The Right Hon. Earl Fitzwilliam, F.R.S., President, in the Chair. The annexed statement of the accounts for the past year was submitted by the Secretary:

**STATEMENT OF THE RECEIPTS AND EXPENDITURE,**

*From 1st January, 1850, to 29th October, 1850.*

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After a few preliminary observations, his Lordship called upon Mr. West to read the first Paper, entitled:

**COMPARATIVE VIEW OF CIRCUMSTANCES ATTENDING SOME OF THE EXPLOSIONS IN COAL MINES. BY WILLIAM WEST, ESQ., F.R.S., ASSOC. CIV. ENG.**

I am not about to deliver, on this occasion, a lecture on the ventilation of coal mines; although I think that it would be highly useful to viewers and other superintendents, if, without expecting to arrive thereby at any nostrum or secret, they listened occasionally to a plain statement of the most impor-
tant facts respecting fire-damp, choke-damp, atmospheric air, combustion, rarefaction, and other agents in those frightful accidents against which they have to guard. Still less have I either nostrum or secret to reveal.

But in the course of preparing two or three such lectures, not yet delivered, some circumstances presented themselves, which, however, singly, well known or obvious, have scarcely met, in connection with each other, with all the attention which they deserve. The report of Sir Henry De la Beche and Dr. Playfair,* it is true, is so able and so comprehensive, that it supersedes much which I might otherwise remark. But several minute and accurate accounts of explosions of later dates have appeared since their general report or essay was written. These enable me to draw inferences from a greater number and variety of well-recorded instances than they had then before them. Many circumstances are only incidentally mentioned, or to be gathered from casual remarks, and are therefore by no means plain on once reading. The result on my mind is a persuasion that tendencies to a dangerous condition exist in mines reputed to be comparatively safe, and that these tendencies are so numerous and vary so suddenly, that no degree of precaution of one kind can exclude the necessity of attention to others.†

The appointment of inspectors of coal mines, and the subjecting them to regular inspection, will, we may reasonably hope, diminish the frequency and the extent of these disasters. I do not anticipate that they will ever entirely cease. But this step, the appointment of inspectors, ought rather to increase than lessen the interest which scientific bodies like this should take in the discussion of past, with a view to the prevention of future, misfortunes. The same records which

* Collieries' Report, 1847, p. 4.
† I use the term "mine," though "pit" is more common, because the latter would cause some ambiguity, since "pit" is in several of these accounts used also for "shaft." It is so in "Collieries' Report," pp. 47, 48, 49.
I have so repeatedly and minutely studied must furnish materials for study to those inspectors.

Again, it is on every account most desirable that the Inspectors should operate on proprietors rather through persuasion and representations than through the gross machinery of compulsion, fines, and prohibitions. On the Continent it is so.* In this country Government or official interference is viewed with more jealousy. We are less accustomed to it. Recommendations from authority are null unless supported by public opinion, and public opinion does not express itself, is not even formed, unless a strong interest is felt by a large portion of the community. All who consume coal, indeed, ought to have a deep, though it must be a melancholy, interest in these occurrences. Many a time when

"Shadows from the fitful firelight
Dance upon the darken'd wall;"

many a time when

"We stir the fire, and close the shutters fast,
And calmly welcome sober evening in;"

may we revert to the thought that, in obtaining the means of domestic cheerfulness for us, numbers from time to time have met with death in horrid forms, and widowhood and misery have been suddenly spread among other hearths. When such recollections obtrude, no feeling heart, no thoughtful mind, but must bid good speed to every inquiry calculated to diminish this source of human woe.

One of the first circumstances evident on comparing these accounts is, that few as they are, they embrace coal fields widely scattered, and very different in many respects. Seven explosions reported on comprehend Durham, Yorkshire,

* In the "Darley Report," at p. 6, Mr. Tremenheere says, "In France, Belgium, and Germany, very nearly all the alterations thought right by the Inspectors, in order to the safety of the people, are obtained by frank and friendly representations alone. To use their own expressions, 'they act by persuasion and the force of conviction far more than by force of law.'" Similar statements are to be found in many other passages of his reports.
Lancashire, Warwickshire, and Monmouthshire, five districts as remote from each other as could be wished if we had made a selection. (See table.) The thickness of the beds varies from four or five to thirty feet. (See table.) The coal at Oldbury is much shattered. At Risca† and at Coppull‡ it is very hard, so that it is considered necessary to blast it with gunpowder. At Haswell, also, though the report does not mention it, gunpowder was employed; also at Jarrow.§

Let us turn to some general remarks. Pits long and extensively worked are justly considered more dangerous than such as have been recently opened. Yet a new pit is not necessarily safe. Deep pits are generally considered more unsafe than those nearer the surface.¶ There is little reason why it should be so, unless where depth implies old or extensive working. But mere depth of shaft is favourable to ventilation where cupolas or furnaces are employed, as supplying a long column of rarefied air. The depths reported vary from 300 yards at Haswell and at Jarrow, to 130 yards and 75 yards at Darley. Some seams are much more fiery, that is, give out much more carburetted hydrogen than others. These undoubtedly are the most dangerous, and require especial care. But I find the character of the seam at Haswell to be "less fiery than many."¶¶ At Darley "but little firedamp."** "No great quantity of Gas."†† So that a mine bearing a tolerable character may be the seat of repeated explosions.

