AN ESSAY

ON

COLLIERY EXPLOSIONS AND

SAFETY LAMPS.

by

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LONDON:
‘COLLIERY GUARDIAN’ OFFICE, 49, ESSEX STREET,
STAND, W.C

1880.

Published by:-

© PICKS PUBLISHING
and
THE COAL MINING HISTORY RESOURCE CENTRE
Web site:- cmhrc.fsn.net

83. Greenfields Crescent,
Ashton-in-Makerfield,
Wigan WN4 8QY
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COLLIERY EXPLOSIONS AND SAFETY LAMPS.

AT no period of the world's history has science reached the altitude at which it stands to-day. Nor has the man of science at any time had so many instruments and agencies to assist him in his researches into the mysteries of nature. In the invention of instruments our forefathers were wonderfully successful, and many of the discoveries of the present had been impossible but for the untiring observation and intelligent skill of the old heroes of science. The mariner's compass, without which distant navigation were all but impossible, the barometer, which enables the pilot to foresee the hurricane, the microscope, which makes the invisible visible, the telescope, which places the observer in close proximity to the far off object, the application of steam to machinery, of balloons to aerial navigation, and many other discoveries of an important character, all attest the ingenuity, the perseverance and the untiring scientific zeal of our fathers.

Amongst the most interesting of all the sciences, geology and meteorology may be said to fill one of the foremost places. Their details may be difficult to master; the phenomena which sometimes occur in their domains may be painful to witness, but to the student few sciences offer so pleasing and interesting a field of observation.

Meteorology is the science which treats of the atmosphere and its phenomena. rain, fog, frost, and snow are some of these phenomena; and it is the province of the meteorologist to observe them and other results of atmospheric influence, so that our knowledge of nature may be extended.

Geology deals with the formation of the earth, and such knowledge of this science has been attained by experts that they can, by simply seeing a country, tell what formation comes to the surface, and whether it contains minerals or not.

It is supposed by scientific men that at one time the place the earth now fills was a thick murky atmosphere. It would only lead us through a host of conflicting opinions to state the different beliefs of learned men as to the formation of the world. All, however, are agreed that what is now a succession of panoramic pictures, was once an indescribable chaos that this wide expanse of ever varying landscape was once a vast scene of desolation. Man has gathered much reliable knowledge of old chaos by his observations of changes in some of the stars during a succession of ages, but great as is the knowledge man has obtained, he knows that he is but on the borderland of discovery and that the illimitable ocean of knowledge still lies before him.

The man of science may trace the little rivulet from the hillside until it becomes a stream, a brook, a river, and finally loses itself in the boundless sea. He may travel through desert, valley and mountain ranges, and note the ever changeful scenery of the globe, from the majestic Himalayas to the bleak, sandy solitude of Sahara. During this journey he may note with an increasing interest the influences of varying temperatures and climates on the vegetable world. Another may observe the stars in their spheres, and note the wonderful accuracy and balance of their motions. But when the observant mind contemplates nature in her angry moods, in the tempest, the cyclone, the volcanic torrent, and the fear-spreading earthquake, it is awed into silence and amazement. Man's knowledge and power then sink into insignificance, and he feels his utter impotence.

Geology offers no such exciting scenes to its disciples, but it opens a book in which the student finds 'sermons in stones and good in everything.' By the hillside, the brooklet's bank, the rugged cliff, the active quarry, the newly excavated cutting, the geologist may gather observations at every step, and in the end perhaps draw conclusions which greatly add to the mineral resources of the country. If his thirst for knowledge is still unsatisfied, he may descend into the bowels of the earth, and investigate the nature of those gases which he will find freely generated in coalmines, and which at one time served to clothe the surface with luxuriant vegetation. In place of now filling an important part in vegetable economy, he will and that the liberated gases, on getting mixed with air, form one of the most violent explosive compounds, and which, when ignited, constitutes what we are unfortunately too familiar with - a colliery explosion.

It will thus be seen that the province of the geologist is an important one. As an aid to discovering the mineral treasures of a new country, his knowledge is invaluable. Without this knowledge immense fields of coal, valuable deposits of gold, and precious stones and metals might lie hidden for ever.

As the wealth of a country depends upon her mineral resources, and her industry in the development of them, so for the discovery of her minerals she is dependent of the skill of the geologist, and for her produce on the labour of the miner and engineer.

In pursuing this subject further the following matters will be more or less treated:-

1st. The formation of the earth.

2nd. Gases found in mines.

3rd. Description of a colliery explosion, and the liability to explosions.

4th. The necessity for good ventilation.

5th. How ventilation is produced.

6th. Lighting of mines and safety lamps.

Lastly. My improvements in the miner's safety lamp.

I. - THE FORMATION OF THE EARTH.

Sir David Brewster says that of the primary formation of the earth there is no reliable knowledge.

Learned men have speculated at all times on this mysterious subject, but only agree in differing.

It may, however, be instructive to state one of the most interesting and best received of the theories respecting the construction or formation of the earth.

At one time it was almost generally believed that the interior of the earth was a mass of fluid fire, the covering of this being a crust which, in the lapse of ages, had cooled down. It was also supposed that the lava and ashes from volcanoes were ejected from this mass of fire.

That the interior of the earth is in a fluid state by heat is probable from the fact that its temperature increases at the rate of 1 deg. of Fahrenheit for every 65 ft. in depth, so that at a depth of fifty miles the temperature would be twice that which is sufficient to melt iron. At so great a depth the pressure of the superincumbent matter would be upwards of 200,000 lbs. to the square inch; and as it has been proved by a series of interesting experiments that the temperature at which bodies melt is proportional to the pressure to which the melted mass is subjected, it follows that the earth's solid crust may be much thicker than forty or fifty miles.

Geology does not pretend to tell us of the process by which the nucleus or kernel of the earth was first formed. Some thinkers, more speculative than wise, have ventured to lay down theories of the primitive formation, but one of our most learned natural philosophers, Brewster, says they have no evidence to support them.

And why endeavour the useless task of solving that upon which the most profound minds are undetermined?

With the stratified rocks, or those which have cleavages or partings, commence our most reliable data. But even with these there is a great divergence of opinion as to the age of the stratified rocks. All calculations as to their age by those most favourable to the Mosaic chronology are very far anterior to it. The era attributed to the making of man is supposed to be 5,844 years ago. Moses beginning his history about 2,500 years after that era. By what authority Moses wrote his history, what data he had for fixing the time and description of the creation, the fall of our first parents, the ceremonies and sacrifices of the priesthood, is not revealed. Some progress must have been made in arts and sciences prior to the time of Moses, but no historical record appears to have been kept in writing up to his time. From his day the Jews have kept their annals in written characters, which have been transmitted to the present in perhaps as unadulterated a form as any historical annals in the world.

It is a singular fact that as the peoples in the western part of the globe have become civilised, those to the East have grown less so; China, the East Indies, Egypt, the nations of South America possess architectural evidences of a far higher stage of civilisation than they can now claim. While we were in a state of barbarism, these nations were engaged in works both of art and science, which the most refined and intelligent nations of the present cannot surpass. Where are now the mechanical appliances which raised the ponderous stones to the summit of the pyramids and erected the Colossus at Rhodes? What has become of the architectural skill which designed the Taj at Agra in the East Indies, and the magnificent tomb of Timour the Tartar? Where is now the enterprise and genius which projected and built the great wall of China? Of these grand huge works of the men of antiquity there is no reliable record of their construction.

But these eras of civilisation require the lapse of many hundred years to perfect. There must have been a gradual approach to the climax which could produce the stupendous works just noted, exactly as there has been a gradual decline.

Well, just as there are cycles in the history of a nation, so are there cycles in the formation of the earth’s crust or surface. Past the limits to which geology can confidently lead us there is no need to venture.

The lowest known rock is the granite. This stratum has never been pierced, and is of unknown depth. Over the granite are measures which, as a rule, overlie each other in regular order, until we reach the lower beds of coal.

in the saying. The sun which shines to-day, and with its genial fertilising heat promotes the growth of the vegetable kingdom, shone many ages ago upon the plants, trees, and shrubs which now constitute coal. Of this fact our knowledge is certain. Millions of years ago, vegetation grew more dense, and to a greater height than it does in our day. Year by year this vegetation grew, ripened, and died, until the surface of the ground became a huge layer of decomposed vegetable matter. The process of time this would become covered with a layer of sand, deposited by the action of water, which even at the present day, is making land in one place, and encroaching upon it at another. During the growth of plants, both carbonic acid gas and hydrogen gas are absorbed, the one from the earth, the other from the rain. Here then we have the two gases which form the deadly firedamp, and which, millions of years since, were assimilated by the mass of vegetation which ultimately became coal.

We know coal to be of vegetable origin by the aid of the microscope, which, in a thin sheet of coal can detect the outline of leaves and the delicate fibres which intersect the leaf. At the present time there is coal half formed in some of the American swamps, in which the process of carbonisation appears to be simply a question of years. Fossils of shrubs and trees also are so well defined in their outlines as leaves no room to doubt of the vegetable origin of coal.

It may, therefore, be taken for granted that our coal-fields were once vast forests of tropical vegetation, some of the trees of which grew to a gigantic size, while the smaller plants covered the ground in a densely close mass.

It is conjectured by Sir David Brewster that the temperature and other meteorological influences of the coal-forming period would be especially adapted to the growth and decomposition of vegetable matter, and that the time necessary for the formation of a thick layer of decomposed vegetation would be much less than is commonly supposed. In the course of time changes in the geological formation of the locality of the coal forests would take place, and they would become subject to the depository action of water, either by flood, stream or sea. Gradually, layer after layer of sand and dirt would be deposited, which, as it became heavier, would compress the decayed vegetable matter below, forcing out its moisture, and the combined influences of pressure, heat, and other agencies would slowly transform the effete and rotten vegetation to coal.

Another theory of the formation of coal is that the primeval forests may have been swept away by a flood to extensive plains at a lower level, where, being deposited, they have been subjected to the same action as above described.

In reading of and noting the changes which have occurred and are occurring in the contour of the earth, nothing is so striking as the absence of uniformity in the various writers' calculations as to the age of the earth.

Some geologists are of opinion that the time since the formation of our deepest coal seams must be computed by millions of years. There would be the preparation of the ground for seed, the first scanty fructifying, the periodical, decay the innumerable sequences of season to compile the gigantic layer requisite to constitute a coal seam. Following this, the gradual change to the conditions under which sand and gravel could be deposited upon the dead vegetation; the lapse of ages necessary to cover to the depth of even a score feet, then another change to dry land, to fertilisation, vegetable growth, decay, and compilation. Taking into consideration the number of coal seams we possess, and remembering that between each seam lie huge layers or measures of rock or shale, it will be apparent to the meanest conception that in the formation of the earth's crust 'a thousand years have been as a day.'

Sufficient has, perhaps, been said to show that the fuel which now warms us once clothed the earth with beauty in the form of trees, shrubs, and plants and that in their growth they absorbed those gases, the emanation of which in the mine renders coal mining so dangerous an occupation.

To those who have not given much heed to this subject, it may seem difficult to believe that the coal we burn was once a vegetable, and played the same part in the economy of nature as plants do at the present day. From the soil plants obtain their carbon, from the air and water, oxygen, from the rain, hydrogen. These three gases chiefly in certain proportions form coal. If it were possible to subject a plant grown during the past summer to the same influences to which the old coal plants were subjected the result would as inevitably be coal as the piece you see burning before you on the fire. This is, however, not possible; but the impossibility serves to increase our astonishment and admiration of the wonderful chemical operations of nature.

By the wisdom of God nothing is destructible. Matter changes, but is not annihilated. The black soil underneath the rose tree will in time become assimilated with it. The mould of the graveyards has no apparent affinity with poor humanity, but to that end all must come. Whatever may be the affection that exist in human society, and the tie of nature that binds friend to friend, when life becomes extinct and the system motionless, we are glad enough to bury the decomposed remains out of our sight, to pay the final penalty, 'dust thou art, and unto dust shalt thou return.' What relationship appears to exist between the acorn and the oak but in years the diminutive seed becomes the stately tree. In the laboratory of nature, decay is but a change of form and constituent parts. The decomposed stubble of last year's corn will enter into combination with something else, and probably be transformed to wheat or barley. Decay and fertility are the two great laws of the vegetable world. Nothing dies, but rises again in renewed strength and beauty. If there is a suspension of this growth and decay, it is for some useful purpose for man. The formation of coal is an illustration of this. When, millions of years ago, the inherent fecundity of plants was suspended, an agent was being enclosed in the earth's crust which, in the far future, should be discovered, developed, and in its innumerable applications become the most powerful promoter of modern advancement. That torpor of the vegetable kingdom in the past is the life and progress of the present.

II. - GASES FOUND IN MINES.

So soon as we break into the earth's crust, so soon do we begin to liberate the gases it contains. Carbonic acid gas is generally the first met with. This gas exists largely at a depth varying from 40 to 50 fathoms. It is a heavy, poisonous gas, and not explosive, either pure or mixed with air. Light Carburetted Hydrogen, or marsh gas, is sometimes troublesome at the same depth, but in smaller quantities only. As we descend to greater depths this gas is met with in much larger quantities. In a pure state it is fatal to life, and extinguishes light. When mixed with air in a certain proportion it becomes an explosive compound of immense power. Light carburetted hydrogen appears to exist in the greatest quantity at depths ranging between 200 and 400 yards. Below the Tatter depth large pockets of gas are exceptional. Below 500 or 600 yards the gases are more condensed or solidified, and the strata also being less porous or open, its generation is not so rapid as at less depths. But although its generation is less rapid, the liability to explosion is not reduced. Deep mines, as a rule, are dry and very dusty, and as in combination with dust 2 per cent. of carburetted hydrogen is explosive, the sensitiveness of a ventilation impregnated with such a compound approaching that degree of mixture will be recognised. To avoid the danger arising from dust, it has been very sensibly suggested that the road-ways be watered. This cannot, however, always be done. The freshest and most explosive dust will lie near newly cut faces, and will always, despite the best application of the watering system, be present in more or less quantities. Then, the deeper the mine, the greater the necessity for excavating larger areas with the same plant, appliances, &c. Large areas mean a numerous company of men whose lives hang on the thread of discipline and good management. Risks of all kinds will need to be reduced to a minimum-roadways must be large; ventilation machinery efficient; discipline must be keen and consistent; every appliance which forms a link in the chain of safety must have ample margin of strength; then, in spite of every precaution which prudence can foresee and provide, there will still he danger of an explosion. How often does an explosion take place in a mine which, up to the moment of the outbreak, was supposed to be free from gas. It is likely enough that in these eases coal dust has been an important factor in the case. There is another consideration, too, in the matter of deep mines, that is, the temperature. This is not an unimportant influence in the causation of accidents.

The hottest mine in England registers 106° Fahr.; some of the Cornish mines show 113° Fahr. The hottest water tried in a Welsh mine showed 1250 Fahr.; at Buxton the hot springs indicate 82° Fahr.; at Matlock 68° Fahr. In the lower levels of the Cornish mines, i.e., those 1,900 to 2,000 ft. deep, the temperature is a uniform 180° Fahr., the water reaching 1500, and in one case after flowing 15 ft. indicated 1570 Fahr. At Rosebridge, the deepest colliery in England, the temperature is 93° Fahr. At one 3,489 ft. deep in Belgium the reading is 78° Fahr.

The effects of heat on the Comstock miners pre sent some of the most singular occurrences known in mining. Men sometimes fall into the hot mine waters (the maximum observed temperature of which is 156° Fahr., but they are usually much under this), and are scalded severely - it may be fatally. But the effects of working in hot air furnish the largest proportion of fatal casualties,-viz., 73 per cent. of this class. Faintness and insensibility, with temporary loss of memory after coming out of a faint, are among the results. A man who has been working in a hot shaft is not allowed to go up alone, because of the tendency to faint on reaching the cooler air. The heat has also been known to cause insanity and death, and there are instances of cramp from drinking ice water, and from standing to cool in a strong draught of cool air, though these remedies are often resorted to. The drifts at the 1,900 level of the Gould and Curry mine, where many heat casualties have occurred, are not above 108^{o}, or 110^{o} Fahr., but several times they have shown 1230, 1260, and 1280 Fahr. Falls of men down shafts are unusually common in the Comstock mines. Such accidents are sometimes due to heat - a timber man, e.g., repairing an upcast shaft becoming stupefied with the heat, steam, and gases. Then, the Comstock rocks are for ever moving, swelling, and forcing the shafts out of line, so that repairs are necessarily very frequent.

An eminent writer calculates that at a depth of 7 to 10 the temperature is $7{,}000^{o}$ above that on the surface, and it is the opinion of many scientific men that the dislocations in the strata, and great cavities and splits in the rocks have been caused by excessive heat. Numerous faults or dislocated measures are met with in mines, which indicate the work of some powerful agency in some past age. However free England may have been during its historical period, there is no doubt that at some prior time it was subject to earthquakes and volcanic eruptions. The hills in the Peak of Derbyshire have at some time been greatly disturbed by internal action. Some of these hills are formed of measures which lie parallel with the surface all round the hills thus showing that the greater force has been immediately under the middle of the hill. Other measures are thrown up in a stepping form, varying length and depth until the same measure, beginning a great depth, has stepped out to daylight. Other measures lie perpendicularly against measures reclining in a normal position; between the two a conglomerate clay, sand and stones. The result of some eruptions has been to separate the measures at a lower level, so to permit a large area of surface to fall between, which as sometimes been overlapped with deeper measures.

One eminent writer says, “the most important phenomena connected with the formation of coal, are the numerous faults and disturbances which occur. There are few who have not noticed in passing through mountainous countries, the different positions in which the beds of rock or strata lie. They may be observed at nearly every inclination of dip, from horizontal to nearly vertical. Sometimes they are even contorted into ribbonlike forms. These positions of the strata tell us plainly that Plutonic force has been at work during an incalculable period of time - either by a gradual uplifting or a series of sudden jerks - to give to them their present appearances; and these processes of upheaval are going on at the present time. The coast of the Baltic, along Sweden and Norway, is being gradually upraised at the rate of about 3 ft. in a century, and has been thus rising for many thousand years. The coasts of Greenland, were upraised nearly 1000 ft. in the course of a single however, are being gradually submerged at the same rate. In 1822 the west coast of South America, for about 100,000 square miles, was raised in some places 8 ft., and in others 7 ft. in a few hours. The Plains of Jorulla, in 1759, night. And in the earthquake of Qalabria, in 1783, the whole of the surrounding country was convulsed, crevices were formed in the ground, some of which were 500 or 600 ft. in width; and, in some of the clefts, one side sank below the other to a considerable depth, as we often find in the case of faults. These are forces which may be called extraordinary ones, but still they occur far more commonly than is generally supposed. Thus, it is known that, on an average, more than 600 earthquakes take place in each year; and of this number about three in two years, or one every eight months, is what may be called a great earthquake, in which whole cities and towns, or large portions of them, have been reduced to ruin, and many lives lost. Probably, there is not a spot on earth which is truly at rest. The whole is in a state of constant oscillation, now uprising and then settling down; so that it may easily be conceived that the forces which have been sufficient to raise large masses of rock of almost unknown thickness, and to bend them into folds and contortions, were amply sufficient, according to the flexibility and hardness of the rock, to break and crack them through, and to cast one portion upwards and allow the other to settle downwards. Accordingly, we find many instances of fissure and cracks running through great thicknesses of rock. Sometimes these occur as mere fissures, but often there is also a displacement of the rocks which have been thus severed. Beds which were once known to be continuous are thus not only broken through, but are also left at different levels on 4 each side of the fissure and one side sometimes many hundreds of feet below the point at which they were once continuous. Hence, we have what are variously called dislocations, faults, dikes, and slips, troubles and hitches; the size and character varying with the circumstances of their situation and formation.

It may perhaps be concluded that by eruptions and other outward effects of internal energy, the pressure of the gases confined in the earth is lessened. To some extent that conclusion will hold good, but so vast is the amount of this subterranean force that earthquakes, volcanoes, are rather an indication than a measure of this power.

Further on, in the chapter on explosions, will be given interesting instances of extraordinary outbursts of gas in mines.

III. - DESCRIPTION OF A COLLIERY EXPLOSION, AND THE LIABILITY TO EXPLOSION.

"But the day of the Lord will come as a thief in the night, in which the Heavens shall pass away with a great noise, and the elements shall melt with fervent heat. The earth also and the works therein shall be burnt up."

Of all calamities to which the mining part of mankind re subject, it may be said there are none more fearful than a colliery explosion. If we take the whole range of casualties or calamities of which men in general are liable to be the victims, there are none which are so deadly in their influence, or which offer so small a chance f escape.

Misfortunes such as affect nations, as epidemics and wars, are frequently the result of causes within control, and many of the people living within their influence are able to avoid their evil effects altogether.

Thunderstorms, hurricanes and cyclones are frightful phenomena to witness, but it is only seldom that any great loss of life is the result of them. Once in a generation, perhaps, it does occur that in an earthquake or a cyclone there is an extensive loss of life.

But what is more certain of its victims, what more terrible and frightful in its effects than a colliery explosion? In a field of battle men voluntarily surrender themselves to the occupation of killing or being killed but in the fiery mine full of toilers, intent only on peaceful industry, "the day of the Lord cometh as a thief in the night." Few have escaped from an explosion to relate its horrors; no eye can discern them and no artist picture them.

Those only who have ventured into the mine immediately after an explosion, have any idea of the havoc it makes, and of the tremendous force which destroys everything in its path.

Having some little experience in these matters I am, perhaps, qualified to make some observations on this head.

Colliers, as a rule, are a cheerful class of men. Uneducated, as schools go, and ignorant, except in what relates to their calling, perhaps kinder-hearted or more liberal-handed men do not exist. When at work in the mine they are full of conversation, generally of a genial character, and they are far from being the miserable workmen their dreary occupation would seem to imply. Although no men on earth work harder and earn a living surrounded by so many dangers, seen and unseen, no class go forth to labour with more cheerfulness and alacrity. So long as the miner sees his place of work properly supported with packs of stone and props of timber, he anticipates no further danger. One, two, three, a hundred days have passed without an accident; today will also surely pass with safety, and he will return home, tired it may be, but not altogether discontented. Such is his simple philosophy, and, perhaps, no more elaborate one is needed by the miner. From his descent into the colliery to his return to the surface, the miners' occupation is one requiring skill of no ordinary kind, which is not acquired so easily as that which forms the capital knowledge of many a cleaner and better paid profession.

His only dread is scarcity of work, his only fear a reduction of wages, his highest aspiration a speedy return to God's sunshine. Alas, how frequently has this aspiration been lost in death? How often in an unexpected moment has every heart been stilled with fear, as a volume of flame has rushed with lightning speed through the workings, driving back the ventilating current like a powerful piston straight away to the downcast shaft, and even to the surface? From a million fissures gas now pours into the heated galleries. Pocket of gas give up their contents, and give additional fury to the flames. Again the ventilation rushes like a whirlwind through he workings, sweeping the poor miners and all loose material like chaff before a wind, and throwing them in heaps in less exposed situations. On the main roads leading to the working places, ponies, boys, horses and trains of wagons are huddled together in one horrifying heap. The ventilation is again mastered, and the storm of fire sweeps down doors and doorways, bratticing and toppings. Overcasts are destroyed, and masses of brickwork and stone work dislocated and shattered in every direction and make up all way of escape. Dust and smoke fly in clouds along the passages, and turn and return with every change in the ventilation, the earth trembles with the shock of the explosion, and the galleries -are blocked by fallen debris. What escape is there from such a combination of destructive agencies? Some will be burnt to ashes, whist others have been crushed out of shape by masses of falling roof, others have lost consciousness and life by concussion, and those who have escaped these, will succumb to the deadly afterdamp.

All is darkness but where the lurid flames make darkness visible. A few seconds only, and the robust, cheery bands of fathers, brothers, and sons are silent in death.

If they have left home without a 'good-bye,' or a parting kiss, the opportunity for that is past now. There no time now for a loving message; no time to soften enmities or strengthen friendships. As they have parted, must the remembrance be. What enemy so cruel as a colliery explosion? What foe so pitiless? There are a hundred agents of Death, but not one of Life. The Destroying Angel hovers on all sides, and bars every way of deliverance.

Meanwhile, with the first shock of the explosion, the alarm is spread through the village. 'As if an angel spoke, they hear the solemn sound.' In one moment everyone conceives the calamity that has fallen upon them. With one impulse they rush to the pit mouth-screams, groans, and cries echoing from all parts of the crowd. Anguish throbs in every heart. Wives cry for their husbands, children for their fathers, mothers for their sons, and sisters for their brothers. Hope, fear, and horror agitate the whole mass.

The manager arrives, and, with blanched lips, endeavours to assuage their grief, and prepares as promptly as he can to take measures for rescuing the poor fellows below. Perhaps other managers and engineers now arrive and consult together as to the best course to follow. While they consult, an explosion perhaps more terrific than before shakes the ground beneath their feet, and the pit,

"Like a furnace mouth,
Casts forth redounding smoke and ruddy flame.'

For the time their skill is baffled. Around them stand workmen with true British hearts, ready at a word to descend into the fiery sepulchre, and try, if possible, to save their fellows, if perchance there be any living. Alas their courage is useless too. Nor skill nor bravery can cope with the warring elements below.

The engineers consult, and, after a deliberation in which all that ingenuity and experience can advance or suggest is considered, they decide to cover up and flood the mine. Hope now dies in every breast, but they linger round the spot as if proximity to those they loved softened their misfortune. The report of the disaster is circulated in a few hours throughout the land, and all hearts, from the Queen to her lowest subjects, melt into tender sympathy for those whose 'nearest and dearest' lie scorched and shapeless in a tomb of fire.

No class withholds its sympathy. Even those who have only seen the ruder side of the miner's character, and who have perhaps thought the man and his labour congenial, are as prompt to help as the miner's best friends, and large subscriptions are poured in to form a fund for the helpless widows and orphans.

The destructive power of a colliery explosion creates little astonishment when considered in a scientific aspect.

Coal seams are more or less of a porous nature, in the minute cells or pores of which is gas solidified by the pressure of the strata above. It will be easily understood that when the coal is cut into, the solid gas, being liberated, will immediately expand into a gaseous state, and in ordinary circumstances be diluted and carried off by the ventilation. Should the current of wind be inefficient, and slow, the gas or light carburetted hydrogen will gradually float to the top of the current, as chaff on water, and catch and accumulate in every break or crevice in the roof, and rise into every cavity of the roof or goaf until all are full. Dust also of a highly inflammable character may be thickly coated on floor and sides. As is often the case, the ventilating current may be thousands of yards long, during the traversing of which of will become highly charged with gas approaching an explosive point. Little more is now required to raise the mixture to a degree at which it will explode.

A slight derangement in the ventilating system, such as a door being left open, or a brattice cloth pulled down, a blown out shot, a slackening at the furnace, or a change in atmospheric pressure. Any of these contingencies happening (and they are far too common) will perfect the conditions for an explosion. Let us assume such a piece of neglect does occur, then concurrent with that any of the following may happen The flame of a lamp may be propelled through the gauze by the blown out shot, or the mixture may come across a naked light; a defective lamp, or the gas exploding inside a lamp may send the flame through the gauze, or perhaps a fire may have spontaneously generated in the goaf. Each of these, simple and probable as it is, is sufficient to cause the explosion.

Thirty years ago, explosions frequently occurred, but, singly considered, were far less destructive than many which have taken place during the last fifteen years. It was common enough at that time for men to be badly burnt, but in the explosions occurring in these times, few within the range of an explosion are left alive. Collieries, at that day were, however, not so extensive as now, and were not, as a rule, worked to such depths.

It has been found by experiment that when an explosion occurs, the heat is so intense that the volume of air and gas expands to eleven times the volume it occupied before ignition. One peculiar property of an explosion is that of the direction of force being against the wind current, or the line of greatest resistance. This probably may be due to the fact that the feeder of gas lies in that direction, supposing the gas to have travelled any distance before being ignited- or it may seek the oxygen in that direction. It is calculated that the temperature of the heated gases during an explosion is about 5,600 degs. Fahr. This, of course, varies in proportion to the mixture of firedamp and air. Such an extreme temperature must, of course, greatly rarefy those gases not ignitable, as nitrogen and excess of carbon, and, as a consequence, cause a partial vacuum. It is during the existence of this partial vacuum that the greatest damage is done to the galleries of the mine. It has also the effect of liberating further volumes of gas, which frequently, if the ventilation be quickly restored after the first explosion, form a nucleus for a second explosion. The force of an explosion is found to be greatest when the parts of gas and air are as 1 of the former to 9 or 10 of the latter.

It has also recently been discovered from the experiments of Mr. Galloway and others that 2 per cent. of coal-dust greatly augments the power of an explosion. It has often occurred that assumed gas has been found after an explosion, which would appear to indicate that the explosion was limited only by the quantity of oxygen in the mine. In a recent outburst at Denaby Main Colliery, it was estimated that 70,000 cubic feet of gas were present in the workings at one time. Had this vast volume of gas been exploded it would have expanded sufficiently to have filled the whole of the mine, or have spent its expansive force in destroying obstacles, overcoming frictional resistance and dashing the poor workmen to pieces. In this instance the safety lamp was the men's and the colliery's salvation. Simultaneously with the outburst, every lamp within its range was extinguished, and the miners, exposed to a fearful peril, escaped in darkness to the bottom. The ventilation was of the best description, devised and carried out by one of most highly trained and scientific mining engineers, and in quantity per man it equalled the highest standard adopted in the most fiery districts in England but what would this have availed had one out of the hundreds of lamps exposed to the outburst been defective?

Nor is this a solitary instance of the blower or outburst filling the workings in spite of the most powerful ventilation.

At Shipley Collieries, near Derby, several instances have occurred of a whole district being flooded with gas in a few seconds and the whole of the lights extinguished.

The following are also notable instances. At Whitehaven in 1783, in a sinking at a depth of 84 yards, a pocket of gas was tapped, which being conveyed to the surface in a tube burnt for more than two years, the flames reaching several yards high. At the celebrated Wallsend Colliery a jet of gas issued from the coal at the rate of 120 cubic feet per minute for several years. At Tyne Main Colliery a 'blower' gave off 6 to 700 cubic feet per minute for some months. After an explosion at the Oaks Colliery gas was given off at the rate of 600 cubic feet per minute. Again, after the Wood Pit explosion, Haydock, the discharge of gas was so powerful that it forced its way against a strong ventilation for several hundred yards. One of the most interesting accounts of a 'blower' is that related by Mr. Arnold Lupton in a late address to the Mining College, at Leeds. He says:-

"This year, on the 17th April, 1879, there occurred in the mine l'Agrappe in Frameries, the most remarkable outburst of gas of which I have ever heard. Here the gas burst out with such force and volume as to reverse the ventilation, rushing up the downcast shaft with a cloud of dust and little bits of coal. It took fire at a fire-place in the engine-room at the pit top, and blazed in a column 55 yards high, which could be seen five miles off at 7.37 a.m., on the 17th of April. Broad daylight, the height of the flame gradually lowered, till at 9.45 a.m., in two hours twelve minutes after its highest, the flame was reduced to a height of 6 ft. above the pit top. Until now there had been ho explosion, the volume of gas being too great to burn until mixed with 1the air on the surface. But now an explosion occurred in the shaft; after this, a number of explosions followed at short intervals, the last explosion being the most violent. The gas came from a bed of coal worked at a depth of 680 yards, and it is estimated that 845,600 cubic metres of gas escaped from the mine in the first two hours following the outburst (85 cubic feet is a cubic metre), that is about twelve million (12,000,000) cubic feet, or say six millions (6,000,000) an hour, or 100,000 cubic feet of gas per minute ?"

In one instance witnessed by the writer, the ground seemed to tremble beneath his feet when the gas was about to burst out. On its doing so, the floor or thill of the mine heaved and broke for many yards in length, the gas issuing in great quantities for some time.

Prior to that time gas had never been found in that part of the mine.

Several eases have been known of miners striking their picks four or six inches into the floor or the thill of the mine, and lighting the gas emitted from the hole, the flame reaching to several inches in height and giving sufficient light for them to work by it.

What foresight can deal with such a terrible ambushed enemy? Overmen may be careful, managers skilful and scientific, inspectors vigilant to detect laxity of discipline and quick to suggest, a prudent government may make laws to enforce a rigid adoption of the safest means of working, but neither the care of the overman, the skill and science of the manager, the vigilance of the inspector or legislative wisdom can deal with an enemy so insidious and so powerful as a blower of gas, if but one slender wire in the thousand meshes of a safety lamp be pushed
aside.

IV. - THE NECESSITY FOR GOOD VENTILATION.

Few questions of late have so much occupied the attention of scientific and practical miners as that of ventilation. Nor has the interest been confined to mining alone. In all new erections special consideration must be given by the architect to ventilation or the building is condemned. The interest awakened in this matter has not been spontaneous. It has been the result of an accumulation of pressure arising from the reports of medical men on the overcrowded state of some of our large towns, of pressure arising from epidemical fevers caused by defective ventilation, and of explosions in coal mines arising from the same cause. At the present time ventilation is rapidly approaching a science. Its principles are subjects of tuition, and in several professions it is an essential department of the students' course.

When God made man he breathed into his nostrils the breath of life, by which is meant the vital principle, but the language, though figurative, implies the necessity of breathing in order to live. When man ceases to breathe he dies. The most vigorous breather is the most vigorous liver. Vigorous respiration means vigorous health, always supposing that the respired air is pure.

We live at the bottom of a sea of air which is estimated to be forty to fifty miles deep. Except in localities where it has become vitiated by repeated use, or intermixed with other gases of a poisonous nature, the air is pure, and, of course, fit for breathing.

That it is essential to life we all know. All that lives, either in the vegetable or animal kingdom, must breathe it or die. The smallest insect that jumps in the grass, the largest animal that roams the forest, the tiniest bird that twitters in the tree, the mighty eagle that soars above the mountains, the tenderest shrub, the largest oak, the grass that forms earth's carpet, the flowers which beautify the grass - all must absorb this air or die.

The properties of air are well known; some of them are apparent to the most ignorant.

1st. It is invisible; 2nd. It has weight; 3rd. It is elastic.

But it is with its composition that we will first deal. It is formed of 79 parts of nitrogen and 21 parts of oxygen. Oxygen is the great vitalizer, and is so active, that its energy would kill if it were not diluted by nitrogen. When breathed, it is absorbed by the small blood vessels in the lungs, at the same time carbonic acid is given off, which, with part of the oxygen, is expired as carbonic acid gas.

In a state of rest a man takes from 14 to 18 respirations or draughts of air per minute, and at each of these about 20 cubic inches are inhaled. Taking the average of exertion and repose about 360 cubic feet per 24 hours pass Through the lungs, or 1.1 per hour. Now, about 1/24th of this is exhaled from the lungs as carbonic acid gas, or nearly 8 ounces of solid carbon. This gas is fatal to life when mixed with air at a standard of 4 or 5 per cent., hence the necessity for a continued renewal of fresh air. A miner's candle converts as much air into carbonic acid gas as a man; a horse six times as much. All these combining would speedily vitiate the atmosphere of a mine to a dangerous extent if it were not kept in a state of continuous motion. To effect this desired end great attention has of late been paid to the subject by all interested in mining. The law also requires that an adequate amount of ventilation shall be kept so that the mine shall be kept clear of gases both poisonous and inflammable.

In ventilating our mines several things require consideration.

Each man employed requires a certain amount per minute, each horse also; then there are the results of blasting, noxious gases and smoke to be carried away, the results of combustion arising from candles and lamps, the exhalation of carbonic acid gas from the floor and sides and old wastes of the mine, the generation of firedamp. It will be clear from this that a strong sweeping ventilation is absolutely necessary. But when we take into consideration the outbursts above mentioned, against which no human skill can hope to do more than provide a

large margin of spare wind, it will be still further apparent that an abundant supply over and above that necessary for ordinary use is essentially requisite, to carry off and dilute the rapid generation of gases occurring from a 'blower' or change in atmospheric pressure.
The quantity of air necessary for the good ventilation of a mine has been variously estimated as follows:-

Mr. Mackworth,
100 cubic feet of air per minute per man for sanitary purposes alone.
Mr. Hedley,
From 1 to 500 ft. per minute for each collier.
Mr. Dunn,
The quantity of air for the most harmless of pits ought to be from 10,000 to 15,000 cubic feet per minute.
Mr. Taylor,
In a mine employing 120 to 130 persons, and yielding no firedamp, 20,000 to 80,000 cubic feet per minute, properly conveyed to the working faces, and made to sweep the districts in which the men are employed. In mines giving off gas, a much greater quantity.
Mr. Warington Smyth,
In round numbers 100 cubic feet per man per minute may be required for the health and comfort of every person employed. But if firedamp be given off, say at the rate of 200 ft. per minute, at the very least 30 times that amount, in addition to 6,000 cubic feet.
Mr. Blackwell
From 250 to 500 cubic feet should circulate per minute for each collier.
Professor Phillips.
In fiery mines an average of 600 ft. per collier per minute, and nearly 200 per minute for each acre of waste.

V. - HOW VENTILATION IS PRODUCED.

There are several modes of putting air in motion under-ground, but the furnace and the fan are the more generally used. Furnaces are the most primitive, and by many considered to be the most effective. Fans have of late years been largely applied. In 1780 we have the first mention of a fan being used at the Long Benton Colliery. This produced 4,000 ft. per minute. Since then Messrs. Guibal, Waddle and Root have invented fans which ale marvels of power and simplicity. Some of these are capable of producing 200,000 cubic feet per minute. The furnace also, well built and fired, has produced an amount exceeding the above. But, although the appliances for producing large quantities are sufficiently powerful, there is no law which deals with the distribution of air, except one dealing with the question in very general terms. Legislation, so far, has dealt in detail with dwellinghouses. In those, it requires that there shall be an inlet and outlet for the purposes of ventilation in each room; but in mines, no hard and fast line is drawn as to the airing of districts. Quantity is no criterion of a just and equitable system of ventilation. One working place may have more than necessary, another may be dangerously deficient.

Taking the law as it stands, a manager may send a whole village into a mine, or as many hundred men as he thinks fit; he may wind what coal he likes, providing his plant is large enough; he may extend his works for miles, and in all directions; expose several miles of working faces; blast as much powder as he thinks well at one time; carry air laden with coal dust from one group of miners to another; no limit to the size of his airways nor the velocity of his air current - the number and size of air-crossings and doors, and air splits - the number of men to each split. There is no control but his own over the means of ventilation, whether by fan or furnace, no matter if the mine be fiery or not. He may allow what kind of light he likes - candles, torch lamps, or safety lamps. He has full power over the method of working. Under the as the manager, however competent or incompetent, law as at present applied, everything is allowed to go on directs, until a disaster occurs. Then, perhaps, blasting is prohibited; a few more lives are lost - then the furnace is abolished, and a fan is erected; more lives are sacrificed, then naked lights are interdicted, and safety lamps are introduced. The way of the law is beautifully progressive, but it is over dead men's bodies.

Now and again, after an explosion has drawn public interest to the question, safety lamps are placed under experiment, very often with the result that the perfect safety lamp is not yet invented. But all these improvements and restrictions, important though they be, are nothing more than healing branches on a tree, the trunk of which is a mass of corruption. For all these alterations avail nothing if the air travels round the workings impregnated with firedamp. No condemnation can be brought on anyone for a bad system of working coal - a bad system of making and recording plans - a bad system of ventilation - the use of furnaces in fiery mines the use of blasting powder and naked lights-insufficient doors - insufficient splits - small airways - too great a velocity of air - too great an extension of workings - too many groups of miners ventilated by one body of wind, or employing 1,000 men when there is not more than enough wind for 500.

We may safely affirm that no subject is more worthy the attention of the legislature than the ventilation of mines, and the writer is of opinion that were the following regulations adopted and enforced by Parliament, the death rate from colliery accidents would be greatly reduced.

1st. In every mining district there should be a Board of Control, consisting of mining engineers and managers, of not less than 20 members.

2nd. That coal mines shall be divided into three classes, viz., fiery, non-fiery, and medium.

3rd. That all plans of projected collieries shall be submitted to the Board of Control, the said plans showing the proposed system of working coal, and the mode of ventilation.

4th. That in no mine whatever shall more than 60 men be employed in the same current of air. In a medium class mine not more than 40 men ; in fiery mines not more than 80 persons.

5th. That fiery mines be ventilated by mechanical power.

6th. That blasting and the use of naked lights be prohibited in fiery mines, or where outbursts of gas are liable.

7th. That a given quantity of air be supplied per man per minute in each division, which quantity shall be determined by the Board of Control, according to the classification of the mine.

8th. That the velocity of the air does not exceed nor be less than a given rate.

9th. That timbering and packing be done according to a system laid down by the Board, as may be applicable to the nature of the roof, &c.

10th. That the Board have power to inspect the plans of any colliery, and advise any alteration as may lead to a safer routine of working.

11th. That the Board of Control be the examiners for the district.

12th. That colliery managers undergo three examinations, 1st as deputy or fireman, 2nd as overman or under-ground manager (and so carrying out the clause of the Regulation Act of 1872, which demands that all mines shall be under the daily inspection or supervision of a certificated manager), 3rd as general colliery manager; and not receive any premium or percentage from his employers.

shall undergo and pass an examination-, 1st as stoker, 2nd as driver, 3rd as enginewright.

That all cages by which men are lowered and raised shall be provided with disengaging hooks and grappling appliances, of approved models.

15th. That all winding drums be provided with steam brakes.

16th. That all mines be worked on the longwall system, where practicable, as that system is admittedly the safest, for ventilating in the most efficient manner.

Respecting the superiority of the longwall system of working coal, