stone or clay, before sending them up the pit: he shall also see that tools and other gear are securely tied to the tub-bow before they are sent up.

21. Not more than four persons at once shall descend or ascend the sinking pit.

It would be better to have the head of the rammer made of brass or copper.

22. The sinkers must not ride in the shaft with or against a loaded tub. They must ram shots with stuff that will not strike fire with the rammer; and shots which miss fire must not be drilled out. The sinkers must load the tub (when sending material up the shaft) below the top of the tub; and they must wall or line the shaft sides at such times and in such manner as the agent shall direct.

23. If a shot has missed fire, the sinkers must not go back to it for at least two hours after they have come "*to bank.*"

24. Every person in or about the sinking pit and premises must obey the orders of the agent and the enginewright.

ON THE PREVENTION OF ACCIDENTS IN COAL MINES.

In this essay I will treat on the various causes of accidents to which miners are subject, under the following heads, viz:

I.—Loose Discipline.

II.—Explosions of Firedamp or Bi-hyduret of Carbon.

III.—Suffocation from the Effects of Gases unfit for the Support of Life.

IV.—Inundations or Flooding of Workings by a Sudden Influx of Water.

V.—Falls of Coal or Roof.

VI.—Accidents in Shafts.

I.—LOOSE DISCIPLINE.

This is so universal, and such a fertile cause of accidents, as to take my first attention, for whilst discipline is neglected accidents from all causes will occur, no matter what other precautions are taken. It proceeds from various causes, which I will enumerate thus:—

(A.) A manager who does not thoroughly understand the working of a colliery, and who will have no competent mining engineer or other person to take charge of the workings.

(B.) A manager, or engineer, or other person thoroughly understanding the workings of a colliery, and giving the most proper orders, but not seeing that they are duly carried out.

(C.) Shortness of capital, which I may divide thus:—

(C′.) Those who have not got the money.

(C″.) Those who, having plenty of money, will not be induced to spend more than is absolutely necessary to get the maximum quantity of coal, and who sacrifice safety by attempting to barely clear themselves from censure in case of accident.

(D.) The practice of giving colliers wages according to their tonnage, without some constant supervision, which practically causes the defect mentioned under head (C″), placing time for money.

Remedies must be applied to all these causes, as follows: To remedy cause (A) a competent manager must be supplied; but under head (B) it appears that a manager must possess more than mere knowledge, for he must also have firmness and energy; and under head (C) it appears that, let the manager combine both knowledge and energy, they are of no avail without capital; therefore I am inclined to think that the person engaged in the commercial department should not take charge of the colliery department, because if he does safety is likely to be sacrificed, in order that he may show a good balance sheet.

A man may have a good knowledge of mining, but, at the same time have no energy or firmness, and so not be fit to see his orders carried out, therefore an examination of manager cannot *ensure* competent management, and I am of opinion that if the remedy for cause (D), to be next described, be carried out, the inspector will be able to judge as to the management, and act accordingly.

Remedy for cause (D). Anyone acquainted with the character of colliers would not for a moment entertain the idea of employing them by the day, and even if that system were adopted the remedy would only be partial, owing to the ignorance and slothfulness of some men of that class. I should advocate the organisation of a competent staff of overlookers, say one for every ten or twenty men employed in getting coal (the number to be varied according as the colliery is more or less dangerous), from whom no work would be required during the working hours of the men whom they overlook, except seeing that the rules and by-laws of the colliery, and the orders of the manager or engineer, were carried out to the letter by the men under their charge; and I would make such overlookers remain with the men during the working hours, and be responsible for their safety. Every short period (say, once a week) each overlooker should meet the manager, or person duly authorised by him, at the colliery office, and give his report, which must be entered in a book, laid out in tabular forms, and kept there for that purpose. Perhaps the following form may convey a better idea of my meaning. The rules of the colliery should be *read* over to the overlookers, deputies, and fire-triers once every month, and *explained* if necessary.

DATE OF REPORT.

Period over which the report extends, from to
Name and address of overlooker.
Portion of mine overlooked.
Number of men and boys under charge of overlooker.

Questions.	Answers. Yes or No.	Describe to what extent.	Remedy applied.	The result.	Remarks.
1.—Has any gas been found in your portion of the mine?					
2.—Has the roof been on the weight?					
3.—Are locked safety lamps used? ...					
4.—Have you been well supplied with					
Props?					
Sprags?					
Lids?					
Brattice?					
5.—If you have any complaint to make against any man, or men, state it in the remarks; also the name or names of the offending person or persons					

This form might easily have a better one substituted, but if it has conveyed my meaning it will have answered my purpose.

The quantities of air in the main intake and return, and also in each split, should be entered along with these reports, which must be open to the Inspector at any time, who will then be able to judge as to the fitness of the management.

The overlookers (if more than one) must not overlook the same lot of men between each report; thus, for example, if there are ten overlookers, every eleventh report would be on the same lot of men by the same overlookers; this, I think, will prevent overlookers becoming negligent, as they will then check one another.

Separate copies of the reports of each overlooker should be fixed to the head gear of the colliery or other suitable place, adjacent to which the report refers, to enable all the men and boys to see exactly the state of the pit; and a time should be fixed when they may make complaints against any false report, and can see that the necessary alteration is made, after which each overlooker must keep his own report, so as to check the colliery report book in case of need. There should be a special rule made for these overlookers. The questions in the tabular form must refer to everything which might cause an accident in a coal mine; thus, amongst other instances in the tabular form already drawn up, there is no mention made of danger from blasting powder, and, doubtless, there are many other omissions, to prevent which an approved form should be printed for all collieries, and every question should have an answer affixed to it.

These overlookers* are not at all intended to take the place of the underground viewer (or the fire-triers and deputies* as now required), who will have the same authority over everyone in the workings as at present, and I recommend that he should have a diary kept in a cabin underground, in which the fire-triers and deputies must enter daily reports, so that he may at once go to any particular place requiring his attention.

Collieries should be surveyed and plotted on a plan kept for that purpose once every half-year, and the plan should not be considered complete until the correct courses of the air, or ventilating currents, and all doors, stoppings, and slits, are marked thereon.

If the number of qualified persons necessary to enforce discipline be insufficient, then discipline will no longer exist. Her Majesty's Inspectors of Mines are not, in my opinion, sufficiently numerous, and I think there should be one inspector for about every 100 collieries: this would ensure every colliery a visit from the inspector of that district twice a year.

I think that in case of the inspector, and manager, or engineer, &c., disagreeing about any matter considered needful for the safety of the miners—of course, excepting a breach of the rules—such disagreement should be decided by reference.

The inspector's sanction in writing on the plans should be obtained in respect of all permanent new arrangements connected with the safety of the

* Perhaps the word "deputies" would be better than "overlookers," and if preferred can be read as such; but as it avoids confusing the deputies as now required with those now suggested, I prefer the word as written.

miners, and not actually mentioned in the rules, and no such arrangement should be altered without the inspector's sanction; this would prevent many great blunders which are now being continually committed.

II.—EXPLOSIONS OF FIREDAMP OR CARBURETTED HYDROGEN GAS.

Before seeking the remedy, I will endeavour to examine into all cases (if possible) leading to explosions of this gas. The different natural agents tending to change the air in a mine—otherwise good—into an explosive mixture, I will distinguish thus:—

(A.) *Sudden outbursts of gas.*

(B.) *Gradual filtration of gas* into "wastes" or other excavated portions of the mine.

(A.) *Sudden outbursts of gas.* There appears to be a portion of gas in the mineral kingdom which is retained only under great pressure; now, if this be so, how will extracting a stratum—say, a seam of coal—affect this gas? The following sketch will render my explanation intelligible:—

Assumed Section of a Coal Field.

Surface of the earth, called (A)..........................

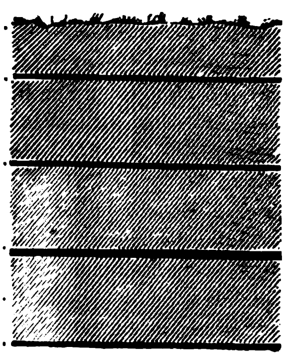
Coal stratum, called (B)..........................

Coal stratum, called (C)..........................

Coal stratum, called (D) ....

Any impermeable stratum, called (E) ....

Coal stratum, called (F) ....

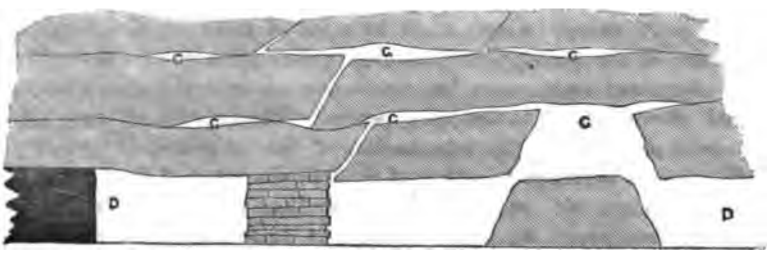


B, C, D, F, represent coal, or any other strata liable to give off explosive gas on a reduction of pressure. Say that D is the coal being wrought, the result of extracting which is that the pressure on strata C and F is greatly reduced, or the pressure necessary to retain the portion of gas—before alluded to—in the coal of either seam, is now represented by the resistance offered to it by the strata between C D and D F respectively, and not, as heretofore, by that between C A and F A respectively. The seam B may, or may not, be affected by the extraction of D.

From this theory, outbursts of gas are explained as follows:—The seam D being wrought, the pressure necessary to retain all the gas hitherto existing in seams C and F is reduced, and the liberated gas will find its way, against the least resistance, in this case, towards D. I will take first the gas issuing from C; all the cracks and interstices above D are, if the gas be sufficiently plentiful, filled with it, the roof of a mine being always in a more or less shattered condition.

The following sketch will, perhaps, give a better idea of my meaning:—

Assumed Section of a Mine.



D, D, represent the wrought portions of the seam of coal. G, G, represent the cracks and interstices.

If this gas were regularly given off into the wrought portion of the seam D, the loss of life by explosions, from its ignition, could easily be remedied by ventilation; but it assumes, suddenly, a very dangerous aspect when the roof of the mine settles, or, technically, "weights," for the interstices, in which the gas is stored, are compressed, and it is forced in a body into D; a fall of the atmospheric pressure will also cause this gas to be given off in increased quantities; besides this, a portion of the gas made from the seam D will also take refuge in the roof, and this, without the aid of the gas from C, will be dangerous when the roof "weights" or the barometer "falls."

I will now take the gas liberated from F, which will force its way against the least resistance until it reaches an impermeable stratum (if such exist) between F and D (called E) of sufficient strength to resist the pressure of the gas in its then attenuated form, under this stratum it will remain until one of the following events happen:—

(A′.) The atmospheric pressure is reduced.

(B′.) In the course of working the stratum D, the mine extends over a place, perhaps it may be a "slip," in the retaining stratum (E) too weak to hold down the gas, and the result is an outburst.

(C′.) As the workings in D extend, the boundaries of the solid coal become further and further apart until, as in the case of a bridge, the same section of girder will not sustain the same weight as the length or span of the bridge is increased, so the stratum (E) will not have strength to resist the same pressure as when the boundaries of the solid coal were nearer together, though, doubtless, in the case of E, there will certainly be intermediate supports as the roof of D settles, and these may, to a certain extent, counterbalance the danger from this cause.

(D′.) A time will arrive when the settlement of the roof will take place; this will cause a pressure on the floor of D at different places, and again compress the strata (naturally to some degree puffed up by the liberated gas from

F) below, through which the gas has percolated, and now exists in a free state; thus the gas is forced to occupy less space, and, consequently, must exert a greater pressure; and if the stratum E, with its superincumbent weight between E and D, be not strong enough to resist this pressure, an outburst of gas is the result.

(B.) Gradual filtration of gas into "wastes" or other excavated portions of the mine. The gas may come from the coal being wrought or otherwise, and gradually fill the "breaks or cracks in the roof, and the old workings (or, perhaps, the workings in use), until by a fall of the roof, or a "weight," or a reduction of the atmospheric pressure, or derangement of existing ventilation, it altogether overpowers the ventilation, so that the air in the mine is charged with fire-damp to the firing points. The ignition of these explosive mixtures is produced by the introduction of fire (unprotected by safety-wire gauze) into the workings by either of the following means:—

(A.) By human aid, such as lighted candles, matches, blasting powder, defective safety-lamps, &c., and, perhaps, in some cases, by sparks rapidly produced from a pick, or metal tool, striking against a hard substance.

(B.) By spontaneous combustion of substances met with in mines, and an explosion is the result.

I will now treat on the prevention of explosions. Doubtless the primary reason of all explosions of fire-damp in colliery workings is because there is not sufficient air to render it harmless (there will be no explosion unless the carburetted hydrogen equals one-fourteenth the volume of air); the question arises, is it not possible to supply this want of air in all cases? If the roof and floor of all mines were perfectly smooth and regular, and could be so maintained, I should say it was possible to produce such a ventilation as would render all explosions impossible, for then the only gas to be dealt with would be that regularly issuing from the seam of coal being worked, increasing only with the extension of the working faces and a "fall" of the barometer, but no such roof and floor are ever to be found, and the liability of either to break renders the ventilation of coal workings, especially deep ones, so subject to outbursts of gas from roof and floor as to make me despair of ever getting sufficient atmospheric air through the galleries of mines to mix with and dilute the firedamp given off in these outbursts, not even if the air travelled at a fabulous rate, for the liberated gas and the ventilating air will both travel at the same speed, for they will both be influenced by one motive power. There are even some cases where the gas is given off in such volume as, for a time, to prevent any atmospheric air from going into the mine, because the partial vacuum at the upcast shaft (necessary to produce circulation of air through the mine) is supplied by the outbursting gas.

Seeing that ventilation alone cannot prevent outbursting gas from charging the air in the mine with firedamp to the firing point, the remedy must be looked for elsewhere; and I think the following suggestions, if carried out, would be effective. To prevent accidents from the gas in the roof, the overlookers, in addition to the fire triers, &c., as specified in the Special Rules (a printed copy of which, as used at the Sharlston Coal Company's collieries, is annexed to the essay) Nos. 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 19, 20, 24, 27, 28, 29, 30, 31, 32, 33, 34, 35, should constantly examine the breaks in the roof with a safety lamp, and after the first appearance of gas no naked light must ever be permitted in the air which has passed over the place where the gas has been seen, but locked safety lamps must be used. I should recommend those known as "Stephenson's" lamps (the light being put out on the lamps being unscrewed) as being the safest. Moreover, gas having once made its appearance in the roof, if a weight comes on, the men over whom gas from this place must pass should leave the pit whether safety lamps are used or not. The barometer should be observed every morning, and the overlookers made acquainted with the relative pressures. As colliery workings get deeper they will be more liable to outbursts from the floor, owing to the gas having been retained under greater pressure.

The gas under the floor (already mentioned) is the most serious enemy to contend against, so many causes of every-day occurrence tend to liberate it suddenly; and as it has been retained under pressure, it generally (when liberated) completely masters the ventilation. The only plan of effectually dealing with it is to keep it under control by liberating or tapping it; this would, no doubt, prove to be very expensive, and might be done either by making deep boreholes in the floor of seam D (but, in this case, the gas would find its way into the workings, which is very objectionable), or else, and, in my opinion, much the better plan, by sinking the shafts below seam D a suitable distance—say 10 yards—and driving galleries in a coal stratum, if possible, under the seam D; these being pushed on vigorously, and the whole of the coal seam D (to be worked) undermined by the galleries which are connected with the upcast shaft, they would act as drains for the pent-up gas, which might otherwise burst through the floor of D.

It would seem from the foregoing remarks, that when an under bed or stratum has been wrought, the liability to outbursts of gas from the floor of upper workings, provided the line of least resistance is not in the direction of the upper workings (see p. 20), is greatly reduced, if not altogether prevented; from this it may be inferred that large outbursts of gas only take place in the lowest seam being worked, and that those seams lying about will be free from outbursts, provided the gas in the lower seam has free vent.

The gas gradually filtering into the "wastes" or other excavated portions of the mine must, and can, be removed by ventilation as it enters the workings, and it is highly important that the best ventilating apparatus is used, so as to produce the largest volume of air through the mine to overcome the resistance offered to it by friction and other causes.

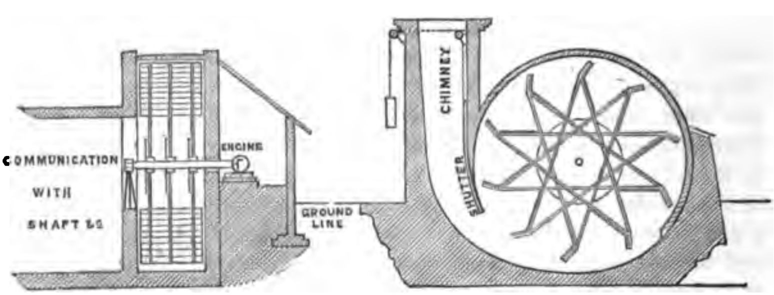
It may be well to suggest here a plan of periodically clearing (to a certain extent) the workings of a mine from gas—stop up the intake airway and cause the ventilating apparatus (not ventilating furnace) to continue working, and so exhaust air and gas from the mine; much damage to the roof, &c., may or may not result from this mode of procedure. I do not pretend to recommend this plan, never having seen or heard of it before, but merely mention it here to be taken for what it is worth.

Ventilation may be produced either by cooling the downcast air, or heating the upcast, or both; or it may be produced by mechanical contrivances, producing a partial vacuum at the upcast, or by forcing air into the downcast.

I do not consider that in this essay it is requisite to enter into the theories and merits or demerits of all the means of producing ventilation, but will take it as an established fact that the greatest effective or useful power, producing the most regular current of air, is obtained by exhausting it from, instead of forcing it into, the workings, and, therefore, the cooling (generally water) and forcing machines should not be used as the only motive powers for producing ventilation, but they may be used as auxiliaries to exhausters in some cases.

The furnace for producing ventilation, as arranged at present in skilfully managed fiery mines, is fixed about seventy yards from the bottom of the upcast shaft (in the same plane as the coal stratum); the heat, smoke, and products of combustion, are conducted to the shaft by a drift inclined at about one in three, so that it enters the shaft about twenty-three yards above the coal stratum; this furnace is supplied with air direct from the downcast shaft, which is, consequently, free from an explosive mixture; the return air or that which passes through the mine, enters the upcast shaft on a level with the coal, so that it does not come in contact with the flame from the furnace. Proper precautions are taken to guard against the seam of coal taking fire at the furnace.

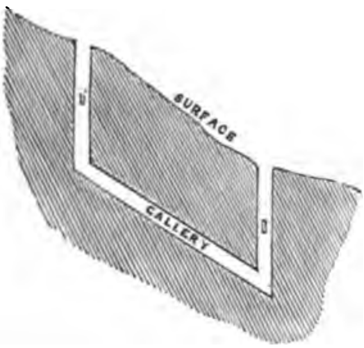
The fan best adapted for exhausting air from a mine seems, from experiments, to be that invented by M. Guibal. It consists of a number of blades about 15 ft. long, and about 8 or 10 ft. wide, fixed on a shaft by means of struts and ties, which occupy about one-half the length of each blade, which half is purposely left open (or unlagged) for the air to enter the fan chamber —the other half, or the blade proper, is covered (or lagged) and gives motion (centrifugal) to the air. The following sketch will illustrate this fan much better than my imperfect description :—



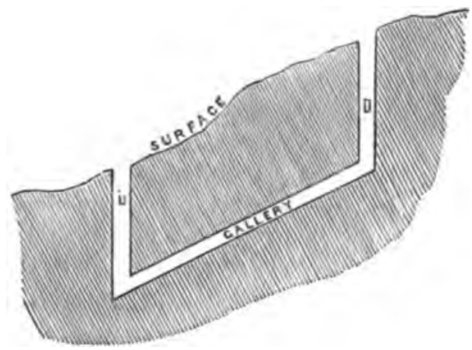
It is found to produce a greater ventilation, with a less consumption of coal than any other apparatus, and from its simplicity of construction is not liable to get out of order.

Perhaps a few pages devoted to the theory of furnace ventilation, and a comparison between fan and furnace will not be out of place here. The following diagrams are necessary to fix the idea:—

No. 1.



No. 2.



In both diagrams D represents the downcast and U the upcast shafts, under different circumstances.

The process of furnace ventilation is this:—A furnace is placed at the bottom of U, and the air heated, which causes it to expand at a known ratio (1-480th part of the volume occupied at 32 degs. Fahrenheit, for each additional degree of heat on that scale) its weight, per unit of measure, decreases; consequently, the column of air in D produces motion towards U. The motive power due to the furnace is calculated thus:—The top of U is the datum, which may be defined as being an imaginary circle, concentric with the earth, and the pressure of the atmosphere at this datum over both U and D is considered as equal, because the shafts are never so far apart as to allow of much, if any, difference; from the furnace, generally the bottom of U, another imaginary circle is drawn parallel with the datum, and the difference of weight, or vertical pressure of the air in U, as against the weight between the two imaginary lines at D, represents the motive pressure due to the furnace.

In diagram No. 1, the air in U has a vertical column acting against it altogether at a higher elevation than the top of D, and as air naturally gets warmer than the external air as it proceeds through a mine, the gallery connecting U and D will act as an assisting upcast against the real downcast shaft D, consequently, all other things being equal, more ventilation will be produced through workings on the dip of the shafts than on the rise.

In diagram No. 2, the air in U has a vertical column acting against it altogether below D; in a case of this sort, the gallery would contain that vertical column of air, and D would only retard ventilation by adding to friction, and the air in the gallery would not be so useful in promoting ventilation as if it were external air, owing to its greater heat.

The following are particulars of observations made at an existing colliery ventilated by a furnace, and I will compare these actual results with what would be given by theory. Both U and D are 480 ft. deep and 12 ft. in diameter. Average heat of air in upcast, 125 degs. Fahr.; in downcast, 61 degs. Fahr.; volume of air passing through the mine, 103,325 cubic feet per minute; water gauge between the bottom of U and D, 0·62 in. The difference of pressure of the air at the bottom of the two shafts is equal to a column of water represented by 0·62 in.

Theoretically, I should find the volume of air passing through the mine thus:—

Weight per cube foot in U = ·06796 lbs.

Weight per cube foot in D = ·07646 lbs.

Each of these weights, multiplied by the distance between the imaginary lines gives the respective pressures in pounds per square foot, thus D = 36·70, U = 32·62, and the difference is the motive pressure per square foot, or 4·080 lbs.; this is equal to a column of air, at 60 degs., of about 53·6 ft., and treating this as a vacuum, I find that the velocity the air would attain, if no resistance had to be encountered, to be given, thus:—

$$8\sqrt{53{\cdot}6} = 8 \times 7{\cdot}321 = 58{\cdot}57 \text{ ft. per second.}$$

This in an upcast shaft of 12 ft. diameter would represent 397,104 cubic feet per minute. The actual resistance encountered by the air in the mine was shown on the water gauge to be ·62 inch, or 3·22 lbs. per square foot. The actual pressure of 4·080 lbs. per square foot is, therefore, disposed of, thus:—

To overcome resistance in mine............	4·220	lbs. per	square foot.
Ditto, ditto, in U and D............	·584	"	"
Producing motion of air.....................	·276	"	"
Total...........................	5·080		

Take the same colliery, the same course of ventilation, and the same amount, it is evident that whatever are the means used to exhaust the air the same resistance to the bottom of the upcast will ensue, and in the case of a fan being the motive power, the friction in the shafts—if they have an area equal to the mean area of the airway—will be in the same proportion as their lengths are to the lengths of the airways. I will assume the airways to be nine times the length of the shafts; if so, the resistance in the shafts will be 0·322 lbs. per square foot of sectional area of shafts, and the total pressure required will be as under:—

To overcome resistance in mine	3·220	lbs. per	square foot.
Ditto, ditto in U and D	·322	"	"
Ditto, producing motion of air	·276	"	"
Total...........................	3·818		

The pressure necessary to overcome resistance in U and D is shown to be less when ventilation is produced with fan than with furnace. The assumption of the length of airways may add to or subtract from this difference, but in either case the resistance will be less with a fan than with a furnace as motive power, on account of the increased expansion and velocity of the products of combustion arising from the furnace.

All upcast shafts should be free from falling water, and should have a larger available area for the passage of air than the downcasts, in proportion with the extra expansion of the air, so that it will travel at the same speed in all shafts.

Horse-power, given out by the furnace, producing ventilation—

$$4{\cdot}08 \times \frac{103{,}325}{33{,}000} = 12{\cdot}77.$$

Horse-power, given out by the fan, producing ventilation—

$$3{\cdot}818 \times \frac{103{,}325}{30{,}000} = 11{\cdot}95.$$

The Guibal fan utilises about 65 per cent. of the indicated horse-power of the engine driving it; therefore, in this case, the engine would exert 18·38 horse-power, which would require about 140 lbs. of coal per hour, whereas the furnace consumed 372 lbs. per hour.

An essay of this description is not the place to work out the reason of this great discrepancy of fuel consumed, but still I cannot leave the subject without expressing my conviction that it will be found to arise chiefly from the following two causes :—

(A.) The large quantity of heat (in the air required to be heated for furnace ventilation) escaping from the top of the upcast when compared with the heat escaping from the chimney of the furnace required to produce steam, and from the steam used in the fan engine.

(B.) Chemical combination produces heat; decomposition takes place at the expense of heat; a good furnace of a steam engine is so designed that more decomposed fuel chemically combines with oxygen than in a ventilating furnace.

The resistance encountered in the mine by the ventilating current is very great, and is, to an extent, preventible by paying due attention to the diagrams and explanations. Another manner of reducing this resistance is to make and maintain the airways as large as possible, for friction of air in mines increases with the rubbing surface, and as the square of the velocity at which it travels; therefore, if the airways had twice the section, the resistance from friction would be slightly more than one-fourth for the same volume. It is also important that the air be distributed through the mine in different currents of requisite quantities, and each current, or "split," sent to ventilate a different portion, and then sent direct to the upcast shaft; these splits have a double effect :—

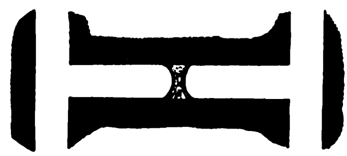
(A.) The resistance from friction is reduced, consequently more air can be got into the mine with the same motive power, because the same quantity of air can be carried through (say) ten airways at one-tenth the velocity required to carry it through one airway in the same space of time; therefore, this shows the necessity of having large shafts, whilst the air travels in one stream.

(B.) It prevents foul air polluting more than its own district, whereas, if the air travelled through the mine in one current, the whole of the mine would be polluted over which this foul air passed; it also has an obvious effect in case of an obstruction occurring in any airway of the mine.

Whilst coal workings are subject to outbursts of gas—and I think all deep workings, at and below a depth of (say) 250 yards, are subject to them (unless remedies already described are applied)—it behoves us to seek means whereby not only the risk of an explosion may be reduced as much as possible, but also, in the event of an explosion, means whereby the loss of life may be reduced to the minimum.

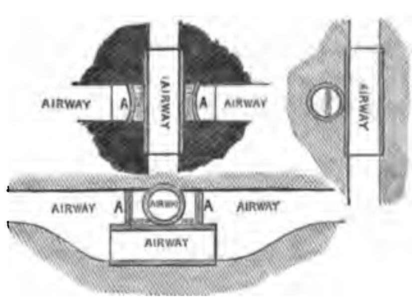
Great forethought should be exercised to have the ventilation of a pit dependent on as few doors and sheets as possible; but, where absolutely needful, they should be self-acting; and in important situations they should be doubled. All slits requiring stoppings should have them exceedingly well built, and of this form—

PLAN.



Or this would, perhaps, be preferable—

Also the air cros sings should be exceedingly strong, and, when of brick or stone, should be built double, thus:—



I have purposely shown the crossing to take place in and under the seam, because a better foundation can thus be secured; but, of course, if the under crossing could not be kept free from water, it would then have to be placed over the seam; it is quite evident that if pillars of coal at A A had been left in the seam, they would answer the purpose much better than the arched stoppings.

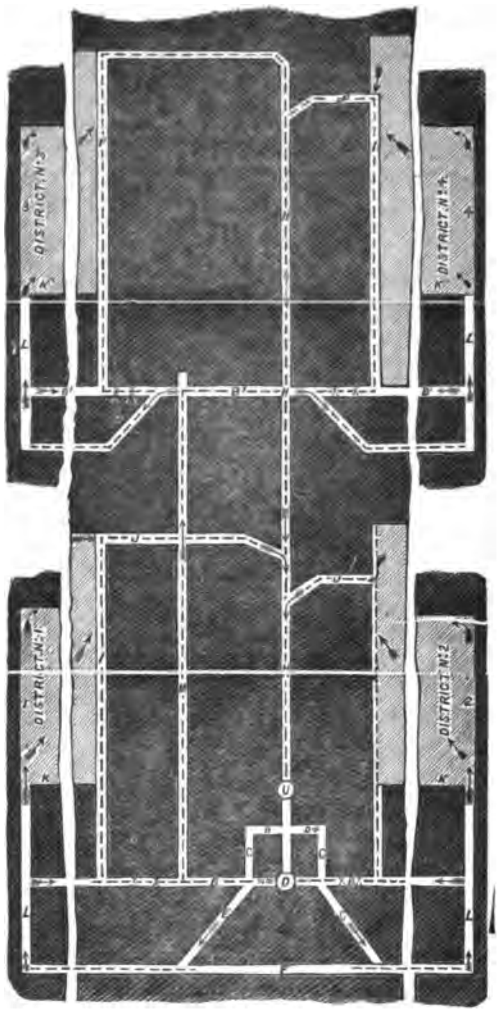
The object of having stoppings and air crossings built on the double arch system, is because they can then resist the blast from an explosion with much greater certainty than if a straight wall were merely supported by stowing; but, in my opinion, it would be both cheaper and infinitely better if air crossings were made of iron cast in segment of a circle, and built together in position, for then one tube would be sufficient to resist a blast from either side; no air crossing should be allowed which will not fulfil this condition.

Air will travel the nearest way it can get from the downcast to the upcast shafts, and that should (even after an explosion) be (theoretically) through the district it is intended to ventilate; therefore, it would be well to have the ventilation of a mine dependent on nothing which can be disarranged by an explosion. I may here state that when a fan is used as the motive power for producing ventilation, there should be a duplicate of all its parts, both fan and engine, and the fan not in use should have its communication with the pit cut off, so that if an explosion occurred, and broke the working fan, the communication between the shaft and the other fan could be made at once; there should, also, always be kept at hand a duplicate pit cover. Upcast air should be conducted, so that, even on its reaching the surface, there will be no chance of it coming in contact with fire.

The laying out of workings for a new colliery is a most important operation, and in this I think the engineer should consult the inspector—*i. e.*, the engineer should lay on the plan of the properties to be wrought the mode in which he intends the workings to be arranged; a copy of this, as agreed to by both engineer and inspector, should be sent to the latter, so that he will have it to refer to at any time, and the engineer must work to this plan; of course, reasons may arise why the plan should be altered, but the inspector's sanction should be obtained (in writing) before any alterations are made. Inspectors should be satisfied that every colliery has the necessary amount of ventilation to render harmless noxious gases (see General and Special Rules, No. 1); and until he gives notice (in writing) to the colliery manager that there is not sufficient ventilation it should be considered that, *up to the time of that notice*, the inspector was satisfied with the ventilation, for the terms in the rules are necessarily vague.

In future deep collieries there should only be two connections with the intake for each district—one to take the air to the end of the district farthest from the upcast, and the other to bring the coals, &c., direct to the shaft—the drawing shaft should, if possible, always be a downcast, and only one connection with the return. No slits between intake and return air, with stoppings or doors in them (excepting where absolutely necessary) should be allowed. I think my meaning as to the general arrangements of the workings for a new colliery will be better understood by referring to the following plan and explanations.

The subjoined plan shows a colliery laid out on the long-wall principle, and divided into four districts :—



NOTE.—A water-gauge through the doors of each district would be useful, as it would keep a check on the state of the airways in each district. The *arrows* denote the course of ventilation.

All colliery workings should be divided into districts, having no connection with each other, except those mentioned in the previous paragraph. The mode of operations on the shafts reaching the coal should be something like the following, viz.—Drive a communication between D (the downcast) and U (the upcast) shafts, and fix a temporary door (or double doors) at No. 1, then, by the aid of air pipes passing through this door, proceed to make the headings B, C, D, also E, F, G; now remove the air-pipes, and place temporary doors, Nos. 2 and 3, also a temporary regulating door, No. 4; continue driving headings, B, in both directions, leaving along the middle of

these headings pillars of coal (see dotted lines on plan) to answer the purposes of temporary ventilation more safely than brattices; these pillars need not be more than two or three feet thick, and should be removed when the headings are completed; F can also be driven in a similar manner, the post to be taken out when completed, but the tramway should be left in (or laid), so that there may be no inducement at any time, when F may require cleaning out, for a slit to be driven between the horse road B and the main intake F; H, I, J must also be driven with pillars and air-pipes, for conducting ventilation, to be afterwards removed; K, and the further extensions of B, may be driven in the usual way, with the aid of brattice and slits, L.

Now the districts Nos. 1 and 2 are opened out, and the permanent double doors (shown thus × ×) must be fixed, and a boy must always attend on them (see Special Rules, Nos. 17, 68, and 69); there should also be fixed, and set back in the solid coal, two sets of duplicate doors (which should be kept open), so that in the event of an explosion taking place these doors may be out of the blast, and used immediately to replace the ordinary doors (shown thus × ×), which might be blown away. The pillars* shown by the dotted lines, and all temporary doors, &c., must now (if not already done) be removed, and districts Nos. 1 and 2 will be ready for opening out the banks. Two very strong stoppings, each built on the same plan as previously shown, must be placed in the heading between the two shafts (*i. e.*, between heads D and shaft U), having strong iron doors (so arranged as to act as scale doors) in them, opening different ways, and locked, the underviewer and deputies only having keys.

Thus, in the event of an explosion, the workings are so laid out that the blast and after-damp will not extend beyond the district in which it occurred; and, provided the duplicate doors are closed (if the others have been blown away), the ventilation must quickly sweep away all after-damp—which is much more fatal to life than the actual explosion, owing chiefly to the collieries having so many doors and stoppings, any of which being blown away would cause stagnation of ventilation in some portion of the workings—and fresh air and help speedily reach the scene of explosion. The men not actually disabled by the explosion would know which way to run in order to reach the fresh air more speedily, because there are no stoppings and doors to be swept away, for there would speedily be help at the shaft bottom to attend to the only doors required.

I will now assume that districts Nos. 3 and 4 are required to be opened out. Another intake (M) must be driven, which can be done as follows:—Having driven M a few yards, and made a slit in the temporary posts, place an air-pipe through the main doors (shown thus × × on the plan), which must extend a short distance along one of the heads of M, the end of which (head) must then be closed, the necessary circulation of air will be promoted through the air-pipe; now continue driving M till J is reached, and a strong cast-iron air crossing must be fixed immediately, as previously described; the head, M, can now continue till B′ is reached, when the roads B′ must be pushed on

* In some collieries these pillars might be made thicker, and, with advantage, left as fixtures, in which case a fall of roof taking place in one road the ventilation will not be entirely stopped.

in both directions; in the meantime, head H should be continued, with the aid of small pillars for ventilation, till the point N is reached. At the junction of H and B′, another strong air crossing, similar to that at the junction of M and J, must be immediately erected (it is important that these "overcasts" or air crossings be put in as soon as possible, after the meetings are effected, for if an explosion were to happen before they were erected the doors and other contrivances which would have to be used in their place, would probably be blown down, and then the air would take the short way to the upcast and leave the working districts without, and it would then be vain to attend to the doors (marked thus × ×); the next step is to form a communication between B′ and H, *viâ* I′ and J′; this being done, a complete and independent circulation is promoted through the new in-take M. The further opening out of districts Nos. 3 and 4 will be something similar to districts Nos. 1 and 2. Pack walls in "banks" or "wastes" should have openings left in them (say) every five yards, so that a circulation of air may be kept up through them.

I have divided the ignition of explosive mixtures under two heads, and will now proceed to show how danger from these causes may be remedied.

(A.) The men will be prevented from lighting matches or candles, &c., where safety lamps are used—tampering with their safety lamps, or working with one that has been damaged, &c., &c.—by the vigilance of the overlookers. Where safety lamps are used, a lamp cleaner must be appointed, who will see that no defective lamp is given to the men. The lamps should not be set on the floor of the mine, but hung or suspended from rings. The lamp keeper and men must also comply with Special Rules 2, 34, 39, 65, 66, 67, 29, 30, 32, 33.

The surest plan of dealing with blasting powder is to prohibit its use altogether where safety lamps are required, as defined in this essay; and where not, the material to be blasted should first be cut (if possible) so as to prevent the charge from being blown out in a stream of fire—*i. e.*, the line of least resistance should be so arranged as to cause the stratum to be shattered to such an extent that little or no flame will be blown out of the drill hole.* On approaching old workings not *known* to be *entirely* without gas, no blasting powder or naked lights should be used; and men over whom air from this place will pass must use safety lamps until the workings have been satisfactorily proved. No man should be allowed to work in or near an explosive mixture, and if such mixture exists, the underground viewer must personally superintend its removal.

(B.) Spontaneous combustion may arise from various causes, and, amongst others, sulphuret of iron (iron pyrites) may produce fire, and also may greasy waste. Phosphorus will combine with hydrogen, and produce phosphureted hydrogen gas, which will take fire spontaneously in atmospherical air. The only remedy is to keep the workings free from all substances likely to fire spontaneously, or produce phosphorus, by sending them out of the pit.

* Blasting the roof of a mine is evidently dangerous. All beaters used to "ram" shots should have copper on brass heads so as to prevent sparks being struck from the coal on ramming.

III.—SUFFOCATION FROM THE EFFECTS OF GASES UNFIT FOR THE SUPPORT OF LIFE.

This may be caused by not having sufficient ventilation, the remedy for which has been described; or by a current of air taking bad air through the workings—say, for instance, any part of the workings taking fire over which the current of air passes. Thus, the whole of the pit ventilated by this air would be foul, and might suffocate the men; but, in the event of this happening, the advantage of introducing the intake air into a district at the end furthest from the downcast shaft is apparent, for the men in this case could escape through the doors, shown thus × × on the above plan. The stables should always be ventilated by a separate split of air, which should then be taken direct to the upcast. Water should be passed down the shaft to the stables, and a hose kept ready to be fixed at any time should they take fire.

It would be well if in colliery districts fire engines were made to run on trams, and small enough to be taken up and down shafts, so as to be available underground in case of fire.

Suffocation takes place by inhaling the after-damp arising from an explosion, and I may here repeat that more deaths under the head of explosions arise from this cause than from the blast and fire of the actual explosion; this will be found to be treated on under the head "No. II.—Explosions of Firedamp." Two downcasts are better than one, for if a fire took place in one of them, there would be the other to flee to for refuge and fresh air.

IV.—INUNDATIONS OR FLOODINGS OF WORKINGS BY A SUDDEN INFLUX OF WATER.

This may be divided under two heads:—

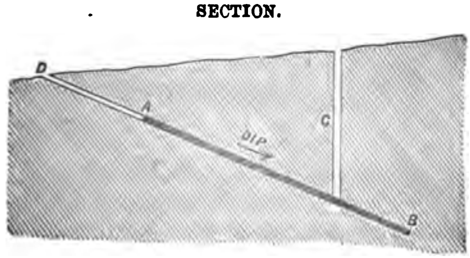
(A.) From water in or near the same plane as the workings, by approaching so near that its pressure will cause it to burst into them.

(B.) From water vertically above the workings, by not leaving sufficient supports underneath.

It is much to be deplored that formerly very inaccurate plans were kept of coal workings, as they are liable to lead persons astray; and as long as they trust implicitly to old plans for guidance, so long will mines be subject to frequent inundations.

(A.) Prevention of accidents from this cause. The following sketch will tend to illustrate my meaning.

SECTION.



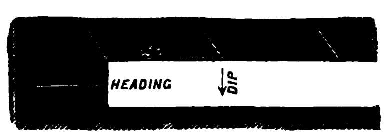
A B is the stratum of coal to be wrought to the shaft, C; A D are old workings filled with water, the position of which is shown on an old plan or otherwise. It is necessary, before any extensive workings are opened out between the shaft, C, and the old workings, A, that a heading should be driven to prove the position of A, but before this is done extensive workings should be made to the dip of C, so that, in the event of the heading coming suddenly upon the old workings, or a quantity of water suddenly forcing its way through the roof or floor, this water will find its way into the dip workings, and before it reaches the shaft the men will have had time to escape.

Suppose the dip workings to have been made, and the heading driven to prove A to be rapidly approaching the position of A, as shown on the old plans or elsewhere, boreholes of a certain length must now always be kept in advance of the heading, thus—

PLAN.

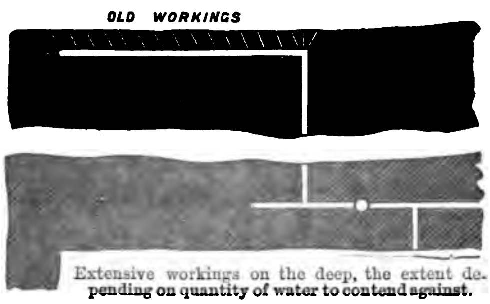
The length of the bore-holes should depend on the size or section of the heading, strength of the coal, and head of water contained in the old workings; thus the water will be prevented from suddenly bursting through the coal, but still it might burst open the floor or roof.

Now, suppose the old workings to have been bored into out of the exploring heading without any mishap, it may be desirable to let the water run gradually down to the pumping shaft, and so be raised to the surface; or, perhaps, to leave a barrier of coal against the old workings, and so keep the water out of the present workings altogether. I will suppose the latter to be decided on; in this case, commence to drive a heading out of the exploring heading already driven (at a suitable distance from the old workings, depending on the strength and thickness of the coal and the head of water to be contended against) parallel with the old workings, as shown on the old plan, taking care to always keep bore-holes in advance and on the rise side of the heading, thus—



When this has been extended to a suitable distance the coal on the deep side of it may safely be extracted *en masse*, provided that the water in the old workings is the only danger to contend against.

The plan of a colliery at this stage would appear something like this—



(B.) Prevention of accidents from this cause. The only method of dealing with water—vertically above the coal stratum being wrought—is to keep accurate plans of the workings and surface, and, if need be, leave pillars to support the water above (when the water is in old workings the old plans will have to be trusted, to a certain extent, and a large margin allowed for error), when the workings approach where it is stored; but extensive dip workings should exist when water is in question before approaching the place supposed to contain it. When I say "dip workings," I do not mean that it is necessary that the workings should be below the pumping shaft, but I mean that there should be a ready means for the escape of the men at a higher point above some extensive workings or "goaf."

V.—FALLS OF COAL OR ROOF.

Accidents from these causes will, in a great measure, be avoided by having competent overlookers, paying strict attention to Special Rules 7, 25, 26, each of whom must not only see after having sufficient material for the support of the strata in his district always at hand, but also that these supports are fixed in proper positions, and that when once fixed they be not removed until he has personally satisfied himself that there will be no danger from an immediate fall of the strata on their removal. The overlookers should at all times pay great attention to the roof.

VI.—ACCIDENTS IN SHAFTS

may be caused by any of the following defects, such as—

(A.) From breakage of ropes and machinery;
(B.) Carelessness of engineman;
(C.) Defective construction of engine;
(D.) Defective construction of cages;
(E.) Defective construction of shaft and fittings;
(F.) Carelessness of banksman and hanger-on;
(G.) Carelessness of man working at repairs in shafts.

(A.) It would be well if a limit was placed on the time during which a rope might be used for raising or lowering persons in shafts. A spring fixed either at the cage or under the pulley wheels will tend to supply the elasticity a rope loses with age, and so render it less liable to breakage. Drums and pulleys round which wire ropes pass, should have large diameters; they ought not to be less than 10 ft. Every rope should be able (when new) to resist some standard tests, to be determined upon for different materials and sections of ropes. Attention to Special Rules 8, 43, 44, 45, 48, 49, 50, 51, 52, 55, 56, 57, must be observed.

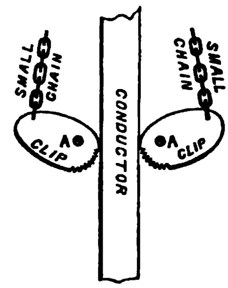
(B.) A person eighteen years of age (Special Rules 1 and 42) is, in my opinion, too young to be trusted with the management of either an engine for drawing men or the superintendence of either the pit top or pit bottom, and I think these rules would be much better if twenty-five years were substituted for eighteen years.

A careless engineman would probably draw the .cage over the pulleys of the head gear. I have known careful enginemen to do so; the defect may be either with the man or machinery. There are numbers of "disengaging hooks" invented, to be fixed between the ends of the rope and the cage, so that when the cage approaches dangerously near the pulley wheel, the "hook" strikes against either the wheel or some special contrivance, and causes the cage to be disengaged from the rope; perhaps these would be useful, but when used catches should be attached to the head gear, so as to prevent the cage from falling on being released from the rope. The Special Rules, Nos. 43, 44, 45, 46, 47, 48, 49, 50, 51, 55, ably teach the engineman his duty.

(C.) This may exist in an engine having bad proportional parts or defective material, but I will pass over these defects, and proceed to the main features, which are the drum, the drum-shaft, the brake, and the machine for indicating the position of the load in the shaft. The drum should, as before stated, be of large diameter, and provided with flanges, or horns (*vide* General Rule 11), to prevent the rope from working over the edge; the rope used for drawing men should not traverse the drum more than once. Each drum should be fitted with a "break ring." The drum shaft (used for drawing men) should, in no case, be made of cast iron—wrought or malleable iron is the most reliable material which can be used for this purpose.

A brake should be attached to the drum of every engine, of sufficient power to keep it from revolving, in case the engine were to fail, and should be so arranged that the engineman can apply it to the drum at a moment's notice. There are many different arrangements of "indicators" (fulfilling its requirements in General Rule 12), but in no case should they be dependent on string, or other flexible material, for their accuracy.

(D.) Cages should have a cover overhead to protect men whilst in the shaft from falling materials; also, there should be a hand-rail within the cage for the men to grasp whilst riding. Before a cage is allowed to be placed in a shaft it should be suspended in the same manner as it will be when hung from the drawing rope; it must then be ascertained if the "guide shoes" for the conductors are plumb under one another, and the centre of the bottom of the cage should be exactly under the rope; when a cage is loaded, the weight should be so distributed as not to alter its (the cage's) manner of hanging. Cages should be provided with safety-catches, so that if the rope, &c., break, the conductors may be clipped by them. A very good "catch"



is of this form: At A, A, pins pass through clips and are securely fastened to the cages; these clips are free to revolve on the pins; when the weight of the cage is taken by the rope the small chains attached to the clips at one end, and the shackles (which connect the cage and rope) at the other, elevate the ends of the clips furthest from the conductors, and because the pins on which the clips revolve are above their centres, they (the clips) recede from the conductors; but if the rope break, the shackles and small chains will drop, and the lower sides of the clips will come in contact with the conductors, and the greater the weight of the cage the tighter will the clips be wedged. The necessary apparatus must be fixed, so as to keep corves from falling out of cages.

(E.) It would be well, and to the advantage of the owner and the safety of the colliers, if all shafts were lined throughout with brick, stone, or other durable material. Sheeting boards should not be allowed as permanent lining for shafts. There should always be two distinct and separate shafts, or other distinct communications between the surface and the seam of coal being wrought, so that in case of need men may use either communication. Drop gates should be used at the top of every "working shaft," so that when the cage is not there all access to the shaft will be closed. No opening in the side of any shaft, not being at the bottom of the shaft, should be allowed to be used by men (unless with the underground viewer). All Special Rule 6 must be carried out, and in no case should coals be allowed to be raised or lowered from there, unless a stage is erected so as to form a bottom to the shaft at that point. Conductors, to guide the cages, should be fixed in every shaft where required by the inspector, and they should be fixed in a true plumb-line, and in no case should a "pass-by" be allowed in any shaft without first obtaining the inspector's sanction. The head-gear of every colliery should be high, so as to prevent overcrowding as much as possible.

(F.) The duties of the banksmen and hangers-on are plainly set forth in rules Nos. 46, 47, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62: but I may again state here that a person eighteen years of age cannot command the deference which is due to banksmen or hangers-on. The banksmen should be very careful to prevent anything from falling down a shaft; therefore no loose material should lie about the top of any "working shaft."

(G.) The remedy rests mainly with themselves, but it is important that the steadiest and most experienced banksmen and enginemen or hangers-on are employed on such occasions.

As this essay is on the prevention of accidents in mines, I think the inspectors should be consulted, as stated herein, for I am persuaded that had such been the case heretofore, numerous great errors would have been prevented, which afterwards, on account of the expense or impossibility of alteration, are neglected. I quite appreciate what is said about the desirableness of owners and agents being the responsible persons for the safety of the miners, and not the Government; but the miners must be protected, and if my suggestions were carried out the effect would be this—the miners would know that every new colliery was laid as safely as possible, and that there is sufficient ventilation for ordinary occasions; also that the inspector can see a just periodical report of the state of the workings and of the discipline; the miners, too, can have this privilege. The colliery owners, agents, and workpeople will, at the same time, be responsible for efficiently working to the rules as heretofore.

Mr. Hermon's Prize Essays.

ON THE PREVENTION OF EXPLOSIONS IN COAL MINES.

MR. WILLIAM GALLOWAY'S ESSAY,

TO WHICH A FIRST PRIZE WAS AWARDED.

I.—ON THE OCCURRENCE AND PROPERTIES OF FIRE-DAMP.

Fire-damp is found issuing from the fissures of coal seams and the strata associated with them, the quantity emitted varying considerably according to the nature of the coal and the depth of the seam from the surface.

In the workings of a coal mine the greatest quantity of gas is emitted from the fresh surfaces which are exposed as the coal is removed at the faces in the "solid." Some gas, however, is also given off in the "broken" and in "goaves," being conveyed thither by fissures in the roof or floor, which act as pipes or channels from the solid coal of the working seam, or from an upper or lower bed of coal. In general, the quantity issuing from the solid coal, or from the roof and floor of the mine, does not vary much where the tension of the gas is considerable; but in collieries in which the fissures are wide, and the tension of the gas is not great, its rate of issue depends on the pressure of the atmosphere.

"Blowers" are usually large fissures, which extend for considerable distances in the coalfield, and penetrate the strata both above and below the working seam. They sometimes give off a large quantity of gas when first "pricked," and some of them continue to emit gas for years. They are generally met with in the neighbourhood of faults. Eruptions of firedamp are not uncommon in some mines; gas in a state of great tension appears to collect in a cavity formed by the bending down of the roof or the heaving up of the floor, and to escape suddenly when a rent is formed, or a fall of roof takes place. Instances are also recorded of eruptions of gas from fissures filled with "danty" or disintegrated coal.

In the year 1815, Sir Humphrey Davy, who was at that time engaged in making the experiments which led to the invention of the safety lamp, pointed out that light carburetted hydrogen was the principal constituent of firedamp. Since then, many specimens obtained from "blowers" have been analysed; they are generally found to contain 80 to 90 per cent. of light carburetted hydrogen, varying proportions of oxygen and nitrogen, and sometimes a little carbonic acid gas. Light carburetted hydrogen is also known by the name of marsh gas, from the fact that it rises in bubbles to the surface of water under which organic substances are decomposing. The symbol for this gas is CH_4, molecular weight, 16 (carbon); C = 12 (hydrogen),

$H_4 = 4$, $CH_4 = 2$ volumes.* A molecule of light carburetted hydrogen requires two molecules of oxygen for its complete combustion.

$$CH_4 + 2\,O_2 = CO_2 + 2\,(H_2\,O)$$
$$\text{2 vols.} \quad \text{4 vols.} \quad \text{2 vols.} \quad \text{4 vols.}$$

One measure requires two measures of oxygen, or ten measures of atmospheric air. When the air and gas are mixed in certain proportions, their combustion takes place with explosion. With five measures of air to one of gas, the explosion is weak; with from eight to ten of air to one of gas, it is most violent, and with fourteen of air to one of gas, the mixture still explodes. But when the proportion of air by measure is less than three or four, or more than fourteen, to one of gas the mixture will not ignite at the ordinary pressure and temperature. The composition of the after-damp depends on the proportion of air that was in the mixture before explosion. When there have been ten measures of air to one of gas, the residual gases are one measure of carbonic acid, two of steam, and eight of nitrogen; and, after the steam has condensed, the after-damp occupies nine-tenths of the original volume. It is, therefore, evident that there is no oxygen left in this or any after-damp which has been formed by the explosion of a mixture containing less than ten measures of air to one of gas. However, when there are fourteen measures of air to one of gas, the after-damp is composed of 4-5 measures of oxygen, 2 of carbonic acid, and 11 1-5 of nitrogen after the steam has condensed. This last mixture is not immediately fatal, and may support life for a short time after the carbonic acid has been removed.

Various methods have been proposed whereby it might be possible to penetrate the after-damp, such as the removal of the carbonic acid by the use of quicklime or ammonia and other alkalies; but, since the composition of the after-damp depends on the proportions of air and gas in the mixture before explosion, it would not, in some cases, be able to support life under any circumstances. The method employed for detecting the presence of fire-damp in the air of a mine is by no means a satisfactory one, since a less quantity than three and a-half to four per cent. of gas gives not the slightest "cap" on the flame of a lamp or candle, and it must be remembered that 7 per cent. makes the mixture explosive. There is, therefore, only a margin of little over 3 per cent. between air that shows the first indication of containing firedamp, and air that will explode. An instrument was described some years ago,† by the aid of which, it was said, as little as 1 per cent. of fire-damp could be perceived; such a contrivance would be of much value in testing the ventilating currents, the fouling of which, even to the extent of 1 or 2 per cent. of gas, must, in many cases, lead to the formation of explosive mixtures in places in which they had not been seen before.

II.—FOULING OF THE VENTILATING CURRENTS.

Before the year 1760, only one system of ventilating the workings was known or employed. It has been called the "Primitive method." The air from the downcast shaft is led in a single current round the edge of the solid

* A volume is 11·2 litres = 683·503 cubic inches.

† "Transactions of the North of England Institute of Mining Engineers," vol. xv.

coal and working faces, until it returns to the upcast. Let fig. 1 represent the general features of a post-and-stall working. The solid coal is shaded from right to left here, and in the other figures. D is the downcast, and U is the upcast shaft. A door is interposed between the two shafts, and the air is made to circulate round the edge of the solid coal, as shown by the arrows. The lines S, S, are stoppings, arranged so as to prevent the air from taking a short course. The shading parallel to the level L, L, shows an unventilated

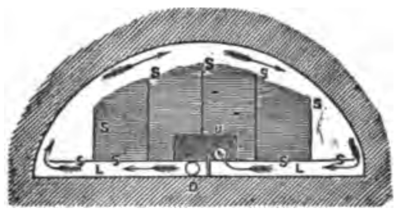


FIG. 1.

space round which the air current travels. By this system, it was possible to obtain plenty of fresh air at the working faces; indeed, it is the only method adopted at the present day in many collieries, in which the emission of firedamp is insignificant, and in these cases it is quite sufficient. But in fiery mines it was found that dangerous accumulations of air and firedamp were formed in the unventilated space when large districts of pillars were barred off from the ventilating current in this manner. Apertures were left in the stoppings, through which it was intended that air should be driven by the movements of the men and horses, and in this way a partial ventilation was effected. This was called "airing by the waft of the barrowmen." Under this system, sudden and unexpected explosions took place,* and it is not improbable that two very disastrous explosions which happened in our own day† are traceable to the existence of a large space of barred-off pillar workings, round which the air circulated on the outside. In 1760, Mr. Spedding, of Whitehaven, introduced the method known as "coursing the air."‡ This system was intended to obviate the dangers arising from the former. By means of suitably arranged stoppings, the ventilating current was made to travel up and down among the pillars, so that it reached every part of the workings. The lines in fig. 2 show how the stoppings were arranged, and the arrows indicate the course of the air. But a new source

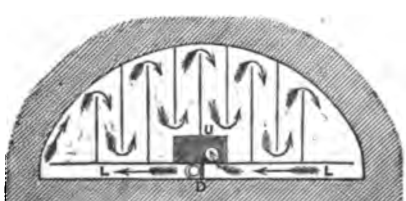


FIG. 2.

* Buddle, Parliamentary Evidence, 1835.

† Nitshill, 1850; Talk-o'-th'-Hill, 1866.

‡ For an early description of this method (1778) see article "Coalery," "Encyclopædia Britannica."

of danger accompanied the introduction of the system. It was no longer possible, certainly, for large accumulations of explosive mixture to be formed among the pillars, but the distance to be travelled by the air was materially increased; and in order that the same quantity as formerly might be supplied to the workings, its velocity would require to increase at the same rate. Now, it is generally accepted as an approximation that the resistance to the circulation of the air in the passages of a mine varies as the square of the velocity, and, if we assume this rate of variation, we find that the power required to make the air circulate varies as the cube of the velocity. For, let v = velocity, r = resistance, c = a constant, P = the ventilating power. Then, since

$$r \propto v^2$$
$$\therefore r = cv^2$$
$$\text{But } P = vr = vcv^2 = cv^3$$
$$\therefore P \propto v^3$$

It soon appeared that the same ventilating power was no longer able to cope with the new order of things, and the air was occasionally so loaded with fire-damp when it reached the upcast shaft that it ignited at the ventilating furnace.

The steel mill and the "dumb furnace" were then resorted to. By the arrangement called the dumb furnace, or dumb drift, the air returning from the workings is sent directly into the upcast shaft without passing over the furnace; and the furnace is supplied with fresh air, which, on being heated, passes into the shaft and mixes with the air returning from the workings. It was found, however, that explosions still took place, even in mines in which the steel mill only was used for giving light. At length, it was discovered that *sparks from the mill* could ignite the inflammable air, but there appeared to be no remedy.

Affairs were in this unsatisfactory state when Mr. Buddle began his career. That indefatigable pitman, who may appropriately be called πολυμηχαν, introduced his system of panel work and double ventilation at Wallsend in 1810. The general features of panel work and double ventilation are shown in fig. 3. A and B are districts in which workings are being carried on; they are separated from each other by a barrier of solid coal. Each district communicates with the upcast and downcast shaft by means of two passages, one

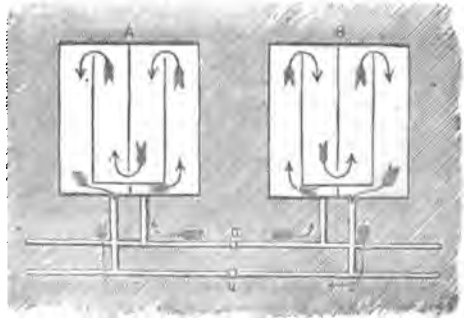


Fig. 3.

being used as the intake, and the other as the return aircourse. At the bottom of the downcast shaft the air current divides itself, one portion going to the district A, the other to B. The stoppings which guide the air are indicated by lines as before. After ventilating its district each current returns to the upcast shaft, through which they ascend to the surface together. Panel work was introduced partly for the purpose of preventing the spread of "creeps" during the working out of the pillars, partly for the purpose of confining the results of an explosion to the district in which it happened. In the system of double ventilation the true secret of ventilating mines was discovered.* Two currents of air were used to ventilate the same place that was formerly ventilated by one. In order, then, that the same aggregate quantity of air might be supplied to the workings, each current required to travel at only half the velocity of the single current, and that part of the power which was necessarily expended in overcoming friction was reduced to one-eighth of its former value.

To the late Mr. Nicholas Wood, of Hetton Collieries, Durham, is due the credit of having fully appreciated and successfully applied the principles of this system to the ventilation of the collieries under his care. Very large quantities of air are thus obtained at the Hetton Collieries—upwards of forty times as much as Mr. Buddle was using at Wallsend (5000 cubic feet per minute) when the great explosion took place in 1835.

Fig. 4 shows the application of this system to a district of pillar-and-stall workings; A B and C D are the main intake and return air courses; *a b* and *c d* the district intake and return air courses; the stoppings are indicated by

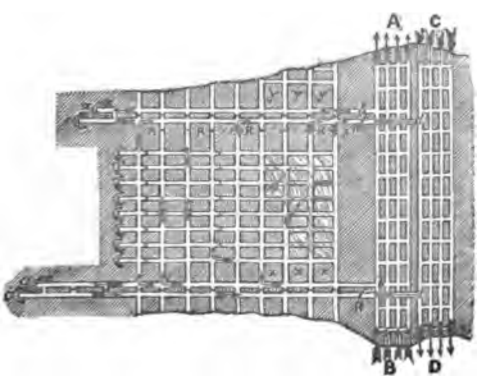


FIG. 4.

double lines; R R are regulators; the part from which pillars have been removed is shaded irregularly. The air leaving the advance drifts *a* and *c*, and that from the working faces in the solid coal goes directly into the return aircourse; the pillar workings and the goaf, on the other hand, are supplied with fresh air. The district return air course, *c d*, is cut in the roof from *f* to *d* at a short distance above the main intake, so that the main return aircourse is completely isolated. In this sketch, each main aircourse

* Short distances, or great area of airways.

is shown to consist of four passages, their frictional resistance, therefore, to the passage of a given quantity of air is only one-sixteenth of what it would be if each of them consisted of one passage, and the power required to overcome the friction is only one sixty-fourth. These remarks are sufficient to show how much more important it is to multiply the number of the airways, increase their area, and shorten the distance to be traversed by each ventilating current, than to increase the ventilating power, when a greater quantity of air is required for the ventilation of any mine.

We have now seen how that in fiery mines it is not safe to conduct the ventilation either according to the primitive method, or Mr. Spedding's method of coursing the air; Mr. Buddle's system of double ventilation has also been briefly discussed. It still remains, however, to be considered when, and in what manner, any ventilating current may become explosive. Let fig. 5 represent the plan of part of a longwall working; A B and C D are the main intake and return aircourses; *a b* and *a' b'* district intake; and *c d* and

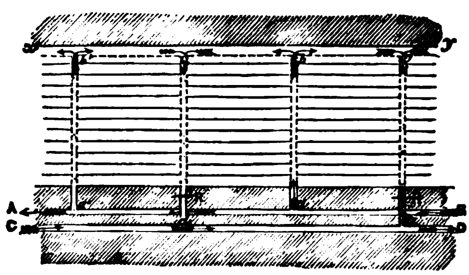


FIG. 5.

c' d' district return air courses. It may be assumed that the air leaving the points *b* and *b'* is always pure, and that the whole of the working face, *x y*, emits firedamp at a uniform rate. Then it is evident that any given quantity of air which passes from *b* to *c*, or from *b'* to *c'*, will always contain exactly the same per-centage of firedamp when it reaches the point *c*, so long as the quantity of air is not increased or lessened, and the quantity of gas emitted from the coal remains unchanged.

1. Let the quantity of air coming from *b* to *c* be twice as great as that from *b'* to *c*, and take the distance $b\,c = b'\,c$. Then, if there be 4 per cent. of gas in the current *b' c*, when it reaches the point *c*, there will be 2 per cent. in the current *b c* at the same place. Now, suppose the quantity of air arriving at *c* to be halved (the relative quantities remaining as before), or the quantity of gas emitted at the face to be doubled; then, in either of these cases, the current *b' c* will be explosive shortly before it arrives at *c*, the current *b c* will not be explosive, and the air in the passage *c d* will contain 5⅓ per cent. of gas, and will not be explosive. If, under these circumstances, ignition takes place at the point *c*, there will only be a slight explosion of the mixture extending towards *b'*.

2. If the air arriving at *c* from one side is explosive, or if that coming from one side or the other contains sufficient firedamp to make both explosive when mixed, then the whole passage, *c d*, will be filled with explosive

mixture. But the air in the aircourse, C D, may be sufficiently pure to dilute that coming from *c d* below the explosive point; or if not, the main current itself may be so diluted by the air from *c′ d′*. In this case, the explosion would extend only to *d* or *d′*, and not to the whole district.

3. If the main return current in C D is not diluted below the explosive point until it meets with another main current, the explosion will extend to the whole district.

4. When all the main currents are explosive, the explosion will extend to the whole of the districts.

It is thus manifest that the purity of the main return current depends on the purity of its tributaries, and the purity of these at any particular time depends on the relative quantities of gas emitted at the face and air supplied to the workings.

In a district of bratticed bords, like that in fig. 4, if the whole of the air current is sent to the face of each bord in succession, the last bord will become explosive before any of the others; but if only a portion of the air is sent to the working face, while the remainder escapes towards the next bord under the door or screen at the entrance, then the air in any one of the bords may become explosive, while the others are free from explosive mixture.

The following algebraical expression shows what is the minimum quantity of air that must be taken to ventilate the bords one after the other, it being assumed that the quantity of gas emitted is somewhat equal to each bord:—

Let $x =$ the whole current of pure air which comes to the entrance of the first bord.

$y =$ the quantity of firedamp necessary to make this air explosive.

$m =$ the number of bords from which an aggregate quantity of gas equal to y could be produced.

$\frac{1}{k} =$ the ratio which the part of the current taken to ventilate any bord bears to the whole current.

$n =$ the number of bords through which the current has passed before reaching any given bord.

The composition and proportion of the current taken to ventilate the $(n+1)$th bord are given by the expression $\frac{l}{k} \cdot \frac{ny}{m} + \frac{x}{k}$ and when leaving this bord it is— $\left(\frac{l}{k} \cdot \frac{ny}{m} + \frac{y}{m}\right) + \frac{x}{k}$. Now, the mixture, $\frac{y}{k} + \frac{x}{k}$ is explosive, so that when $\left(\frac{1}{k} \cdot \frac{ny}{m} + \frac{n}{m}\right) = \frac{y}{k}$, the mixture at the face of, and leaving the $(n+1)$th bord, is explosive. From the above we get $m = n + k$. Suppose, for example, that there are twelve bords, and that the whole of the air taken to ventilate these twelve would become explosive if the gas from sixteen similar bords were added to it. Then the minimum proportion of the *whole* current that would prevent the air at the face of the first bord from becoming explosive is one-sixteenth, or rather more, the second one-fifteenth, the third one-fourteenth, and so on to the last. One-fifth of the whole current would require to be sent to the face of the twelfth, and although this bord produced exactly the same quantity of gas as the first, an explosive mixture would be formed at the face with this or any smaller proportion of the whole current. From these considerations it is seen how the air leaving a district of bratticed bords may not be explosive, while several of the bords are explosive at the face; and how, by slightly decreasing the whole quantity of air, one or more of the bords may suddenly become explosive.

NOTE.—It should, perhaps, be mentioned that the currents are understood to be explosive near the roof only, at first, in the foregoing cases.

III.—ON THE FORMATIONS AND EXTENSION OF EXPLOSIVE ACCUMULATIONS.

When firedamp issues from the fissures in a mine, it immediately rises to the roof, on account of its low specific gravity (·5589, air = 1). It collects in cavities in the roof ("pot holes," and the highest spaces in "goafs"), and in unbratticed working places of which the inner end is higher than the entrance; and from such places it can only escape by diffusing into the outer air. The rate of diffusion per square metre per hour has been determined for certain gases by Professor J. Loschmidt, of Vienna,* but, so far as we know, scientific investigations have not been made to fix these quantities for light carburetted hydrogen and air; it will, therefore, be necessary to consider only the general law in this case. Considering a space, A B C D, closed at the top and sides, and open at the bottom, into which a uniform quantity of gas is admitted, while there is pure air outside. After a time, if the air inside be analysed, it will be found to contain a certain per-centage of gas, varying in the manner indicated by the figures in Fig. 6. As long as the conditions are unchanged there will be no change in the quality of the contents at the different heights, but as much gas will escape at the entrance as is admitted at the top. Now, let the outer air contain 5 per cent., while the same quantity of gas, as before, continues to be admitted at the top, then a displacement will occur, so that all the space below *b* will contain 5 per cent. of gas. But no diffusion can now go on from the entrance A D, until the line above which there is 5 per cent. of gas has moved down to the position A D; and during all this time the whole of the gas admitted at the top will be retained in the space A B C D.

FIG. 6.

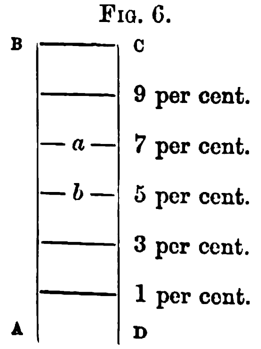
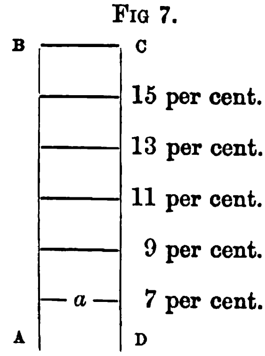


FIG 7.



* Experimental Untersuchungen über die diffusion von Gasen ohne poröse scheidewände. Sitzb. b. k. Akad. d. Wissensch. Bd. lxi. (March and July, 1870.)

After a time it will be found that the per-centage of gas at different heights again remains constant, but that it is different from what it was under the former circumstances. Fig. 7 shows how the quantity of gas has changed at the different heights. The point *a*, at which the mixture first begins to be explosive, is much nearer to the bottom than it was before.

Again, suppose a small space, G K L M, fig. 8, in which there is no explosive mixture, at the top of which, however, gas is admitted, so that the per-centage

FIG. 8.

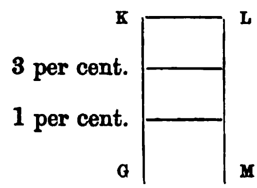
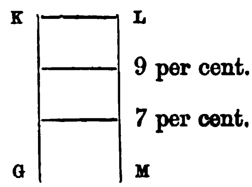


FIG. 9.



in the space is shown by the figures when there is pure air outside. Now, as before, suppose the air into which the diffusion is going on to be changed, so that it contains 5 per cent. of gas, then the contents in the space G K L M will also change before diffusion can take place again. The new per-centage of gas is shown in fig. 9, and here it will be observed an explosive mixture has appeared, without any increase in the quantity of gas admitted at the top. The transition from the consideration of the imaginary spaces A B C D, &c., to the consideration of the cavities in the roof of a coal mine is easy. The gas in the mine is controlled by exactly the same laws as gases elsewhere, so that an increase of 1 or 2 per cent. of gas in a ventilating current (although it may possibly not be perceptible by the test usually applied) immediately affects the accumulations; the point at which the air in the goaf will explode moves downwards; cavities in which gas could not be seen before, becomes explosive in the higher parts; and unbratticed working places and the spaces between packwalls are affected in the same manner.

IV.—CAUSES WHICH LEAD TO A FOULING OF THE VENTILATING CURRENTS.

In the last two divisions of the subject it has been shown how a decrease in the quantity of air circulating in the ventilating currents, or an increase in the quantity of gas added to them, directly increases their tendency to become explosive; and how a fouling of the currents, even to a slight extent, causes explosive mixtures to appear, and accumulations to extend. The causes by which the quantity of air is diminished, or the quantity of gas increased, will be shortly discussed in the present part. They may be classified in the following way:—

A.—Meteorological.	1. Increase of temperature at the surface. 2. Fall of atmospheric pressure.
B.—Incidental.	1. Leakages and falls in the aircourses. 2. Eruptions of gas from blowers. 3. Eruptions of gas from the roof or pavement.

A.—Recent investigations have shown that explosions coincident with meteorological changes are by far the most numerous. Diagrams,* illustrative of this, by Mr. Theo. Wood Bunning, for the years 1868 and 1869, and still more recent researches, by Robert H. Scott, F.R.S., and the Author, for which the most accurate meteorological data obtainable were employed, seem to place this question entirely beyond dispute.

Fig. 10 is part of the diagram for 1870. The shaded squares are the fatal explosions—those numbered IX. VIII. IV. VI. II. and III. are supposed to be due to high temperature causing a partial stagnation of the ventilating current; those numbered X. to fall of atmospheric pressure, liberating gas from wide fissures and accumulations; each space representing a day. The dark

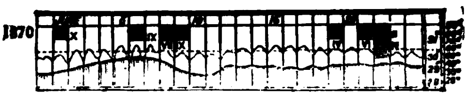


FIG. 10.

II. North and East Lancashire or Manchester; IV. Midland; VI. South-Western; III. South-West Lancashire and North Wales; VIII. South Wales; X. Yorkshire; IX. Northumberland, North Durham, Cumberland.

curved line is the continuous barogram, and the light curved line the continuous thermogram at Stonyhurst † throughout (say) the twenty-five days. The scales to the right are degrees for the thermometer, and inches for the barometer. The *data* at the observatory nearest to the place of explosion correspond with those of Stonyhurst.

On the day before the explosion on June 1, the barometer was lower than it had been on any of the previous sixteen days. It might be supposed that the effect of the low pressure would have passed before the explosion took place, but a consideration of what was said in Part III. will show reasons why this may not have been the case. The explosions on the 6th, 8th, 19th, 21st, and 22nd are evidently due to the high temperature, while that on the 9th may be a consequence either of the low barometer or of the sluggish currents of the four preceding days. When the pressure of the atmosphere *decreases*, every portion of air or gas to which it is accessible *increases* correspondingly in volume. Let Vo be the volume at 31″, and Vn the volume at 30″, and let the pressure decrease from 31″ to 30″. Then the ratio of the new volume to the old is given by the formula—

$$\frac{Vn}{Vo} = \frac{31}{30} \text{ or } Vn = Vo\,\frac{31}{30}.$$

The new volume is 31-30ths of the old, or has increased by 1-30th. When the atmospheric pressure becomes less, each fissure must emit some of the gas kept back in it, however minute the quantity, and each accumulation gives off part of its contents to the ventilating current, so that there must be a fouling of the air to a greater extent than usual. As a consequence, some of the currents themselves may become explosive; but, in any case, the accu-

* "Transactions of the North of England Institute of Mining Engineers," vol. xix.

† Compare with curves in Quarterly Weather Report of Meteorological Office for Glasgow, Falmouth, Kew, Aberdeen, Armagh, and Valentia.

mulations are increased, and some of them may become explosive. The effects of increased temperature at the surface will be considered in connection with natural ventilation.

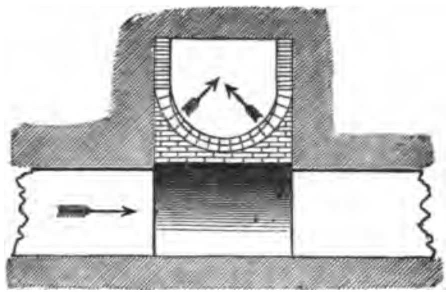


FIG. 11.

B.—1. Leakages between the intake and return aircourses are caused by falls of the roof, which damage stoppings, trap doors, &c. Important stoppings should, therefore, be securely built, and supported behind by a close stowing, so that the roof is well underpacked; they should also be plastered well in front. Air crossings and stoppings should be made as strong as possible, in order that they may be able to resist the sudden strain when an explosion unfortunately occurs. The lives of many men who fall victims to the after-damp might be saved by a better isolation of the return aircourse. Where this object is proposed the air crossings should be of very great strength, and might be able to resist an enormous strain if built after the manner of the one shown in section, fig. 11, with an inverted arch above in the return aircourse.

2. Eruptions of gas from blowers may be met without much danger by cutting exploring drifts in advance of the ordinary workings, and conveying the return air from them immediately into the return aircourse. Return air from such places should *never on any account* be allowed to pass ordinary working faces. Of two or more exploring drifts, the one which receives the air last should be the most advanced, and should have a bore-hole in front in critical cases.

3. Eruptions of gas at the working faces are sometimes avoided by boring holes into the roof or floor, as the case may be. Wherever they are apprehended, any single ventilating current should only be allowed to travel a short distance along the face. If this arrangement is made, and an eruption of gas takes place from a fall or rent in the floor, the foul air is soon carried into the return aircourse, and the probability of its becoming ignited is lessened according to the smaller number of lamps it has to pass; moreover, if it is ignited, only a local, and not a general, explosion will ensue—such as would be the case if it travelled a great distance in the workings before meeting with a defective lamp or a naked light. The safety lamp should be in continual and careful use in all exploring drifts, and in all parts of the workings into which a large quantity of gas may be thrown suddenly and unexpectedly.

V.—NATURAL VENTILATION.

So long as the workings of a mine have a higher temperature than the air at the surface, a current of air will flow into the downcast shaft, pass through the workings, and return to the surface by the upcast. This phenomenon is called natural ventilation—the air flows from a region of higher to a region of lower atmospheric pressure. Take the case of two shafts situated at the same surface level, each 100 fathoms deep, and let the atmospheric pressure at the surface be 2116·8 lbs. per square foot. Then, if the temperature of the air in each shaft be 56 degs., the pressure at the bottom will be about 2163·2 lbs. per square foot, and, under these circumstances, although an opening be made between them at the bottom, there will be no interchange of air. If, however, the temperature of the air in one of the shafts be 30 degs., and the tension of water vapour = ·1681″ of mercury, while the temperature of the other is 56 degs., and the tension of water vapour ·449 inches of mercury, then the atmospheric pressure at the bottom of the former will be 2165·9 lbs. per square foot, and at the bottom of the latter 2163·2 lbs. per square foot. The difference of pressure, 2·7 lbs. per square foot, divided by ·082 lbs., the average weight of a cubic foot of air and water vapour in the colder shaft gives 33·6 ft. as the dynamic head; and this determines the velocity of the flow of air which takes place when an opening is made between the shafts at the bottom. Now, if we conceive the temperature of the air in the colder shaft to rise gradually to 56 degs., and the tension of the water vapour to increase according to the temperature, we reach the point at which the air would cease to flow from one shaft to the other; but let the same difference of pressure (2·7 lbs. per square foot) be maintained by some mechanical means, and the same weight of air will flow as before. Again, let the temperature of the air in one of the shafts rise to 82 degs., and the tension of water vapour to ·5196″ (66 degs.), while for the other the temperature is 56 degs., and the tension of water vapour ·449″ as before; then the difference of pressure is 2·27 lbs. per square foot, and in order to cause the same weight of air to flow from the hotter to the colder shaft, it will now be necessary to produce an artificial dynamic head whose pressure on the square foot is equal to 4·97 lbs.

The air returning from the workings has a constant temperature throughout the year, and it is nearly always saturated with water vapour, but it cools somewhat in ascending the shaft, losing its heat partly to the sides of the shaft, partly on account of its increasing volume as it ascends. Accordingly, in the foregoing examples, we have assumed 56 degs. as the mean temperature of the air in the upcast shaft, while we have considered that in the downcast to vary between the limits of 30 degs. and 82 degs.

The effect of change of temperature at the surface on the ventilation of a mine will now be obvious. For instance, if 100,000 cubic feet of air per minute are passing through a mine when the dynamic head represents a pressure of 2·7 lbs. per square foot, we have—

$$\frac{100,000 \times 2\cdot7}{33,000} = 8\cdot2 \text{ horse-power}$$

as the work performed—by the heat of the earth when the air in the downcast shaft is at 30 degs., in the examples we have considered, and by mechanical means when it is at 56 degs.; but when the temperature of the downcast air rises to 82 degs., it is necessary to increase the effective power of the mechanical ventilator to—

$$\frac{100,000 \times 4 \cdot 97}{33,000} = 15 \text{ horse-power}$$

in order to maintain the same ventilation.

It is not to the extent of the daily range of temperature that we must look for dangerous vicissitudes in the ventilation of a mine so much as to the sudden setting in of an unusually high temperature for a few days, for the artificial power is not usually employed to a greater extent than it is required, and the first intimation that more air is wanted is a partial stagnation and fouling of the ventilating currents. The danger is greatest in the first few days of high temperature; as soon as the artificial power is sufficiently increased, the work may be carried on as safely as before. In the year 1870 the temperature rose to 70 degs. and upwards on twenty-six different days between April 17 and July 27, and only on one occasion did it reach 70 degs. for five consecutive days. Accordingly we find fatal explosions on twelve of the twenty-six days, two explosions on one of the twelve, and one on each of the other eleven days. Coincidences like these are more than accidental—they point to a most intimate connection between the phenomena, they offer a rational explanation of the causes which lead to many explosions, and, at the same time, they indicate the remedy distinctly.

VI.—CONCLUSIONS.

A rise of temperature at the surface can influence the condition of a mine only in so far as the mean temperature of the air in the downcast shaft is increased, thereby causing a partial stagnation and fouling of the ventilating currents; a fall of atmospheric pressure, on the other hand, liberates gas and foul air from the fissures and accumulations; again, we have fouling of the currents and the appearance of explosive mixtures where not expected. Now, so long as the quantity of air supplied to the workings is sufficient to preserve them in a state of safety under the usual atmospheric conditions only, it must appear, from what has been already said, that adverse meteorological changes will sometimes cause parts of the workings, and sometimes the whole mine, to relapse into a state of danger, and the concurrence of what we have called incidental causes will add to the peril. Under these circumstances, the safety lamp has undoubtedly averted a local explosion, or a general catastrophe, times without number; but the more often the crisis is apt to return, the greater is the probability that at some time or another the gas will be ignited at an injured or defective lamp. Ultimately, then, *everything depends* upon the relative proportions of air supplied to the workings and gas emitted by the coal, so that the greater and more regular the supply of air, the less is the probability that ever at any time an explosion can take place.

It does not appear that the introduction of scientific instruments for the purpose of foreseeing and providing against the effects of adverse meteorological changes can be very successful. The true index of the state of a mine at all times is the main return aircourse, and thither we must go in order to ascertain whether the quantity of air is diminishing, or the quantity of gas becoming dangerous; the former object can be attained by the use of instruments recording the velocity and resistance of the ventilating current; an increased quantity of gas, however, is not so easily perceived, and danger from this source can best be provided against by *supplying at all times* a greater quantity of air than is absolutely necessary under the usual conditions of the mine.

The safety lamp employed should be self-extinguishing as soon as there is sufficient gas in the air to make it explosive; *under no circumstances whatever* should work be carried on in an explosive atmosphere. A sound wave from a violently exploding shot (possibly even at a considerable distance) will, under certain circumstances, pass the flame of the firedamp through the gauze of the lamp, and hence it is, probably, that we find explosions have occurred when the place in which the shot was fired contained no explosive mixture. The vibration of the air caused by a local explosion will act in the same way upon all lamps situated in explosive mixtures, and, when of considerable amplitude, its influence will be extended to the most remote districts of the workings. Risca, 1860; Ferndale, 1867; and Haydock, 1869, are notable examples of double explosion, and several others might be mentioned in which there appeared to be no train of explosive mixture between the districts in which simultaneous explosions took place. The explosion which happened at Ferndale in 1867 is probably the most striking example of this kind that has ever occurred.

[A plan of these workings is appended.]

Finally, the pertinent question arises whether air which contains so small a proportion of gas to make it explosive under ordinary pressure and temperature does not become so at the instant of compression and heating when it is traversed by an intense sound wave. Davy* found that when he rarefied a mixture of hydrogen and oxygen to one-sixteenth of its original volume it would no longer explode when the electric spark was passed through it, but when he heated the top of the eudiometer to redness a slight explosion of the heated part of the gases could be effected. Abel† mentions that loose guncotton set on fire by a flame burns quietly, but when a detonating compound is used to ignite it there is a violent explosion. The consideration of these facts, in connection with the compression and heating which take place in a sound wave, seems to indicate the way towards a satisfactory explanation of the mysterious violence which has distinguished some of the more celebrated explosions.

* "Phil. Trans." 1817, p. 46. † Ibid. 1870, p. 497.

Mr. Hermon's Prize Essays.

THE PREVENTION OF CATASTROPHES IN MINES.

MR. WILLIAM HOPTON'S ESSAY,

TO WHICH THE SECOND PRIZE WAS AWARDED.

INTRODUCTION.

The writer of the following essay is well known as the author of "Conversations on Mines, between Father and Son," a useful little work in which he has adopted the form of a dialogue, supposed to be carried on between a veteran and experienced miner and his son, who is also engaged in the same industry, and anxious to obtain all the knowledge by which he may become best qualified for the successful pursuit of his calling. This style of writing has its advantages, and also some disadvantages; but Mr. Hopton is so far satisfied with it that, to a large extent, he has adopted it in his Prize Essay. The Essay itself is divided into two distinct branches—one of which treats on "The Causes of Loss of Life in Mines," and the other is headed, "To Prevent Loss of Life in Mines." In the original document, these two branches are arranged side-by-side—the one occupying the left-hand page, and the other standing opposite to it on the right-hand page. In now printing the work we have departed from this arrangement, but we have clearly marked the distinction by the employment of ordinary Roman type for the conversational part of the paper, which treats on "PREVENTION," and *italic* type for the Author's remarks *in propriâ personâ*, which deal with "CAUSES."

I.—IMPROVEMENT IN THE QUALIFICATIONS OF COLLIERY OFFICIALS.

SON: What would you suggest, father, for the "prevention" of catastrophes in mines?

FATHER: Examiners or inspectors should be appointed at once, whose office and duties should be to examine all managers, overlookers, firemen, and deputies as to their knowledge of the atmospheric air, ventilation, mine gases, mines, and mining: each successful candidate to receive a 1st, 2nd, or 3rd class certificate, according to his abilities.

SON: Then, examiners being appointed, all officials "would have to pass" an examination, and prepare themselves at once to gain certificates, time being given for the efficiency of all?

FATHER: No colliery officials should hold office, say, after the expiration of ten years, except those who have passed a careful examination, and received certificates of 1st, 2nd, and 3rd class abilities. Ten years' grace would wear out all the old officials, and others, young and able, would have ten years' time for self-culture. Then, and not before, will the right man be found in the right place; all would (if certificates were offered and required), endeavour to excel each other in knowledge, and many successful candidates might obtain situations long before the expiration of ten years.

SON: Suppose a fireman had to be examined, how would you proceed?

FATHER: I would proceed by asking these questions, and require such answer as follows each succeeding:—

Examiner: Can you read and write? *Fireman:* I can; and I have also a knowledge of arithmetic.—*Examiner:* Have you a perfect and thorough knowledge of gases, &c.? *Fireman:* Yes; and also of the atmospheric air.—*Examiner:* What do you know of gases? *Fireman:* The atmosphere consists of twenty-one parts of oxygen, and seventy-nine parts of nitrogen in 100, or one part oxygen, and four parts nitrogen.—*Examiner:* What is the composition of firedamp? *Fireman:* It consists of four parts of hydrogen, and one part of carbon.—*Examiner:* Do you know the composition of (blackdamp) carbonic acid gas? *Fireman:* It consists of six parts, by weight, of carbon, and sixteen parts of oxygen.—*Examiner:* You know, I presume, the composition of after or choke damp? *Fireman:* It is formed of one part of carbonic acid, two parts of water vapour, and eight parts of nitrogen.—*Examiner:* You know, of course, the weight or specific gravity of such gases? *Fireman:* The specific gravity of the atmosphere is 1·000; firedamp, 0·555; and blackdamp, 1·524.—*Examiner:* Do variations in the weight affect mines? *Fireman:* Mines are affected by them in the following manner: firedamp being 0·555, it is only half the weight of the atmosphere (1·000), and, as such is the case, it makes its way up into every hole in the roof, and all workings which are very high, to the top of which it rises, and to bring the gas down both a great force and quantity of air would be required.—*Examiner:* Does blackdamp also affect mines by its weight? *Fireman:* Blackdamp being 1·524, is near one-third heavier than the atmosphere; it settles downwards to the floor like mud in water, fills the lowest workings, and to bring it up therefrom both force and quantity of air are required, which, if it should be insufficient, will only pass through the gas, and not remove it.—*Examiner:* Very well, that will do for the present, but call to-morrow, and the examination shall be resumed.

All other colliery officials should be examined in the same way on mining questions.

SON: Officials thus qualified would have a thorough knowledge of their duties, and might prevent catastrophes which now frequently occur through their gross ignorance and inability?

FATHER: Undoubtedly, for those in charge of mines, and the lives of men, should have a perfect knowledge of the nature of gases, ventilation, and the atmospheric changes, &c., which so often affect mines. This would be a step in the right direction towards preventing catastrophes in mines; and if Government only took the matter in hand, a great improvement would speedily take place, for which ten years' grace would be ample time for all to prepare themselves.

To the thinking portion of those engaged in mines, it is a well-known and undisputed fact that a great improvement is much needed in the qualifications and abilities of colliery officials, and one that must take place before we can hope for, or expect to see, a better state of things. By far the greater number can neither read nor write, and many are ignorant in the extreme as to the natural laws which govern the atmosphere. Ask if they *understand anything of the atmospheric changes, how such changes affect mines, and of the properties, &c., of mine gases, and you will find them totally devoid of all knowledge of these subjects—perfect acquaintance with which is so very essential to the proper and safe performance of their duties.*

As instances of this, I give the following: Forty lives were lost by an explosion of firedamp, and at the inquest I heard the Inspector of Mines ask the underlooker of the colliery, who was of twenty years' standing, if he knew the "cause" of a mine "discharging" more gas at one time than at another, and he replied, "Because some person might leave a cloth down." The question was put a second time, and the reply was that "a door might be left open." So much for his knowledge of the cause in the variation of gas discharged. At another explosion, in which sixty lives were lost, the underlooker, who was of twenty-one years' standing, said, "I will tell you what, in my opinion, has been the cause of this explosion." Every eye and ear was open to have the mystery solved; he then gave it as his opinion that the smoke of the gunpowder had exploded, and had afterwards to confess (when he had shown such ignorance, and caused people to laugh) that he neither understood the atmospheric changes nor mine gases.

Can we expect or hope for a better state of things when such ignorance prevails even amongst those who have the control of mines? No, never!

Employers, it is true, are obliged to have a certain number of firemen, and other officials, but men are frequently engaged by underlookers regardless as to whether they understand their duties or not. If only the specified number of firemen are at work, irrespective of their capabilities, the employers are clear from the law. This should not be.

II.—IMPROVEMENT IN THE CULTURE OF MINERS.

SON: Should not miners, also, be better informed?

FATHER: Yes; Government should pass an Act similar to the Educational Act, making it binding, under a penalty, for all persons under twenty years of age, to receive annually a stated number of lessons in reading, writing, arithmetic, and the atmosphere and mine gases, &c.

SON: Will not the Education Act have a tendency to improve young people employed in mines, as they will at least be able to read and write?

FATHER: Yes, if only a law were made, making it binding, under penalty, to continue receiving lessons.

SON: People say it is useless to educate young persons, because when they go to work they lose all they have learnt?

FATHER: That, in many cases, will hold good; therefore, so much the more reason for Government making it compulsory for youths to continue their course of lessons even after they commence work, unless they have attained some standard capacity to be determined. I learnt, after a hard day's work in a coal mine, all I know.

SON: That would be a great improvement on the present state of things, and the lessons might be obtained during their leisure hours.

FATHER: Each student must continue to receive instruction from his schoolmaster, or from some properly appointed tutor, until he has obtained that information which every miner ought to possess. This would be another step in the right direction, from which a better state of things would soon take place, and much ignorance be removed, and loss of life and property prevented, and, at the same time, a good class of colliery officials would be obtained therefrom.

Can we expect to see a good state of things when miners are ignorant and uneducated to a culpable degree? Very, very few can either read or write, for they seem to think of little else in their leisure time but man-fighting, dog-fighting, cock-fighting, race-running, pigeon-flying, gambling, and drinking. If there is leisure time for wickedness and vice, there is time for mental improvement and self-culture. How many lives have been lost in mines by ignorant miners eternity only can reveal.

The following wanton act, which is only one out of hundreds, took place at the Thornhill Colliery, on the 27th December, 1871: In the place where the deceased men had been working, lamps were found unlocked, others had their tops off, and in their clothes were found matches and lamp keys. Such is the present state of things in mines. Let the Government make a law to improve them, and we shall shortly have an improvement.

III.—SUGGESTIONS FOR THE IMPROVEMENT OF INSPECTION.

SON: Could not inspection be improved?

FATHER: It could; and catastrophes would be much oftener, and many more lives lost or sacrificed, no doubt, were it not for inspection; but I think each inspector should (as their duties are so manifold), be assisted by a subordinate officer, whose province should be to inspect every part of the workings, not to order, compel, or demand colliery officials, but report only the state of things to his superior—thus, another danger might be removed.

I have no doubt, by what I have been informed, many colliery officials allow things to get into a bad state when they expect no visit from the inspector, and are only kept near the mark when visits are frequent. Once it is known that the inspector is coming to visit the colliery, great improvements by some managers are immediately commenced, such as enlarging airways, stoppings and doors repaired, the roof propped and barred, &c. &c.

IV.—TO PREVENT OUTBURSTS OF GAS FROM THE FLOOR AND GOAF, WHICH IS THE GREATEST DANGER IN MINES.

SON: The greatest danger to contend with in coal mines is from the sudden outburst of gas taking place, emanating from the floor and goaf, and such, you know, father, might be prevented by a little expenditure?

FATHER: Hundreds of lives have been sacrificed by sudden outbursts of gas from the floor and goaf, and miners are constantly working in jeopardy, when a small expense would remove the gas, and prevent the casualties.

SON: How would you remove the danger, and prevent catastrophes from these outbursts?

FATHER: I would erect an engine on the surface to pump gas out of the floor and goaf, through one large gas pipe from the surface to the bottom of the shaft (any of the shafts would do), and small branch pipes therefrom, laid in the floor of the workings to the extremity of the coal to be worked out; the small pipes should be left in the goaf, buried in the floor, to prevent falls of roof in the goaf breaking them. The pipes left in the goaf must have open valves at certain distances, to take in the gas which might accumulate therein, such open valves being protected by stone walls built round them. See large plan No. 1.

SON: That, no doubt, would do to take gas out of the goaf, but how would you drain off the gas from the floor?

FATHER: I would make boreholes in the floor at determined distances in the intakes, and fix a small branch pipe therein from the pipe passing along the return. The gas in both the floor and goaf would then be pumped out through the pipes along the roads safe to the surface by the engine working a gas cylinder, erected on the surface, and the gas thus obtained might be made a source of profit.

SON: Then, if the gas passed through the pipes from the floor and goaf safe to the surface, the current of air would have very little gas left in it?

FATHER: Very, very little, and a great source of danger would be removed.

SON: The pipes left in the goaf to drain off the gas would be lost, but the loss would be nothing when compared with the benefit and safety that would be derived?

FATHER: One length of pipes would be capable of draining, say fifty yards, on either side of it, and a four-inch pipe (and in many cases a less than four-inch would do) would cost 4s. 6d. per yard, or, in other words, expenditure of 4s. 6d. in pipes would drain 100 square yards of goaf, a trifle not worth naming when we consider the great sacrifice of life and property that might be prevented.

SON: Gas pipes may be seen in the large plans, Nos. 1, 2, 3, and 4.

FATHER: Just so; and the plans show also the goaf ventilated with roads around the goaf, to convey the discharge of gas away safe to the upcast shaft by way of the returns, yet I know that this road round the goaf may be safe and good in some collieries, but it is not practicable in all mines. The pipe system is PRACTICABLE, and may with safety be adopted in all mines discharging much gas.

[By inspecting the large plan, No. 1, the engine on the surface, and pipes laid through the mine and along the goaf, may be seen.]

I have had the management of mines when a fall in the atmospheric weight, or a reduced pressure, has swelled and expanded gas out of the goaf, causing it *to overflow the workings, filling the airways and pony roads for hundreds of yards. These sudden outbursts of gas occur without giving the least warning, and as quickly disappear.*

The goaf is full of gas, and not only will a reduced pressure in the atmosphere swell it out, but a fall in the goaf will force it into the workings and tramways.

All mines discharging much explosive gas are, more or less, subject to these periodical outbursts from the goaf and floor, therefore a remedy for such would be the removing of one of the greatest dangers that have to be contended with in mines. During the course of my experience, I have seen many large outbursts of gas from the floor and goaf, and most explosions attended with great loss of life and property, have been caused by such in several mining districts.

At the Stafford Main Collieries, near Barnsley, a short time ago, an outburst of gas from the floor occurred, and so sudden was the irruption that an immense volume of air was immediately brought to the firing point. In August, 1870, *a second serious outburst of a similar character took place, when a hole was bored in the floor to the depth of* $74\frac{1}{4}$ *ft., and a* $1\frac{3}{4}$*-in. pipe inserted therein, well wrapped round to make it firmly tight. To the end of the tube was attached a loaded valve and pressure gauge, and in a very short time a pressure of* 110 *lbs. to the square inch was indicated. A party of mining engineers afterwards conducted some experiments with the gauge and valve, to ascertain in how short a time the pressure of gas would accumulate from blowing off at zero to its maximum, when the gauge rose to* 10 *lbs. in the first minute, to* 73 *lbs. in fifteen minutes, and then to* $95\frac{1}{2}$ *lbs. at which point a leak occurred.—See* Colliery Guardian, *December* 23, 1870. *The same journal of January* 12, 1872, *states that another colliery discharged from the floor* 16,200,000 *cubic feet of gas in nine hours, and stopped a current of* 20,000 *ft. of air for the same length of time.*

How desirable, then, for the safety of all concerned, to have the gas in the floor and goaf pumped out and brought safe to the surface, for hundreds of cases similar to the above might be quoted.

V.—GUNPOWDER AND SAFETY LAMPS.

Son: We have had many explosions and much loss of life with gunpowder and blown-out shots in mines where safety lamps are used; what suggestions have you for the safe working of such mines?

Father: The best safeguard is to clear the mine of the explosive power (gas); that is, remove the cause, and the effect will cease. Blow-out shots only cause explosions in the presence of gas, therefore, the fault is not in the shot, but with the gas. I would suggest, then, for the safety of the workmen, that every underground manager adopt a similar plan to one I have adopted in all mines under my charge, where gunpowder had to be used, and in this respect it is only what I have done and am doing myself—that is, to carry a naked light through the airways about twice a month. This duty should be compulsory on all underground managers. If the manager is worthy of his situation, he will understand the several degrees of the impurity of the air, and, if unsafe for a naked light, it is equally so to explode gunpowder; therefore, his duty would be to see that the current is pure, if only for his own safety, and finding it not so, at once to stop the explosion of gunpowder. This he must attend to, or get out the coal with hydraulic machinery, or some other substitute for gunpowder.

SON: Then you would not allow the manager to transfer this naked light duty to the hands of a subordinate officer?

FATHER: No; he himself only must attend to that duty. In him there is power to discontinue its use when there is the appearance of danger, but not so with others, for they might fear the loss of their situations, and, because of that fear, fail to show the real state of things when bad, and so go on, from bad to worse, until an explosion takes place. Yet, if there is no explosion, they only give themselves more and more license for neglect, until the air becomes so charged with gas that every life in the mine hangs upon one turning point, that is, if the furnace power should be diminished for a short while, a door left open for a moment, a fall in the airway take place, the temperature on the surface to rise and diminish the current (which it would do) in the mine, or a fall in the atmospheric weight (which would cause the letting-off of more gas), every soul would be suddenly sent into the spirit world. Let the underground manager take the responsibility, and pass through the airways with a naked light, because, as I have before said, if not safe for a naked light, it is not safe to explode gunpowder. Hundreds of lives are more valuable than one, and particularly so when that one is responsible for the wrong done. Only let this be a law of compulsion, and we shall have fewer lives lost with the use of gunpowder, because he would then attend to the current's purity by seeing that the airways are large enough, and the furnace of sufficient force, whenever gunpowder is about to be used. I have had a few slight explosions by allowing naked lights where gunpowder had to be used, but such explosions only took place by the workman deranging the brattice cloth, causing gas to accumulate in his place, and as I always looked well to the purity of the air, the explosion only affected the person who ignited the gas; therefore, the explosion not being able to spread, I have only had one death by the naked light system, and his death was caused by the man seeing and yet passing over a danger signal. There may, then, be slight explosions, yet such being slight will only be forerunners to compel managers to look well to the purity of the ventilating current, then an explosion cannot affect all, only the person who ignites the gas.

SON: Are not many lives lost by explosions of gunpowder in drilling out the hole after missing fire?

FATHER: Yes, undoubtedly there are, and if a "copper," instead of a steel drill were used, such accidents would not occur.

If explosions are to be prevented in mines, and the use of gunpowder and safety lamps continued, the responsibility of the purity of the current ought to be with the underground manager, who understands his duty, until a *better class of underground officials are obtained. We have too many ignorant and even reckless colliery officials, who allow things to go on, growing worse and worse, and giving themselves more and more license, simply because they escaped an explosion on some previous occasion when things were in a most dangerous condition, and, knowing no explosion took place when it was so bad, they continue to go on, thinking all will go well, again and again, until an explosion, cutting short their career, occurs, sweeps into an untimely grave large numbers, and destroys an immense value of property.*

VI.—NUMBER OF SHAFTS AND VENTILATING POWERS REQUIRED FOR SAFE WORKING OF MINES.

SON: It is the opinion of many people that if we had more shafts there would be less explosions?

FATHER: An increased number of shafts might, in some cases, improve the safety, yet several things must be considered before making a law to compel colliery proprietors to sink more shafts. Some mines discharge more gas than others, and in other mines they can always have large airways, by which much air can be obtained, while, in others, the airways cannot be so large, because of the falling and heaving-to of the roof and floor; consequently, if all had to increase the number of shafts, while in some cases it would only be right and proper, in others an injustice would be done.

SON: What law, then, would meet the requirements of the case?

FATHER: Every ventilator should always have a surplus power at command, ready at any moment to increase the quantity of air when required to one-sixth larger than the ordinary circumstances, so that if 20-horse power would produce air to dilute the gas, 10-horse surplus power should be kept in readiness for an emergency.

SON: You would have this extra power of ventilation always ready, then, not at work, so that if the workings were extended more and more, it would only be because no cap of gas appeared in the current, or this surplus power was not required?

FATHER: It should always be seen that the furnace power is able to do its work well, so that if the inspector called at any colliery and found a cap of gas in the current, it might be removed during the time he was in that part of the mine.

SON: When this surplus power is required to remove the gas from the extended workings, the duty of the manager would be to increase again the furnace power accordingly?

FATHER: Either to do so, or enlarge the airways, to produce more air, or afterwards open out new shafts. A surplus in the ventilating power is required, and should at all times be ready for the safe working of mines, and not go on extending the workings regardless of the furnace power; if not, we may expect catastrophes whenever there is a fall in the atmospheric pressure, or a rise in the temperature on the surface. This surplus power, if always ready and attended to, would diminish the number of explosions, and another danger be removed.

The purity of the current is often neglected; and the furnace power, while it should be greater than is required, is kept even below a proportion to the work required to be done for the safe working of the mine. And again, some managers keep extending and extending the workings, until the current is surcharged with gas, and yet with no regard to the power of the furnace, its whole power being at work, and showing its inability to keep the current clear by the safety lamps being now and again filled with flame. When such is the state of things, explosions may well take place. If we were able to invent a mechanical ventilator to produce double the quantity of air now produced, under such management as the above, in a very short time things would be little or no better than they are now; as the workings were extended, the airways would be proportionately diminished, or more workings added for the furnace to ventilate, and so things would soon be as bad as before.

If, suppose, there were also an increased number of shafts, the airways would, no doubt, be diminished accordingly, with more workings again added, and, if so, the safety of the mine would be no better than before, therefore the furnace power should be attended to.

VII.—HOW THE AIR SHOULD BE CONDUCTED FROM THE DOWNCAST INTO THE WORKINGS FOR THE SAFETY OF THE MEN.

Son: Pure air, and not impure, should pass, I presume, through all tramways into the workings where the men have to travel and work, and repass with the coal?

Father: Just so. There is a right and a wrong way of conducting pure air to, and the gases away from the men, and through the workings of the mine. I will make this subject more clear by a simple illustration, so that you will better understand my meaning. Suppose a number of chemical works to be near a large population, who are affected by breathing impure air every time the wind blows from the works towards them, and in case a change takes place so as to blow the gases in an opposite direction, even if its force be only one-twelfth of that which blew the gases to them, yet by this change of the wind all would breathe a purer air, as no gas can force itself against the wind, be its velocity ever so small. And so, in like manner, is the ventilation of mines. The air should be conducted pure from the downcast along the roads where the men pass and repass with coal and to their work, and the impure air conducted safe to the upcast along such roads as are not in use or required for the men to pass backward and forward. If this way of conducting pure air into the workings be properly attended to it will greatly diminish the danger now existing in mines and prevent loss of life.

[See large plan, No. 4, for this system of ventilation.]

There is no regard or regularity with some managers as to the way and manner of conducting gases and the impure air through the workings of a mine, so that all the gases discharged and swelled out of the goaf are thrown out into the tramroads, by which every life in the mine is jeopardised. This should not be, if loss of life must be diminished.

VIII.—HOW TO VENTILATE THE WORKINGS.

SON: What improvement would you suggest for the ventilation of mines?

FATHER: The air should be divided, split, or separated into distinct currents or parts of (say) 4000 to 6000 ft. of pure air for each separate division. By splitting it into parts, the explosive power, gas, is prevented from collecting in large quantities. If 100 ft. of gas were discharged per minute from one group of miners, 500 ft. might be discharged in the workings of five groups, and to ventilate all that with one current, the whole volume of 500 ft. of gas might be exploded at once, but only one-fifth if ventilated separately, and so the power of the explosion would be reduced to one-fifth, the amount of choke-damp left by the explosion would be reduced to one-fifth, the route the explosion would spread would be reduced to one-fifth, the danger to life would be reduced to one-fifth, and the number of doors to less than one-fifth; therefore, if loss of life and property is to be prevented, dividing of the air must be adopted, because the danger lies in the gathering and exploding of too large a quantity of gas. Divide, therefore, the air, and you divide the explosive power, gas.

SON: The dividing of the air would prevent outbursts of gas from passing into any working place but the one in which it is discharged.

FATHER: Just so; therefore only one working place would be affected by it, not all, and the quantity of gas discharged might be too large in mixture for the quantity of air in the said division, by which the explosive power (if one did take place) would be diminished accordingly, as the power of an explosion is in proportion to the mixture as well as the quantity of gases discharged.

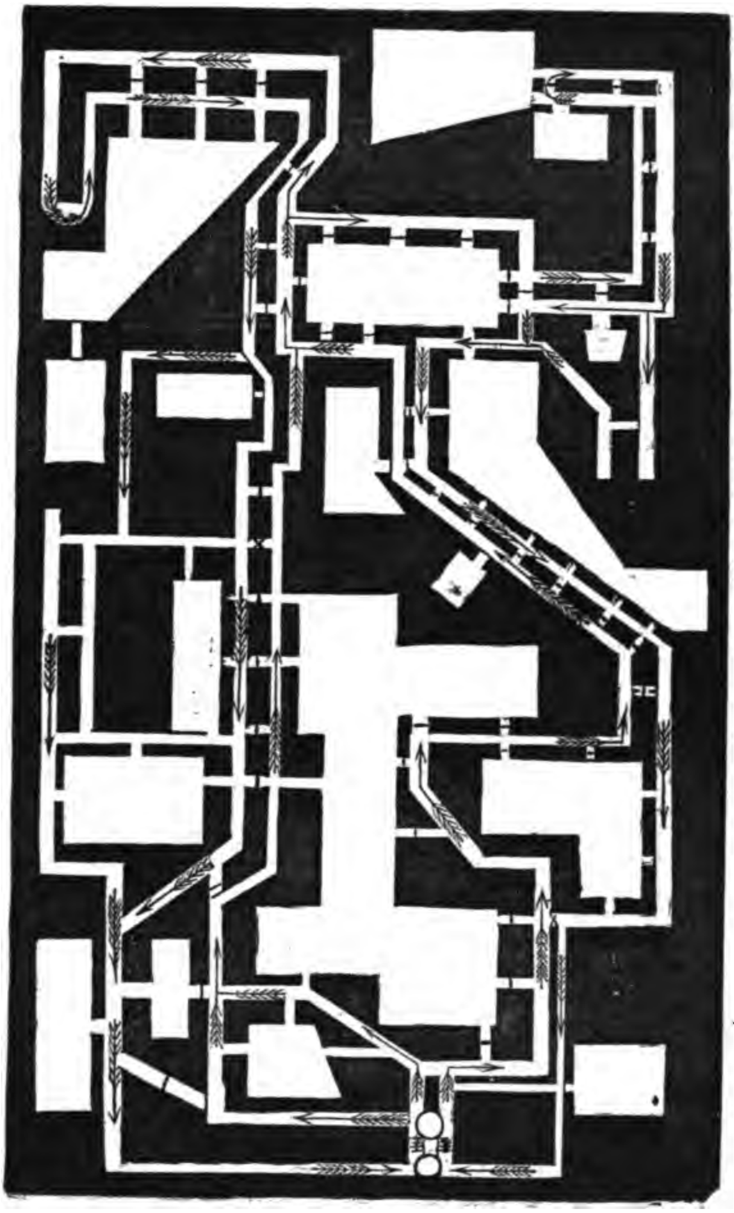
SON: By the dividing of the air, would not the velocity of the current be also diminished?

FATHER: Yes, and there would be less danger of propelling the flame of the lamp through the gauze, for there is very great danger of doing so when the current passes through the airway at a great velocity. Great loss of life would be prevented by dividing the air.

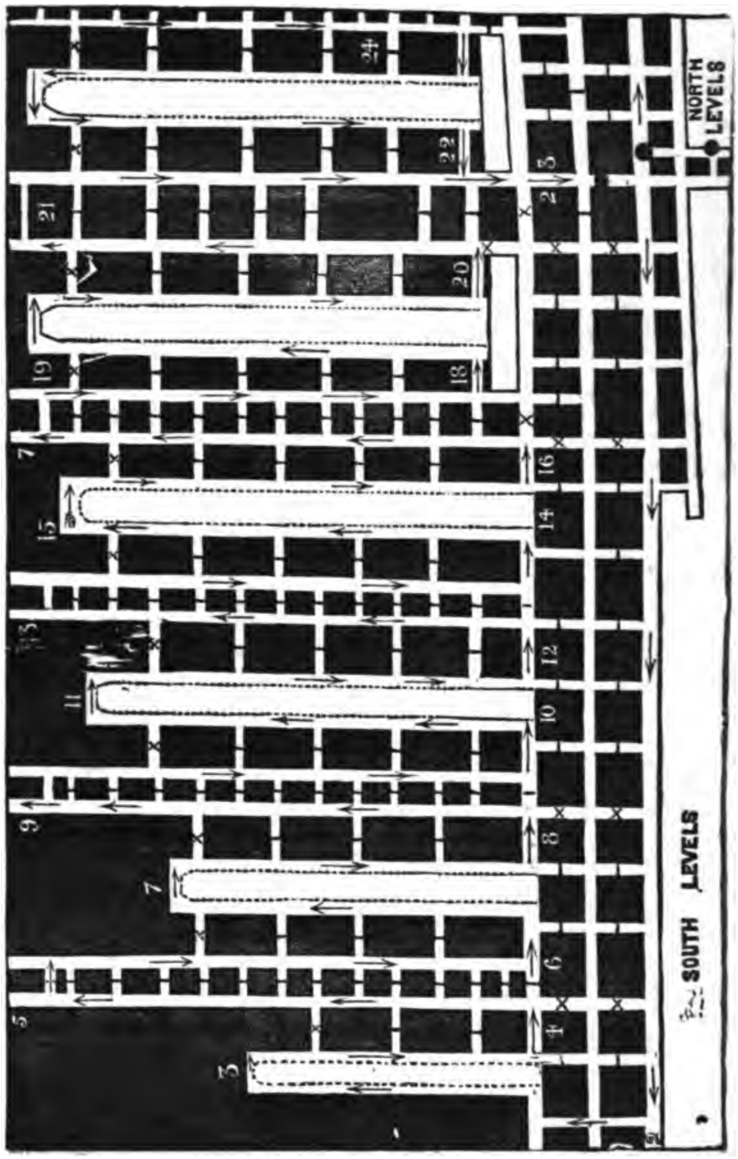
[See the large sheet plans, Nos. 2, 3, and 4, for the dividing of the air, and for supplying each tramway with pure air.]

If 30,000 ft. of air pass through five working places in one continuous route, all the five places would be affected by an explosion, because each and every part accumulates gas in the current in which the explosion takes place, and, as all are ventilated by it, all would in like manner be affected. Among the first group of miners all the air enters, after which it leaves

Plan D.



PLAN A.



that group or place and passes on to the second, and so on to the fifth. In the first place, the men are well ventilated, and may be considered safe, provided that air and gas be not allowed to pass over a burning fire or furnace. In the second place, they are less safe, from the fact that all the firedamp accumulated in the first place goes directly in a current upon the second group, then proceeds on to the third, fourth, and fifth, gathering and accumulating gas as it passes around each place. Who, indeed, does not see that the miners in the fourth and fifth places are liable at any moment to be destroyed by an explosion of firedamp? One part of the mine would be filled with raging flames, and the men scorched to death, in another they would be killed instantaneously by the explosion of hot air and gases, and in other parts they would be suffocated by the noxious gases left after the explosion.

Plan A shows the one current system of a mine in which an explosion took place, and 189 lives were lost.

The arrows show the passage of the air; it commences its route at No. 1, from there it travels on the south level to No. 2, from there to No. 3, from there back to No. 4, then onward to No. 5, back again to No. 6, from there onward to one of the working faces at No. 7, then it is conducted back to No. 8, from there to the face of one of the narrow workings at No. 9, it then returns to No. 10, from there to the face of another working place at No. 11, then it returns to No. 12, it then enters the narrow working place at No. 13, and comes back again to No. 14. What a great route air travels by this mode of ventilation, yet, if the route extended as far, from the downcast through the workings to the upcast, as one end of the river Nile is far from the other, go it must if only it can travel. There is no alternative with some managers but one continuous route, which must conduct explosive gases into all parts of a mine. It will be seen that the air has yet to travel in and out from No. 14 to No. 22; and is it to be wondered at that explosions and loss of life are frequent when such modes of ventilation as this are tolerated?

IX.—STRENGTH OF STOPPINGS AND AIR CROSSINGS.

SON: Should not stoppings and air crossings be strong enough to resist the power or force of an explosion?

FATHER: Yes, for many lives have been lost by after-damp, which the air would have removed at once, and without loss of life, had not the stoppings and air crossings been blown down.

SON: In all mines, then, discharging much explosive gas, they should be strong enough to resist the force of an explosion; and, if so, the men would be safe (or much more so) from suffocation.

FATHER: Just so. Stoppings, instead of being formed by straight walls, should be constructed of two semi-circular walls, filled in with earth, so that instead of being blown down by an explosion, they would become all the more tightened, and thus render loss of life from this cause a thing not to be feared.

SON: I understand you, father, perfectly; but how would you make air crossings strong enough?

FATHER: In some cases it would be well to make a tunnel or drift in the roof over the intake; but in others a large plated iron circular tube would be better than a tunnel, and should be of sufficient strength of plate to resist the force.

SON: And would you not also have the stoppings at the end of this circular tube air crossing built in a semi-circular form?

FATHER: Just so; because both they and the tube would present a semi-circular face, no matter in which direction the force of an explosion might come. If it were made compulsory to do this in all mines discharging much explosive gas, another great danger would be removed.

[See plan No. 6 for air crossings and stoppings.]

A great number of stoppings are blown out, and air crossings destroyed, by the force of explosions, and when such is the case, many lives are lost through suffocation. Such air crossings are blown down at once, because they are only made of a few boards and bricks, and when an explosion occurs, the greater number are the victims of after-damp, which can only be removed by the current, but its passage having been blown up, through the stoppings and air crossings not having been of sufficient strength, the air returns to the upcast without being able to effect its purpose.

X.—BRATTICE CLOTH, AND HOW IT SHOULD BE FIXED TO REMOVE GAS FROM HIGH WORKING PLACES.

SON: Has not great loss of life been the result of explosions caused by ignorant firemen, deputies, &c., not understanding the nature of gases, and how to remove them?

FATHER: Undoubtedly; and every fireman, deputy, and underlooker should have a knowledge of the respective gravity and velocity of air and gas, and always be guided thereby; and in fixing brattice cloth to propel light gas from any high place, the cloth should be so arranged that the larger space will be in the air going to the gas, and the lesser space in its going from it, so that the requisite "force" may be obtained in the return current; if not so arranged, explosive gas being much lighter than air, the air will pass through it without bringing any away. When this is not attended to, which is often the case, miners work in momentary jeopardy of their lives, while the danger might be removed so simply. Therefore, firemen should see that there is force in the current in coming away from high working places, and such being the case, there is no danger of an explosion from this source.

[See large plan No. 5.]

It is my opinion that many lives have been sacrificed, and many more are often placed in jeopardy, by men having to work in explosive gas, when a knowledge of those laws which govern the atmosphere would at once remove *the danger. I have frequently had to remove gas when the firemen have seen no possible way of doing so, and all through the want of a knowledge of these very laws.*

XI.—BRATTICE CLOTH; ITS USE AND ABUSE IN THE WORKING OF MINES.

SON: Should not working places requiring brattice cloth be in short distances between the cut-throughs for removing gas from the face?

FATHER: Yes; bratticing will remove gas from the face if used to a limited extent, but it is now often changed from its use to its abuse; therefore, that which was first used to remove danger is now, by its abuse, the cause of danger.

SON: How is brattice cloth the cause of danger?

FATHER: Because in narrow places cut-throughs or openings are too few; for, while there should never be a greater distance than from 20 to 30 yards on the level, and a shorter distance in up-brows, there is often a distance of 60, 80, and even 100 yards between, and this for the paltry purpose of saving a comparatively trifling expense. Gas accumulates at the face, and brattice cloth, even when properly fixed, is unable to remove it at such a great distance, therefore its abuse is the cause of danger, and not unfrequent loss of life. I would recommend that Government prohibit the practice of long bratticing, and not allow an excess of 30 yards of brattice cloth in any one place. If this were attended to, and also seeing that no narrow place when finished become, as they often do, a magazine for gas—for in mining there is great danger of the same becoming such, and loss of life the result—another danger would be removed, and tend greatly to the safety of mines.

When narrow places are bratticed, for 60, 80, or 100 yards, it is impossible to keep them clear of gas, and if work is proceeding in five or six places near each other, an explosion in one place would explode the gas in all, and, this being the case, the power of such an explosion would be very great. Government ought to forbid such a practice. [Long bratticing may be seen on the large sheet plan No. 5.]

XII.—SAFER TO PROPEL AIR DOWN INTO A MINE THAN TO PUMP OR EXHAUST IT OUT.

SON: If a mechanical ventilator is employed to pump air out of a mine, is there not more danger than if it propelled air down?

FATHER: There is great danger if employed to pump air out, because, if the airway suddenly closed up, every stroke of the engine would empty out air, and by so doing would diminish the weight from off the pent-up gas, by which the gas would swell out from the strata, the goaf, every hole in the roof, and all working places, and might so suddenly fill the mine that an explosion would be imminent; but if, on the contrary, employed to propel air down into a mine every stroke of the engine would press more and more weight upon the pent-up gas, and thus give time for the men to escape when danger appeared. The subject of "propelling" currents of air through the workings has been the cause of much controversy; that subject is fully explained in the "Conversations on Mines."

XIII.—WHEN FURNACES SHOULD BE SUPPLIED WITH "PURE" AIR.

SON: Should not the furnace be supplied with pure air?

FATHER: The furnace should be supplied with pure air in all mines discharging explosive gas, because if an explosion should take place at the furnace, few people, if any, in the mine, would escape. My father was lost by an explosion at the furnace, and the mine in which it took place was worked by the one-current system. Government should prohibit the practice of supplying the furnace with the return current where safety lamps are used, which would be the removing of another great danger. In mines where candles are used there would be no danger in supplying the furnace with the return current.

XIV.—MEN ASCENDING AND DESCENDING BY THE FURNACE SHAFT.

SON: The heat in furnace shafts being so very high, what would be the result if an accident were to occur through the cage being stopped in the shaft?

FATHER: In some shafts the temperature varies from 100 to 150 degrees or more, and should such an accident occur in a shaft of this temperature, it would be certain death to all the occupants of the cage. Workmen should never be allowed either to ascend or descend a shaft that has a temperature of or above 100 degrees, and then an accident could not occur from this cause.

I have for years expected to hear of accidents by suffocation in furnace shafts, and Joseph Dickinson, Esq., inspector of mines, also stated in his evidence before the Select Committee on Mines that "he believed there would be, sooner or later, a number of men suffocated in furnace shafts."

XV.—WHY FURNACES SHOULD BE FIXED IN AN ELEVATED POSITION.

SON: Would it not be better, father, for furnaces to be fixed in a shaft of elevated position?

FATHER: It would, as explosive gas is so light that its tendency is to ascend, and the current also, having become warm and impregnated more or less with gas, has a tendency to go upwards, therefore neither of them can be propelled downwards very well; and where the practice of propelling them downwards to the upcast is followed, the danger of the mine is increased, because the gas, being driven against its natural tendency, will lodge in every possible place where the current is not strong enough to get at it and carry it along; but if the upcast be in an elevated position, gas would ascend to it without even the force of the current, which conclusively shows the necessity of upcast shafts being elevated. But if the upcast shaft cannot be placed in an elevated position, a current of air should be sent to the highest point of the goaf, so that the gas in the goaf might be drained to that point, and pass therefrom along the return to the upcast, thus draining the gas from the highest point of the goaf, as water is from the lowest by pumping; this will prevent any accumulation of gas taking place in the goaf, and thus another danger is removed.

XVI.—THE BEST SAFETY LAMP TO USE.

SON: Which do you consider, father, are the best kind of safety lamps?

FATHER: Where safety lamps are required to be used, it would be best to use only those kinds that cannot be opened by miners without extinguishing the light, such as Stephenson's, constructed with air passages to admit only just the quantity of air required to feed the flame, and if an explosion should take place within the lamp, it would enlarge the flame, and as an enlarged flame requires more air to feed it than the passages can admit, it would die out for the want of air, just as a person would die for the want of food. Such lamps have been the means of preventing accidents scores of times, and the best safety lamp to use is, in my opinion, Stephenson's; and making it compulsory for such lamps only to be used, would be another step towards the improvement of mines and the safety of workpeople. On the 20th of February, 1872, an improved safety lamp, invented by Henry D. Plimsoll, Esq., of London, was subjected to some severe experimental tests, performed by Mr. William Utley, underviewer at the Wombwell Main Collieries, Barnsley, the inventor (Mr. Plimsoll) and myself, with other friends, and the issue of the experiments was so successful that I have no hesitation in giving an opinion to the effect of its being the best safety lamp yet invented, as the following qualifications, which were fully borne out by the results of the tests, will amply show:—(1.) It is very sensitive to gas. (2.) The moment an explosion takes place within the lamp, its light is thereby extinguished. (3.) By unscrewing the lamp-top the light is extinguished, therefore there is no inducement for miners to tamper with it. (4.) It gives a very much clearer and purer light. (5.) The force of the current cannot extinguish its light, be the velocity ever so great. (6.) Should an explosion take place within the lamp, there is no possibility of the current propelling the flame outside. As the experiments have been made since I penned my opinion in favour of Stephenson's lamp, I felt bound, both in justice to Mr. Plimsoll and myself, to make the foregoing remarks, as the results of the experiments were such as to leave no doubt of its superiority over all others I have yet seen.

XVII.—LOSS OF LIFE FROM FALLS OF ROOF AND GOAF.

SON: The nature of the roof is not, I believe, father, the same in all mines?

FATHER: No; neither are coal and floor alike in all.

SON: If so, the same plan of working that may be pursued with safety and economy at one colliery, could not be pursued at another?

FATHER: The nature of the roof in some mines is such that if wagon roads are cut in the whole coal in advance of any other place, it will fall, while in others it is quite the reverse. Great caution and care should, therefore, be exercised to keep the roof whole in wagon roads, as neglect cannot but result in loss of life.

SON: Then it is not safe when the roof is broken either in the working places or the wagon roads by the cutting out of coal here and there, as it were, at random.

FATHER: The roof, as much as possible, should be kept whole for both economy and safety, therefore tramways or wagon roads should be cut, as shown in plan B; that is, to the extremity of the coal to be worked out, and then get the coal back from the extremity, which ensures the roads being safe and good; or work out the coal from the commencement to the extremity, as shown in plan C. If the lives of miners are to be protected from falls of roof and coal, such, or similar modes of working coal must be adopted. The roof must not be broken by the getting out of large blocks of coal here and there, leaving large pillars to be worked afterwards, which can only be accomplished at the almost certain loss of life.

SON: Are not the roof and coal very peculiar at some collieries, and full of natural joints and divisions?

FATHER: Yes, and they are so difficult to detect that falls will occur unexpectedly unless great care is taken.

SON: In mines having roofs with these peculiarities, and yet so difficult to detect them, the danger and probable loss of life must be increased very much if people employed in them have not a thoroughly practical knowledge of how to work them.

FATHER: Workpeople are constantly changing from one colliery—with a good, strong, safe, rock roof—to another treacherous, full of natural joints and divisions which falls unexpectedly, and lives are often lost by falls which would not have taken place had they had that knowledge which is to be derived from a constant habitual working of them.

SON: What would you suggest for the better and safer working of mines having roofs of such a treacherous nature?

FATHER: A person, or persons, possessing a thorough knowledge of them from years of constant employment in their working, should be appointed as roof examiners.

SON: Would you make those examiners prop and bar the working places for the men, and the employer be responsible for accidents which might occur?

FATHER: No, I would make the manager responsible if he did not appoint a person to examine who understood the nature of the roof and his duties well, and see that the examiner wrote a report showing every day what orders he had given to the workmen in his district, but the workmen must be responsible for any accidents which might occur afterwards.

SON: Why not throw the responsibility of propping upon the employer?

FATHER: I have several reasons for not doing so. If every working place required propping regularly, one place first, then another after, in a systematical way, then the examiner might prop and bar the places. It is not so. If a roof examiner were appointed to prop a certain number of places, no place might require him at one time; then, two or three come at once, and before he can finish those, five, six, or all the places might require him at once; he then would have too many irons in the fire, and because he could not split himself up into parts and be in all places at one and the same time, if an accident occurred in any one place and he not there when required, he would be imprisoned and the employer heavily fined; therefore, to be safe, one person as examiner must be appointed to sit and wait in every place until required; this would not do, the workman must prop for himself his own place, as he undermines the roof in the absence of the examiner.

SON: Then you would have examiners to see every workman's place only?

FATHER: Just so; and inform the workman how, and where, to fix his props and bars, and see that he is provided with timber (all he requires) free of cost.

SON: You would not, I see, prevent the workman fixing his own timber?

FATHER: No, only he must be careful to fix his props in the places ordered by the roof examiner, and as many more as he may think necessary for his own safety, and many a life would be saved—thus another danger would be removed.

In some mines there is no regularity whatever in the mode of getting out the coal, working it out from any place, here, there, and anywhere, of which mode Plan D is a representation; large blocks of coal, as shown in this plan, are left between two goafs or gobs, and to work these blocks of coal out, there is not only imminent danger of life being lost, but heavy expenditure and loss of coal.

XVIII.

SON: What would you suggest for the prevention of accidents from the breaking of ropes, overwinding, and peg-top or conical drums?

FATHER: I would suggest, for the prevention of accidents from the breaking of ropes or chains, the compulsory use of safety cages in every place where practicable, and not to allow more than half the load of persons to that of coal to come up.

XIX.

I would suggest the use of the spring hook safety catch or disengaging apparatus for the prevention of accidents from overwinding.

XX.

And for greater safety, in the use of peg-top or conical drums, I would suggest that they be placed as straight as possible, to prevent the slipping of the rope.

Since writing the note on opposite page, with reference to peg-top or conical drums, I am (through the time for sending in the competitive essays having been postponed) in a position to give an instance, unfortunately accompanied with fatal result, which shows the urgent necessity for improvement in regard to peg-top or conical drums, which is as follows:—Thomas Rosbotham was killed at the Haydock Collieries by the slipping of the rope of a conical drum, on the 22nd of January, 1872, and, at the inquest on the body, the inspector of mines, P. Higson, Esq., said: I inspected this drum, which I had noticed before, and remarked something about it. I never think them safe if they rise at all, and I hope we shall have, before the close of this session, a law to reach such cases.

XXI.

SON: Ought not the furnace to be more strictly looked after than is often the case?

FATHER: Improvement is needed in that regard. A furnace detector ought to be fixed in all mines discharging much explosive gas, which would show any irregularities in the ventilation or the furnace in time for their being remedied before an accident could take place.

XXII.

Every furnace-man should have a barometer fixed near the furnace, so that he might see at a glance when a fall in the atmospheric weight takes place; and there should also be an alphabetical telegram from the surface to the furnace, to inform him when a rise takes place in the temperature above, so that he might increase the furnace power accordingly.

XXIII.

A barometer and a thermometer should be fixed at the top of every mine from which explosive gas is discharged, so that each official could at once see the changes of the atmosphere, from which they would know when danger was near.

XXIV.—HORIZONTAL GALLERIES OR SEAMS OF COAL.

SON: Is there not great danger in the way in which horizontal galleries or seams of coal are worked out from one and the same shaft?

FATHER: There is; and I would suggest that the mouthing in the shaft be fenced round, to prevent persons, coal, and dirt falling down to the bottom of the shaft, as I have known lives to be lost by reason of not having had this protection.

XXV.—GUIDES OR CONDUCTORS IN SHAFTS.

SON: Every shaft (except sinking shafts) should have, I presume, conductors to keep the tub steady when people are wound up and down?

FATHER: Yes, the tub should be guided by conductors, for lives have been lost by its swinging first to one and then the other side of the shaft, causing its occupants to fall out, and smashing them to pieces.

XXVI.—SHAFTS TO BE WALLED WITH BRICKS OR STONE.

SON: Many shafts, although they have been sunk through soft earth, are not walled round; now, should not all those parts where there is no rock be walled?

FATHER: Yes, every part of a shaft in which there is no rock should be walled, and supported with iron or wood rings at stated distances, not to exceed four yards, and if this were well done, accidents from falls in shafts would be a thing of the past.

I have had relations, and known many others, lost by the falling in of shafts, and I have myself had many hair-breadth escapes of losing my life, and the cause of this is supporting, or rather attempting to support, the soft sides of the shaft with boards or timber.

XXVII.—CROSSING AND RE-CROSSING THE PITEYE.

SON: For the safety of workpeople, there should, I think, father, be a separate passage cut near the shaft, to prevent the possibility of accident in crossing over from one to the other side of the piteye.

FATHER: Yes, there should, for in winding coal, &c., there is great danger when people cross the piteye, and a separate road would do away with this.

XXVIII.—FIRING SHOTS.

SON: Do you consider it safe, father, to charge two or three shots in one working place, and only explode one of them?

FATHER: I do not, and to prevent accident the ends of the fusee should be placed in clay when it is intended to fire only one.

I have known accidents from firing one shot when two or three have been charged, the flame of the exploded shot igniting the fusee, and the men not being aware, entered the place just as the other fired.

XXIX.—PLACES OF REFUGE.

SON: Places of refuge on inclines have to be provided every twenty yards?

FATHER: Yes, that is the law.

SON: But do you think that is sufficient in very steep inclines?

FATHER: No, I do not; they should vary in proportion to the slope. Twenty yards is ample in a slope of (say) one in twelve, but in a slope of one in three a person is more likely to fall, and, consequently, there is greater danger.

SON: Yet, as the law now stands, the distance in each and all slopes is the same, and, if the wagons were to break loose in a slope of one in three, the speed at which they would run would not give time for escape, therefore I think places of refuge in these slopes should be more frequent, or vary in proportion to the slope.

FATHER: Yes, undoubtedly they should. In slopes of not more than one in eight, twenty yards would do, but from that dip to one in four, fifteen yards ought not to be exceeded, and at a distance of not more than ten yards in a slope of one in three. This would meet the requirements of the case, and might put accidents from that cause out of question.

XXX.

Every colliery should have two shafts, with a good passable road from one shaft to the other, in each working mine or seam.

XXXI.

In addition to the Government Inspector, the workmen at every colliery should have power to appoint a competent person, that is, a person well informed in mining, to inspect the workings in which they are employed; such person to inspect every part of the workings in a friendly manner, and give advice, if required, for the safe working of the mine.

The many terrible catastrophes, and the great sacrifice of life and property, have induced me for years past to do all in my power to improve the condition of mines. For this reason, I was led to publish my little work, from a careful perusal of which it will be seen that I have, to the best of my ability, and in as simple and concise a way as possible, shown how things should be conducted for the safe working of mines. I have now spent over forty-one years of my life in working in and managing mines, and, from the experience that I have gained, feel confident that if the suggestions contained in the foregoing essay were fully carried out, together with a rigid observance of those rules hereunto annexed, accidents would be very few and far between.

I now, in conclusion, submit the foregoing essay for perusal, and, while I feel fully alive to the fact that imperfections will be found therein, I am also conscious that I have done all that my knowledge could devise, or my experience suggest, in endeavouring to show how, in the most practical and economic way, to make mines so safe that, instead of accidents being of the frequent occurrence that they are now, they would be very rare indeed.

The following rules, I submit, if properly attended to, will also prevent accidents and loss of life:—

GENERAL RULES.

1. An adequate amount of ventilation shall be constantly produced in all coal mines or collieries and ironstone mines, to dilute and render harmless noxious gases to such an extent that the working places of the pits, levels, and workings of every such colliery and mine, and the travelling roads to and from such working places, shall, under ordinary circumstances, be in a fit state for working and passing therein.

2. All entrances to any place not in actual course of working and extension, and suspected to contain dangerous gas of any kind, shall be properly fenced off, so as to prevent access thereto.

3. Whenever safety lamps are required to be used, they shall be first examined and securely locked by a person or persons duly authorised for this purpose.

4. Every shaft or pit which is out of use, or used only as an airpit, shall be securely fenced.

5. Every working and pumping pit or shaft, shall be properly fenced when operations shall have ceased or been suspended.

6. Every working and pumping pit or shaft, where the natural strata, under ordinary circumstances, are not safe, shall be securely cased or lined, or otherwise made secure.

7. Every working pit or shaft shall be provided with some proper means of communicating distinct and definite signals from the bottom of the shaft to the surface, and from the surface to the bottom of the shaft.

8. All underground self-acting and engine planes on which persons travel are to be provided with some proper means of signalling between the stopping-places and the ends of the planes, and with sufficient places of refuge at the sides of such planes, at intervals of not more than twenty yards.

9. A sufficient cover overhead shall be used when lowering or raising persons in every working pit or shaft, where required by the inspectors.

10. No single-linked chain shall be used for lowering or raising persons in any working pit or shaft, except the short coupling chain attached to the cage or load.

11. Flanges or horns of sufficient length or diameter shall be attached to the drum of every machine used for lowering or raising persons.

12. A proper indicator, to show the position of the load in the pit or shaft, and also an adequate brake, shall be attached to every machine, worked by steam or water power, used for lowering or raising persons.

13. Every steam boiler shall be provided with a proper steam gauge, water gauge, and safety valve.

14. The flywheel of every engine shall be securely fenced.

15. Sufficient boreholes shall be kept in advance, and, if necessary, on both sides, to prevent inundations, in every working approaching a place likely to contain a dangerous accumulation of water.

SPECIAL RULES.

1. *Descending and ascending Pits.*—No workperson shall descend the pit contrary to the directions of the banksman, or ascend contrary to the directions of the hooker-on. Nor shall he go down or up with a greater number of persons at a time than shall be specified in a notice placed near the top of the pit; nor on the top of a cage, or with a cage containing a full load of tubs, nor upon a full tub, nor against a full tub, nor until the proper signals have been given and distinctly understood. Nor shall he take any loose material down or up the pit, unless it be securely placed in the cage or tub. He shall not be under any pit's mouth whilst the cage or tub is in motion; nor shall he leave open any rail or other fence at a mouthing or opening into a shaft or sump.

2. *On going to Work.*—Every workperson shall obey strictly the directions of the underlooker, or other officer, under whose control he may happen to be, as to the work required to be done. He shall work only where they permit, and shall not go into any part of the workings, except such as he may necessarily pass through in going to and from his work.

3. *Firedamp and Signals.*—If firedamp has been found in any of the shafts or workings, no workperson shall proceed further than the station to be appointed for that purpose from time to time, until the underlooker or fireman has been through the levels, workings, and travelling roads, to ascertain that they are safe. If any part is found unsafe from firedamp, or from any other cause, the underlooker or fireman will put up in some conspicuous place, at a sufficient distance from the point of danger, a well-known signal, or a board, on which shall be legibly painted, on a black ground, the word "fire," facing the entrance. No workperson shall pass beyond such signal, without the special directions of the underlooker or fireman. If the place be safe, the underlooker or fireman will put a well-known signal, or the other side of the board painted white, facing the entrance, by which the workperson shall know that the place has been examined and found safe for him to enter. If the place be safe, he shall remove the signal or board to a place appointed by the fireman, for use the next day.

4. *Workpersons to examine for themselves.*—In addition to the examination by the underlooker, fireman, or other officer, each workperson must satisfy himself of the safety of his own working place, before commencing work, both at the beginning of a shift, and after any intermission of working, and whilst at work.

5. *Safety Lamps.*—Whenever safety lamps are required to be used, no workperson shall use, or attempt to use, any such lamp, until it has been first examined and locked by a person duly authorised; and at the beginning of a shift, or after any intermission of working, no workperson shall enter his working place with any light except a safety lamp; and every workperson, upon being ordered by the underlooker or fireman, or other officer, shall cease to use in the pit in which he may work any naked light, and shall withdraw from the place until he be provided with a good safety lamp, with a proper lock, and which shall have been examined and locked as aforesaid. If the lamp become damaged or extinguished he shall not open it, but shall take or

send it to the appointed station, and the proper officer shall either provide him with a fresh lamp, or unlock and relight it; or if the gauze of his lamp becomes smeared with oil, or clogged with dust, he shall cease using the lamp until it shall have been properly cleaned; and no oversight on the part of the person authorised as above shall be an excuse for any workperson having in the mine an open, unlocked, insecure, or defective safety lamp.

6. *Firedamp and Fall of Roof.*—No workperson shall enter any place known or suspected to contain firedamp except with a safety lamp, and then only under the special directions of the underlooker, fireman, or other officer in charge of the pit; and when approaching any place suspected to contain firedamp, and also when taking props likely to occasion a fall of roof, and give off firedamp, he shall cease using any naked light in such place, and immediately give notice, and apply to the proper officer for a safety lamp. If he strike through into any old working suspected to contain firedamp, or other noxious gas, he shall at once stop up the hole, and inform the officer in charge.

7. *On getting into Firedamp.*—Any workperson getting into firedamp shall not throw away his lamp, or attempt to blow it out, but shall hold it near the floor, extinguish it by drawing down the wick, avoid jerking the lamp, and steadily retire with it into the fresh air.

8. *Leaving Lights and firing Gas.*—No workperson shall leave any light in his place of work, or in any part of the workings, unless it be under the care of some other person remaining therein; nor shall he light a blower or accumulation of gas.

9. *When to fire a Shot.*—When safety lamps are partially used, and blasting is permitted, no workperson shall fire a shot until he has first carefully examined the air in that particular place; and if it is in the least explosive no blasting shall take place until the cause of danger has been removed. Where safety lamps are exclusively used, no shot shall be fired except in the presence and by the direction of the fireman or underlooker.

10. *Powder and missed Shots.*—No workperson shall take down the pit any gunpowder or blasting powder, unless it be secured in a flask or horn—and only a sufficient quantity for one day's use—nor drill out a shot that has missed fire, except with a copper drill or water; nor shall he approach any charge or shot, until at least ten minutes after such charge has missed fire.

11. *Smoking Tobacco, &c.*—In those places where safety lamps are used, no person shall smoke tobacco, or take any match into the pit, or open his lamp, or try a place with a naked light to see if it contain firedamp, or, where prohibited, use gunpowder.

12. *Spragging and Propping.*—Every collier and miner shall set a sufficient number of spraggs during holing, and shall, where necessary, securely prop the roof of his place; and if, upon application to the underlooker or firemen, he should not be provided with sufficient spraggs and props he shall cease working, and report the same to the manager, or at the general office.

13. *Doors and Ventilation.*—No workperson shall injure or interfere with any aircourse, brattice, or stopping, or leave open any door which he found shut, nor do anything to check the ventilation of the mine, or damage the property of the owner.

14. *Furnacemen.*—Every furnaceman shall carefully attend to the furnace under his charge, and shall constantly keep a clean, brisk fire. Where day-and-night furnacemen are employed, one shall not leave until the other come, except to inform of his non-attendance, and in such case he shall return with all speed.

15. *Lampmen.*—The person in charge of the safety lamps shall daily examine and lock each lamp, and see that it is in good order, and clean, and free from any broken wire or wide space in the gauze; also, that it has a closely-fitting hoop inside the gauze, and that the pricker fits the hole.

16. *When sinking or repairing Shafts.*—No workperson shall send down or up any shaft or pit being sunk or repaired, blocks of stone or pieces of rock, unless the same be securely placed in a tub, cage, or hoppet.

17. *Riding on Tubs.*—No person shall ride upon any engine-plane, self-acting plane, or brake-road, or upon any train of loaded tubs, without the permission of the manager or underlooker.

18. *To obey particular Instructions.*—Every collier shall work according to such instructions as may from time to time be given him; and, when ordered by the underlooker, shall keep a borehole in advance of, and on each side of, his place of work.

19. *To give Information.*—Every workperson shall give immediate information to the underlooker, fireman, or other officer, of any firedamp or other noxious gas, or any unusual quantity of water, or of any insecurity of the roof or other part of the workings, or of the shafts, ladders, or stages, or of any air door being left open, or partially so, and also on cutting into old workings.

20. *Ropes and Cages.*—The banksman shall frequently examine the ropes, chains, carriages, and cages, and all their couplings. He shall report any defect in the same to the manager or underlooker; and, if it be of a nature to endanger the workpersons employed, he shall immediately give notice to the engineman, who shall cease using the same for drawing up or letting down any person until the defect has been remedied. The banksman shall keep the frame and surface near the pit's mouth free from coal, stones, or loose materials, and shall put up the fences at the pit's mouth when operations have ceased.

21. *Strangers.*—The banksman, hooker-on, and engine man respectively shall prevent from going down the pit, or entering the mine, any person not employed therein, unless by a written order from the manager, or by the directions of the manager or underlooker.

22. *Working Hours.*—The banksman and engineman shall not allow any person to go down the pit after the time fixed; nor shall they allow any person to go down the pit in a state of intoxication, or to take intoxicating liquor down the pit; nor shall any person drink it upon the works, except by permission of the manager or underlooker.

23. *Signals.*—The following signals shall be observed:—

ONE KNOCK—To stop, when the engine is in motion.

ONE KNOCK—To go on, when the engine is standing.

TWO KNOCKS—To lower.

THREE KNOCKS—When any person is going to ascend or descend.

Other signals may be appointed for special occasions, which shall be printed and hung up at the top and bottom of the pit, and also in the engine house belonging to such pit.

24. *Signals to go down and up.*—The hooker-on and banksman shall give the proper signal to the engineman to raise or lower the cages or tubs before any person shall be allowed to go up or down the pit or incline, and shall not allow a greater number of persons to ascend or descend the pit at one time, than shall be specified in the notice at the top of the pit, and shall inform the underlooker if any person disobey their directions.

25. *Signal to Hooker-on.*—The banksman shall not allow any person to descend a pit until he has signalled the hooker-on that some one is about to descend, and had the signal back: and the hooker-on shall then send up the empty cage or tub.

26. *Riding with Tools, &c.*—The banksman or hooker-on shall not allow any person to go down or up the pit with tools, props, or other things until he has seen them secured, and shall not allow any person to get upon or off the cage or tub when it is in motion. They shall see that the means of signalling for the pits and inclines are kept in good order.

27. *Hooker-on to lock Safety Lamps.*—The hooker-on, when directed by the underlooker, shall unlock, light, and re-lock the safety lamps of those workpersons who are ordered to use them, and shall not allow such work-person to go from the piteye until he has ascertained that such lamps are locked; and, in such case, the hooker-on, so directed, shall be held as duly authorised for that duty.

28. *Water in Boilers.*—The engineman shall not exceed the allowed pressure of steam, and shall maintain a proper depth of water in each boiler; and if anything happen to prevent this he shall immediately damp the fire, and report it to the underlooker or superintendent.

29. *Ropes, Engine, Machinery, and Boilers.*—The engineman shall run the ropes of the pit up and down every morning before any person descends; and he shall, at least daily, and at every opportunity, examine the state of the engine, machinery, and boilers under his care, and shall report any defect to the underlooker or superintendent as soon as possible; and, if dangerous, he shall not work the engine until it is repaired.

30. *Ropes, Drums, and Engine House.*—The engineman shall examine all ropes or chains fixed to the verticals, drums, cages, or tubs, and see that they are properly fastened, and the flanges or horns of the drum project above the outer coil of rope or chain, and if he find any defect he shall immediately inform the manager or superintendent, and he shall not, without the permission of the manager, underlooker, or superintendent, allow any person to enter the engine house, or to work or handle the engine.

31. *Not to leave the Engine.*—The engineman shall, on no account whatever, leave his engine during the time any one is going down or up the pit or incline.

32. *Doubtful Signals.*—The engineman shall attend to the signals, and if they are not distinct he shall wait until they are repeated.

33. *General Control.*—All operative details below ground shall be under the charge of the principal underlooker, or, in his absence, of the assistant

underlooker, who shall see that the fireman and other workpersons in their several departments discharge their several and respective duties.

34. *Observance of General Rules.*—The underlooker, fireman, and all other officers shall, each in his department, and as regards all matters under his charge, efficiently carry out the *General Rules.*

35. *Number to ride.*—The underlooker shall specify from time to time the number of persons who shall be allowed to go down or come up the pit or incline at one time, and shall put up and maintain, in a legible state, at the top of the pit or incline a notice indicating the same.

36. *Underlooker to examine Ropes, &c.*—The underlooker, or other appointed person, shall, in addition to the duties imposed on the engineer or banksman, frequently and carefully examine the state of every engine and boiler, and of the winding machinery, and winding ropes or chains, and other apparatus, at every pit under his control or supervision, and shall, on perceiving or receiving notice of any defect therein, immediately stop the winding engine, if requisite, and take the necessary measures for remedying such defect.

37. *Ventilation under Scaffolds.*—The underlooker and fireman shall see that there is sufficient ventilation in the sump, and below each scaffold, and elsewhere in the shaft. The sump shall be kept covered or fenced off.

38. *General Duties.*—The underlooker, or person acting for him, shall frequently and carefully examine the workings of the pits in his charge, the state of the ventilation, and furnace (if any), the air doors and roof, and the direction and width of the roads; and shall see that all airdoors are fixed so that they will close of themselves; and that two sets of doors be placed between the intake and return aircourses in all cases where practicable. He shall examine or appoint some competent person to examine the shafts, conductors, and bearers, or horse-trees, at least once a month, and more frequently if necessary; and shall, upon finding anything dangerous or defective, cause such danger or defect to be at once repaired. The underlooker or fireman shall, when necessary, and from time to time, appoint the stations mentioned in Rule No. 3.

39. *Safety Lamps.*—The underlooker, fireman, or other officer, shall ascertain the necessity for using lamps, and cause them to be examined and locked; and shall, when approaching any place suspected to contain firedamp, or upon receiving notice of danger, or otherwise ascertaining the necessity for using safety lamps, order such lamps to be used.

40. *Spragging and Propping, &c.*—The underlooker or the fireman shall personally see that the furnaces in their charge are in good repair, and carefully attended, and shall examine, as often as practicable, the state of the roof in the travelling roads and in the working places of the men, and shall, upon such examination, cause the roof to be propped, or otherwise made secure, and the coal securely spragged, where necessary, and shall see that sufficient props are provided; but this shall not be held in any way to relieve the workpersons of the duty of securely propping the roofs of their own places, in terms of Special Rule No. 12.

41. *Gates at the Mouthings.*—The underlooker, or person acting in his absence, shall see that every mouthing or opening into a shaft, elsewhere than at the bottom of the shaft, shall be provided with a rail, chain, or gate, and

shall give proper orders for the same to be kept closed when the person in charge of such mouthing or opening is absent, or when the working is suspended.

42. *Boilers.*—The underlooker, or superintendent, to whom such duty shall have been committed, shall inspect, as often as practicable, the state of every steam gauge, water gauge, safety valve, and boiler, and cause them to be kept in good repair.

43. *Firemen's Duties.*—The underlooker shall inform the fireman what portion of the workings is under his charge, and the fireman shall go to the pit at the time appointed by the underlooker, and shall descend the pit and carefully examine, with a safety lamp, the state of the ventilation in all the working places and travelling roads, and ascertain that they are in a safe condition before any workperson shall be permitted to go beyond the respective station mentioned in Rule 3; and if he find any part unsafe, he shall put up in some conspicuous place, as appointed from time to time by the underlooker, and at a sufficient distance from the point of danger, the signal or board indicating danger, mentioned in Special Rule No. 3. If he find the place safe, he shall put up the signal or board, indicating the same, mentioned in the said Special Rule, No. 3.

44. *Fireman to examine all accessible Parts.*—The fireman shall frequently examine all accessible parts of the mine under his charge, whether frequented by workpersons or not, and he shall instantly take measures for removing any cause of danger.

45. *Notice of Non-Attendance.*—Any officer, when unable to attend his work, shall cause his superior to be informed in sufficient time to enable him to find a substitute.

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