That habit, and comparison with yet greater risks, can lead men to apply very gentle terms to the degree of danger in their own case, is shown in the instance of Jarrow, respecting which it is said,—"Not reputed to be very fiery, but the quantity of gas is very considerable."††† In this "not

very fiery" mine six explosions had taken place in twenty-eight years, causing the death of 140 persons.*

Some may be inclined to sum up and dismiss the subject with—"You must have good ventilation." But the reports, in this respect, as to some of those places where the worst explosions of late years have occurred, show the compatibility of ventilation deemed generally "good" with fatal deficiency in the hour of need. At Haswell the ventilation is reported as "most admirable."† The ventilation at Jarrow seems to have been good in the estimation both of the scientific visitors and of the workmen. Dr. Playfair says, "The testimony of those at work in the pit four hours previous to the explosion shows it to have been free from fire-damp, and well ventilated."‡ John Atkinson, a hewer, who lost a son, torn limb from limb, says, "The air was very good."§ Jacob Barnborough lost a son by the explosion, yet he says, "The air in the pit was very good; I had a son lost, but I acquit the masters of all blame in his death; there was nothing wrong in the ventilation."‖ Emanuel Dufty, "The pit was quite chokeful of air, and in beautiful working order."¶ Another, "The air was quite good, and plenty of it."** Yet, a few hours later, forty persons were deprived of life. At Risca, the ventilation was avowedly in a transition state, but no pains nor expense were spared; and a workman says, "There is famous air in the pit."†† At Coppull, Mr. W. W. Smyth, the Government Mining Geologist, says, "I found the ventilation in very good order, and have no reason to think that it had been neglected before the accident occurred."‡‡ Ventilation, therefore, such as is deemed "good" and "sufficient," does not by itself produce security.

* Report on Darley, p. 17, Note by Dr. Playfair.  
† Philosophical Magazine, vol. xxvi., p. 22.  
‡ Report, P. 16.  
§ P. 17.  
‖ P. 18.  
¶ P. 19.  
** P. 18.  
‡‡ P. 49.
But a further consideration of importance presents itself. So far as the quantity of air conveyed to a certain extent of workings is concerned, (and the abundance of this, probably, would be the common idea of good ventilation), a limit, in most of these mines, seems to have already been reached. This limit arises from the inconvenience of too great velocity of current near the entrance, before the splittings take place, and in the narrower passages afterwards. At Jarrow, a witness says, "The candles swealed away." "I burnt six candles in my shift. There is more air goes through the Low Main (the seat of the explosion) than through the Bensham (the seam next above), and that has to do with it."* At Risca, "There were two or three, perhaps, working with lamps, because they could not keep their candles lighted for the draught."† James Padfield says, "You can hardly carry a candle in the wind-ways."‡ Richard Cottle says, "I was obliged to use a lamp to keep a light, the wind was so strong."§ At the Oaks, John Pickford says, "I have been obliged to take my cricket to keep the wind off my candle."‖ And Richard Hodgson, "It would sweal away a candle in two or three minutes any day."¶ Even at Darley, where the practical and scientific gentlemen agreed in considering the quantity of air to be but about a third part of what was necessary,** two witnesses state that the men complained of the wind swealing their candles,†† and their burning too many in consequence. Where this limit is thus already reached, we must look for additional security from some other source than greater strength of current. To attempt to compel the formation of new or additional shafts would be an interference of

* Report, P. 18, Jacob Barnborough. † P. 36, Mr. Joseph Green.
‡ P. 38. § P. 39. ‖ P. 64. ¶ P. 65.
** Mr. Tremenheere, Darley Report, p. 1, and Mr. Smyth, p. 11.
†† Mr. Locke, the colliery agent, and George Addy, fireman. Supplement to the Leeds Mercury, 3rd February, 1849.
the kind which provokes resistance, since it might involve enormous additional expense. Yet it remains for the calculation of proprietors themselves whether explosions and their consequences do not exhibit a large per contra figure. Jarrow Mine, six times wholly or partially stopped, six times to be repaired and restored, in twenty-eight years, must have furnished some set off to the expense of providing different shafts for different purposes, instead of one shaft divided into three parts by wooden brattices. To place the shafts, at the first laying out of the workings, at proper distances instead of close together, would not involve, in many instances, much additional expense; and it is of great importance. At the Oaks, where the upcast and downcast were only nine feet asunder, the men and boys who reached the bottom of the shaft were kept between the danger of suffocation by after-damp, or being crushed by stones, with very few yards of fresh air. At Darley, where the arrangement of the ventilation ensured a supply of air for a considerable distance, many of those carried out as dead subsequently recovered.* At Jarrow, Jacob Barnborough, hewer, says, "If they (the masters) gave us two shafts instead of one, it would give us a better chance of escape after an accident." Every arrangement which tends to keep up the current of fresh air after an explosion, or to facilitate its speedy restoration, is of great importance in lessening the extent of injury to life. To nothing do the accounts more generally testify than that the greater part of the deaths take place from the choke damp, or after damp—carbonic acid gas. I find from my examination of the evidence, that at Risca it seems doubtful whether more than four or five lives were destroyed by burning, out of thirty-five lost. We have instances of stupor being produced, and recovery following after the

* Report on Darley, p. 10.  
† Report, 1847, p. 18.
lapse of many hours. At Jarrow, William Cranstoun recovered, after being insensible, as he believes, for thirty-six hours.* And some recovered after shorter periods in other cases. While I was writing this paper another lamentable explosion took place at Oldham (October, 1850). As the newspaper account gives many of the particulars which I have endeavoured to ascertain in the other instances, I have added it to my tables, although not included in the official reports.

It strikingly proves the mischief of one shaft, divided by bratticing, when an explosion does happen. The force of the blast extending to the shaft, the bratticing was in part blown out, and the entire stoppage of ventilation in the passages of the mine was but a part of the evil consequent on this. The wreck of the brattice formed a pile at the bottom of the shaft, six or seven yards high, and sufficiently solid to prevent the cage from descending for that distance. Think of men and boys, burnt, enfeebled by the effects of choke damp, and distracted by terror, climbing up a loose pile of broken wood, for six yards! Several were, in fact, maimed or hurt by falls. It was four hours before three cages could be got to the bank! One boy, clinging, in his eagerness, to the first cage after it was full, lost his hold from exhaustion, and was killed by the fall. Lamps alone were used. The immediate cause of the explosion is believed to have been a fall of roof upon a lamp which the hurriers had left upon the ground in one of the bays, while they went to the shaft bottom with a journey of coals. The seam then in working had only been opened two years, and the workings were not extensive, only 55 yards to the north, and 140 to the south from the shaft.†

I now approach what has been elsewhere a topic for many controversies—the wire gauze lamp. If it become so here,

* Report, 1847, p. 22. † Leeds Mercury, October 12th, 1850.
it will be, I believe, through others than me. For I am willing to yield for the time every point except one, that flame surrounded by wire gauze is less dangerous than a naked light. Whether Sir Humphry Davy was really the first inventor of the instrument named after him, whether previous attempts or later improvements are really superior to "The Davy," may, so far as my object is concerned, be left unanswered. The case is narrowed with me to "Wire Gauze versus Candle." Nor does it need, for a decision in favour of the Davy, that it should be safe under all conceivable, or all actually occurring circumstances. I think it a pity that the name of "Safety Lamp" was ever given to it; as "The Davy," "The Stephenson," "The Clanny," "The Upton," would not, by their mere names, have raised ill-founded expectations. There is certainly one way in which a lamp, safer than candles, but not absolutely and infallibly safe, may do mischief. This is if, in reliance upon its efficacy, work be carried on by its means in more dangerous situations, or with fewer provisions for safety, or less caution in other respects, than would have been the case were it undiscovered or discarded.* But we cannot ascribe to this any one of the particular explosions now under consideration. At Haswell, lamps alone were employed; but since the seam is stated to be

* "The Committee of 1835 pointed out that more persons had lost their lives by colliery explosions for the eighteen years succeeding the introduction of the Davy safety lamps in 1816, than in the eighteen years preceding the invention, and accounted for this fact by the working of numerous 'fiery' seams of coal, which had, in consequence of the assumed security of that lamp, been undertaken, and the abandonment of many precautions considered requisite when candles were commonly employed in collieries." (Report, 1847, p. 8.)

"An unfounded confidence in the lamp has been productive of great loss of life. First, by causing work to be carried on in dangerous mines, without other measures of security against explosions; and still more unfortunately, by leading to a serious limitation in the number of shafts." (Edinburgh Review, No. 180, p. 545.)
"less fiery than many," and its ventilation "most admirable," it is evident that it would have been worked, and worked in the same general manner, had the safety lamp been unknown. At Risca, where the general use of gunpowder would have seemed to render the precaution of lamps almost vain, only about one-third of the lights were lamps. We cannot, therefore, suppose the use of these to have caused any neglect in other respects. And at the Oaks, where candles were "chiefly" used, and at Jarrow Low Seam, Oldbury, Coppull, and Darley, where candles alone were employed by the hewers, and lamps confined to the doggy or fireman, for purposes of inspection merely, no dependence on the safety lamp can have influenced either the opening of the mines, their modes of working or of ventilation, or the conduct of the workmen. If "many precautions formerly considered requisite" have really been abandoned since the discovery of the lamp, it confirms what I am endeavouring to impress upon you, that mischief will attend every undue dependence on any one means of safety. The real question is, then, "Is wire gauze any protection?" "Is the lamp safer than a candle?" On these heads I have no doubt. The nature of the case, abundant observation, the testimony of scientific men, even that of pitmen, (who, however, prefer the greater light of candles,) all concur to show that, to a certain extent, wire gauze is a protection, and the lamp safer than a candle. Every time that the cylinder is filled with flame, that flame would extend, and an explosion follow, but for the wires. Sir Henry De la Beche and Dr. Playfair three times expressed their opinion that "much additional security is obtained by the proper use of the original Davy, or its improvements." That they "cause security in all cases where proper care is employed, though they may not be absolutely safe under

all circumstances.”* That “safety lamps, properly used, do effect much security in the working of coal.”† Dr. Playfair again expresses his “conviction that the accident at Jarrow would, in all probability, not have occurred, had lamps been employed instead of candles” in the Low Main.‡

I leave to colliers the question between higher wages, with greater danger, and lower with safety; to coal masters, whether to allow all or any part of the increased wages or allowances claimed for the use of lamps. But the testimony in favour of lamps is not confined to theorists or men of science. A workman at Jarrow, after making the usual complaint of the Davy being “so dark,” is asked, “You have had long experience in pits; did you ever know an accident take place where the Davy was fairly used?” He answers, “Never.”§

We have further some very interesting facts, furnished not by a philosopher writing in his study, but by a viewer at Walker Colliery, near Newcastle-on-Tyne. On November 13th, 1846, when approaching a slip dyke, a mass of coal was displaced, weighing about eleven tons. On the displacement of this block, and the discharge of fire-damp that followed, being observed by the two men working in the drift, they immediately extinguished one lamp, (the other having been put out by the accident,) informed the other men in the pit, and retired to the shaft. The air rendered foul in an instant was ascertained by subsequent measurement of the passages to which it extended to be more than 40,000 cubic feet. A second violent discharge took place from near the same spot on the 10th December. Judicious precautions had been taken to prevent mischief. While the men were breaking down a portion of roof, to enable the tram-road to be carried up, the “danty” or broken coal in the slip of the dyke, above where a bore-hole had just been made, was

violently forced out, with a noise, continuing for some time, which resembled the blowing off of an immense high-pressure steam-engine, and a violent discharge of gas, that extended over a distance of 640 yards in length, with an area of 86,000 feet. At 400 yards from the point of issue it was met by one of the deputies. Though he drew down the wick of his lamp, the gas continued to burn for ten minutes, heating the wire red hot, and leaving the particles of coal attached to the wire gauze burnt quite red. At the end of the 640 yards, the gas burnt within the lamps of five men and boys there employed, until they extinguished them in a sump or pool at hand. There can be no doubt, therefore, that the explosive mixture extended still further. Where would the workmen on these occasions have been but for the lamp?

A low state of the barometer is obviously favourable to the discharge of gas. Many practical men are aware of this. The most curious instance of its operation is that mentioned as occurring in a pit of Mr. Jobling's, of Jarrow, where, with a low barometer, inflammable gas was habitually noticed to issue from the coal; while, when the barometer was high, common air was observed to enter the coal at the very same fissures. But how many of those whose employment it is to inform the workmen when caution is requisite possess or understand a barometer?

I was the more encouraged to bring forward this paper by finding, as I proceeded, that several circumstances then acquired an interest, in connection with others occurring elsewhere, which they by no means possessed while detached. But a cursory perusal of the accounts, by persons ever so well acquainted with the subject, would not exhibit these in their full force and bearing.

I have attached to this paper some tables,* which include

* The Diagrams on the wall contained these Tables, a little abbreviated.
most of the particulars admitting of comparison. On some
desirable heads the accounts give little information, such as
the quantity of air computed to enter, the kind of roof and
of floor, &c. And I should wish to see inserted in future
accounts several heads respecting which our present accounts
furnish no materials. Such are—the speed of the air current
in the principal air passages; the amount, and kind, and period
of sinking in the country above, &c.

It is remarkable that at three of those places from which
we have the most particular accounts, coal getting had been
suspended shortly before the accidents. At Jarrow, for six
days, until four days before the explosion. At Risca the
day before,* and at Darley the day before,† respectively. The
events might create a doubt whether the ventilation had
in each case been carried on as actively during the intervals
as if the usual labours of the pit had been continued. This
subject was not remarked on by the Government Com-
missioners, or, so far as appears, by the Coroner, in either
case. Whether, in these instances, it be a significant fact,
or only an accidental coincidence, it is quite clear that venti-
lation should never slacken. The gas is constantly issuing
in pits subject to it, and it will accumulate during the absence
of the men, to be ready for any contingency favourable to its
inflammation after their return, unless it be in the mean time,
and as fast as it issues, diluted and carried off. It is also
observable that at Risca both the firemen had, through illness,
or being engaged elsewhere, entrusted, on that day, their
usual duties to others. At Darley also there had been
a change, though both must be supposed equally skilled.
George Addy, fireman, who had gone down to "try the
fire" daily for two years, being ill, Joseph Thompson, the
bottom steward, took his place. I attach no importance,
however, to this. Let me remark that, in commenting on

the circumstances attendant on any of these sad catastrophes, I mean no unkind or unhandsome reflection on any of the parties concerned. Those circumstances are as much matter of history as the explosions themselves, and as such are open to fair and candid remark. The "scaling off" of a portion of fresh air to feed the furnace, recommended by Mr. Warington Smyth,* and conducting the return air into the upcast shaft at a safe height above the fire, occurs as being practised in none of these reports. For want of this the fire in the furnace at Risca, and that at Darley, had to be put out just when a powerful current of fresh air was most wanted. And time, any moment of which might make the difference of life or death to some perishing sufferer, was spent in giving the needful directions, or waiting for their fulfilment. Double doors, allowing a corve or tub to enter the space between, and the first to be shut before the second is opened, prevent even the momentary interruption of the proper ventilation, and lessen the danger of a disarrangement of longer continuance from accident to, or neglect of, a single door. They are referred to by Sir H. De la Beche, but in the other cases the doors seem to be single. I believe they are very commonly so.

Oldbury appears to be the only mine where the upcast shaft was unprovided with a furnace. The catastrophe at this place produced a pamphlet, or rather a book, from a gentleman of that neighbourhood, which consisted almost entirely of the advice to build a tower over the mouth of the upcast shaft, thus increasing its length, and not to use furnace or fan, or any other artificial means of producing a current. I do not agree with him. Mr. Smyth recommends a tower or stack at Darley, where the up shaft is much shorter than the down, but would retain the furnace.

* Darley Report, p. 16.
I am not prepared to say that the employment of gun­powder should be forbidden, or that a seam which cannot be profitably worked without it should be abandoned. But I do think that the difference in cost between gunpowder and the pick alone should be considerable, to render blasting, on the whole, advantageous to the proprietor. That it forms of itself a naked light, and thus renders almost nugatory the use of lamps, is obvious. The sudden dislodgement of large masses of coal must favour sudden and rapid discharges of gas; while the loose, open, shattered condition, which it is the very object of blasting to produce, is no less favourable to keeping up the emission. When the coal is cracked and crushed, the pillars or "posts" left must either be larger, or they will be weaker, and not the coal alone, but the roof, will suffer, and those "falls" of stone or shale take place which are the causes of fatal accidents in various ways, and explo­sions among the number. It is not, then, alone a question between so many pounds of gunpowder on one hand and so many weeks' additional wages on the other; the coal shaken by blasting is also less valuable, from the readiness with which it falls into "slack."

Many considerations point to the goaf or wastes, or worked out portions of a mine, as the source and seat of explosions. The evidence, it is true, must be, from the nature and results of the calamity, inferential, rather than direct. What no living eye has witnessed, no living tongue can remain to tell. But in the Haswell Colliery, and in some other cases, satisfac­tory evidence as to where the gaseous mixture fired was afforded by the direction in which its force acted, and by the condition and situation in which the bodies of some of the pitmen were found; and the goaf of thirteen acres was there indicated as the largest reservoir of gas. At Jarrow the waste was clearly pointed out. At Risca the evidence
shows that the immediate cause of the accident was a man (William Curtis) going into the gob, where he ought not, with a candle.* At the Oaks, the upper class of witnesses, skilful in coal working, after hearing the evidence as to the finding of the body of William Walton, came to a like conclusion as to the cause of explosion there.† (See table.) But even before this they imputed it to a fall of roof in the south waste.‡ In either case the waste is concerned. From Oldbury and from Coppull I have not the reports of the evidence at the inquests; my information and my tables are therefore less full and precise as to those two than the others. At Oldbury, however, the “old sides” were professedly walled off, but two of the walls were “uncapped;” “probably not produced by the accident,” says Mr. Warington Smyth.§ The old sides, or waste, therefore, most likely, were concerned. At Coppull, “the roof is free from gas, and even after it has fallen down, and left large cavities above, is said not to harbour any other noxious gas than ‘black damp.’”¶ But if not given out by these cavities, it must collect in them. At Darley Mr. Tremenheere says, “The colliery was worked on a plan by which, as the coal was got out, large cavities were left, only partially filled up by the breaking down of the roof; and those cavities became so many magazines of explosive gas.” In at least four mines, then, the great reservoir of inflammable gas was the goaf, and in three others very probably so. At Oldham alone was the gas collected evidently in the working parts, or bays, of the mine.

We need not wonder, then, seeing the special danger which attends the goaf, that Faraday and Lyall, at Haswell, directed their attention almost exclusively to some special means of ventilating it; nor that in the instructions

* Report, p. 38.
† Joseph Littlewood, p. 63; B. Byram, Esq., p. 66; Mr. Utley, p. 66.
‡ B. Byram, Esq., p. 66.
§ Report, p. 47.
¶ P. 47.
issued by the Secretary of State for the Home Department, this subject occupies a distinct head. But the more carefully and repeatedly I peruse these reports, or converse with practical men on this part of the subject, the more I find discrepancies, amounting almost to confusion, as to what is now attempted, what is now accomplished, or what can at any time hereafter be hoped for. And the difference in the accounts on this head does not appear to depend on real differences between the mines themselves, so much as on variety of belief, or of modes of expressing belief, as to what now takes place. On the whole, the following expressions seem to convey the general opinion—"Sweeping the outskirts of one or two gobs."* "Coursing by the side" of the goaf.† "Passing round it."‡ "This current takes its way sluggishly through the lower parts of the goaf, or moves round the outside of it."§ "All that oozes from it into the workings is removed by the air courses."|| But if there be any truth in the description given by Faraday and Lyall, of the space above a goaf as an inverted basin of inflammable mixture, whatever difficulties may attend their plan, or any other, for its separate ventilation, only on effecting this depends our deliverance from the greatest danger of all. Many passages in these reports, too long to quote, confirm the accuracy of their description, and I might say of my own. Their statements are not matter of opinion, but of the most undeniable calculation, as to many thousand cubic feet of explosive mixture issuing at one spot, upon a sinking of the barometer, of only one-tenth of an inch, or a fall of roof, lowering the upper edge of the goaf basin only three inches. They understate their case, for they suppose only one-tenth. The fall

§ Farady and Lyall, Phil. Mag., p. 23. || P. 57.
within a short time is often greater; and they take for a basis the Haswell goaf of thirteen acres, instead of the Felling, or the Jarrow Bensham seam, of 100 acres each. More than all, they assume the goaf mixture to be itself simply explosive, instead of being capable of rendering explosive many times its own bulk of previously pure air. This latter must more often be the case.

Keeping in view these facts, to "sweep the sides" of a goaf, or carry off what "oozes" from it, may carry an explosive mixture to naked lights at a distance from the goaf, but cannot prevent its formation, or its discharge. And to pick up every stone from the floor, as held out at Jarrow, incomprehensible as it seems—or to pierce the fault bounding the south waste at the Oaks—would leave the goaf cavities untouched. It is not clear at what levels the "permanent windways over the gobs" at Risca* are placed. If they are at the top of the highest cavity in that weak shale, the first part of Faraday and Lyall's recommendation is effected; it is, therefore, practicable. What is further wanting is to carry off the goaf air separately, instead of into the air courses of the workings. If they are only at the level of the roof before its breaking down, they also leave the hollows untouched. Sir H. De la Beche and Mr. Smyth say, "The height to which it (the gas) might be mixed with the broken roof could not be estimated."†

As to sinking of the surface, I have heard persons engaged in coal mining converse on this matter as if, very soon after the last procurable coal was extracted, and the "juds" drawn, the roof settled down quietly, evenly, and entirely from the top, to meet the floor, or creeps in it, • Report, p. 57.

† And Faraday and Lyall (p. 20)—"How high the heap of broken strata, and the vaults inclosing it, extend, is not known in a large goaf, nor, as far as we are aware, even in a small one."
until the whole cavity is filled at the expense of the surface. Now I know that the instances of subsidence are very curious, but their being objects of curiosity implies some degree of rarity. I believe the complete filling up of old mines from this sinking process to be slow, irregular, and by no means to be depended on. This is implied also in several passages of these reports.

We have the river Sirhowey flowing over the works of Risca colliery. Indeed, among the many mines of all kinds carried under rivers or the sea, I remember but two or three instances of flooding by irruption of water from the surface.

I have omitted many interesting particulars, out of regard to your time, and to the authors of other papers. The printed documents will well repay the attention of persons of all ranks engaged in such undertakings. It would be a great mistake to suppose that the appointment of inspectors in the least degree relieves proprietors or managers of collieries from responsibility, or that it will at all cramp their own exertions for the preservation of their property, and of the lives of their workmen. The intention is, and if all classes concerned do their duty, the effect will be, to assist, as well as to stimulate, individual exertion. It is much to be hoped that from the time when the inspectors about to be appointed commence their operations, they will collect, record, and publish all such particulars of every explosion of mark as may furnish to themselves, other inspectors, proprietors, and agents of every description and name, the means of learning from them what to adopt and what to avoid, for the purpose of preventing, or rendering less destructive, these calamities.

I do not deem it needful to dwell long upon that undeniable and prominent source of danger—the carelessness or fool-hardiness of workmen. We find from the evidence
in several of the cases that they have strong objection to lamps, on account of their giving less light than candles.* Mr. Green, at Risca, says, "I have much trouble with the men respecting the use of the lamp. I have frequently been obliged to make them an allowance, either by putting a boy with them, or by giving them an extra price, when they were asked to use the lamp. I have many times seen colliers with the safety lamp hung up by them burning, and they working with a naked candle, also burning, close to each other."† Nowhere did the workmen complain that they could not readily obtain lamps, but wherever the subject is mentioned, we find unwillingness to use them; and this, although, as the evidence implies, the cost of lamps, oil, and wick was borne by the masters, but that of candles by the men themselves.‡

Mr. Smyth says, "Men have been known to dash to pieces Upton and Roberts’s lamp, on account of its weight.§ As candles could always be smuggled into the pits, there appears little prospect of effecting, by compulsion, the general use of any safety lamp. Unhappily, the case of a coal mine, so far as explosions are concerned, differs from that of a ship, and from many other dangerous occupations, in that the care of the most prudent does not secure even themselves, while the carelessness of one may at any time involve the whole in destruction. At Jarrow, and at the Oaks, the immediate cause of explosion seems to have been, in each instance, a man going with a candle into a part of the waste notoriously unsafe; at the Oaks, too, after being repeatedly warned against it. The story is familiar to many, of Dr. Faraday, during his inspection of the Haswell mine, after the accident there, asking of the group of smokers among whom he was resting, "Where

* John Bainbridge, p. 20, at Jarrow.
† Report, 1847.
‡ P. 54.
§ P. 47.
is your powder?" and being startled from his rest by the answer, "You are sitting upon it."

The remedies for insensibility to their own preservation, and that of their fellows, must be chiefly of a moral nature, and must be very slow in their operation, requiring generations to produce much effect. Mr. Tremenheere shows, in a passage too long to quote, how, without compulsion, a taste for some degree of mental cultivation may be induced, and some degree of intellectual advance imparted. We must make great allowance for the very low state of degradation, and the almost complete isolation from the rest of the community, in which, a century ago, colliers were sunk. In Scotland they were, by law, a kind of serfs. On the Tyne, at Kingswood, and in Staffordshire, they were wholly a distinct class—the amusement, the wonder, and the terror of their neighbourhoods. I have lived near coal mines for forty years; I believe it is neither fancy, nor use alone, but some degree of approach towards the habits and manners of other workmen, which renders it far less easy to me to distinguish at a glance a collier, whether man or boy, by his dress, gait, and features. However this may be, they are human beings; and those masters and managers who, not only by liberal wages, but by kindness, and the evidence of their own concern for the men's safety, attach these to them, will have a security for the observance of needful regulations, stronger and more constant than fines, or sudden and angry dismissal.

I concur with most of the conclusions to which the different scientific reporters have come. I need not recapitulate them at any length. More shafts; separate and, so far as may be, distant shafts; scaling fresh air to the furnace; effectual ventilation of goafs, if possible; increased use of lamps; increased care and intelligence among the workmen, especially the firemen, wastemen, &c. The evils
**TABULAR VIEW OF SOME RECORDED EXPLOSIONS.**

<table>
<thead>
<tr>
<th>Date</th>
<th>Reported on by</th>
<th>Character as to Gas.</th>
<th>Condition on That Day.</th>
<th>Character of Ventilation.</th>
<th>Air. cubic feet of Air per min.</th>
<th>Speed of Current.</th>
<th>Lights used.</th>
<th>Apparent or supposed Cause of Explosion.</th>
<th>Improvements recommended or suggested in the Reports.</th>
<th>Statements as to Waste of Candles.</th>
<th>Explosions in same Pit.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sept. 1844</td>
<td>Dr. Faraday and Sir C. Lyall</td>
<td>&quot;Less fiery than many.&quot;</td>
<td>&quot;As little as any in that part of England.&quot;</td>
<td>Good</td>
<td>&quot;Most admirable.&quot;</td>
<td>25,400</td>
<td>Lamps only.</td>
<td>Fall of roof on a lamp in drawing Jud.</td>
<td>Drawing off the gas from the goaf, separate from the general ventilation.</td>
<td>Almost impossible to keep a candle lighted in the windways.</td>
<td>0 in 28 years.</td>
</tr>
<tr>
<td>Aug. 1845</td>
<td>Mr. W. W. Smyth</td>
<td>Not reputed very fiery, but quantity of gas very considerable.</td>
<td>&quot;No blower or other unusual escape observed.&quot;</td>
<td>&quot;Sufficient.&quot; (Dr. P.)</td>
<td>&quot;Very good.&quot;</td>
<td>40,000</td>
<td>9 ft. per second in shaft</td>
<td>Candles in the Low Main</td>
<td>Additional shafts. Use of lamps in the &quot;Low Seam.&quot;</td>
<td>Great complaints of &quot;sweating.&quot;</td>
<td>Some &quot;worked with lamps because they could not keep a candle lighted; &amp;c.&quot;</td>
</tr>
<tr>
<td>Jan. 1846</td>
<td>Sir H. De la Beche and Mr. W. W. Smyth</td>
<td>&quot;As a whole, much gas.&quot;</td>
<td>&quot;Very fiery.&quot; (Pitman.)</td>
<td>&quot;Examined that morning; no gas observed.&quot;</td>
<td>Sufficient air; the plan in a &quot;transition state.&quot;</td>
<td>Never observed.</td>
<td>14 miles per hour</td>
<td>Lamps</td>
<td>Man going into goaf with a candle.</td>
<td>An additional shaft and other arrangements for ventilation, as in progress.</td>
<td></td>
</tr>
<tr>
<td>Jan. 1847</td>
<td>Mr. W. W. Smyth</td>
<td>&quot;No efficient system of ventilation can be said to exist.&quot;</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Candles, except doggy.</td>
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<tr>
<td>Jan. 1847</td>
<td>Ditto</td>
<td>&quot;Quantity of gas rather large.&quot;</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Candles, except from man.</td>
<td></td>
<td></td>
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<tr>
<td>Mar. 1847</td>
<td>Mr. W. W. Smyth</td>
<td>&quot;Average quantity.&quot;</td>
<td></td>
<td>Not complained of.</td>
<td></td>
<td></td>
<td></td>
<td>Candles</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mar. 1847</td>
<td>Mr. W. W. Smyth</td>
<td>&quot;But little.&quot;</td>
<td>&quot;No sulphur.&quot;</td>
<td>&quot;As usual.&quot;</td>
<td>Quantity of air too small.</td>
<td>Average</td>
<td>9,000</td>
<td>Candles.</td>
<td>High wind, interfering with ventilation.</td>
<td>Much more air. (Mode of working disapproved.) Air should be &quot;scaled off&quot; for furnace. Upcast shaft too shallow; a tower or stack wanted. Shafts too near each other. (A third shaft intended.)</td>
<td>&quot;Would sweep away a candle in two or three minutes, any day,&quot; &amp;c.</td>
</tr>
<tr>
<td>Oct. 1850</td>
<td>Mr. W. W. Smyth</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Candles</td>
<td></td>
<td></td>
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<tr>
<td>Newspaper</td>
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</table>

* In Low Main.  
† In Bensham.

**TABLE 2, CONTAINING CHIEFLY ENGINEERING PARTICULARS.**

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</thead>
<tbody>
<tr>
<td>Haswell</td>
<td></td>
<td></td>
<td>310</td>
<td>200</td>
<td>1 24 24</td>
<td>To S. E.</td>
<td>Almost free.</td>
<td>Sand and sandstone.</td>
<td>Sandy clay; not apt to rise in creeps.</td>
<td>One of 13 acres.</td>
<td>Believed to have been two.</td>
<td></td>
</tr>
<tr>
<td>Jarrow</td>
<td>1 bratticed into 3</td>
<td>14 feet.</td>
<td>300</td>
<td>1 24 24</td>
<td>To S.</td>
<td>Several slight.</td>
<td>Some guncowder used.</td>
<td></td>
<td></td>
<td>Said to be kept clear.</td>
<td>Two; the last worst.</td>
<td></td>
</tr>
<tr>
<td>Risca</td>
<td>9—24 feet</td>
<td>166</td>
<td>6 to 18</td>
<td>Curved; Aver. 9 in 2 to 1 in 6</td>
<td>To N. W.</td>
<td>Some.</td>
<td>Very hard. Guncowder said to be necessary.</td>
<td></td>
<td></td>
<td>Walled off.</td>
<td>Small in proportion to damage done.</td>
<td>In &quot;sides of work.&quot;</td>
</tr>
<tr>
<td>Oldbury</td>
<td>2—a few yards</td>
<td>160</td>
<td>Small at one time</td>
<td>30</td>
<td>Irregular.</td>
<td>To S. W.</td>
<td>Very many.</td>
<td>Much shattered and injured. The height forbids the use of lamps.</td>
<td>Tender bind; in some parts sandstone.</td>
<td></td>
<td>&quot;The air sweeps the cuttings.&quot;</td>
<td>Long, or Shropshire.</td>
</tr>
<tr>
<td>Coppfell</td>
<td>2 steps; 1 at considerable distance</td>
<td>140</td>
<td>200</td>
<td>5 7</td>
<td>To E.</td>
<td>Very many.</td>
<td>Guncowder said to be necessary.</td>
<td>Carbonaceous shale; not strong.</td>
<td></td>
<td></td>
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<tr>
<td>The Oaks</td>
<td>2—9 feet</td>
<td>288</td>
<td>8 14 14</td>
<td>To E.</td>
<td>1 Up. 17 ft.</td>
<td>16 W.</td>
<td>Small</td>
<td>readily breaking away.</td>
<td>&quot;Air-courses by the side.&quot;</td>
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<td>128</td>
<td>8</td>
<td>One principal.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Oldham</td>
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<td>Small</td>
<td>42</td>
<td>To S.</td>
<td></td>
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attendant on blasting; the use of firemen understanding and observing the barometer; the error of supposing the wastes to fill up rapidly and entirely by subsidence; and, most of all, the hopelessness of increasing the speed of the air current, where candles are used, much beyond its present rate;—these are among the considerations which either have not occurred to those reporters, or have impressed me more strongly than they appear to have done these writers.

I end as I began; all that I have here collected and compared, all besides that I have read, all that I hear, even from those who advocate reliance on some single means of defence, convinces me that a single means is not enough. It will not do to trust alone to a strong current of air, to the superiority of "long" methods of working over "short," or "short" over "long," to the use of lamps, to frequent and minute inspection, or to regulations for workmen. Let each, or any, be observed; but let no other helps to safety, which are applicable to the situation and circumstances be neglected.

ON THE EXISTENCE OF FOUR CRYSTALLINE SPECIES OF CARBON. BY H. C. SORBY, ESQ., F.G.S.

The four species of carbon are diamond, graphite, hard coke, and charcoal. They have long been distinguished practically; and the object of the present paper is to show their various crystalline forms and mutual relationship.

In the first place we have diamond, which is well known to be crystallized in the regular system, and to have a specific gravity of about 3.52.

Secondly, we have graphite or plumbago, which is found crystallized in regular hexagonal prisms, and has a specific gravity of about 2.18.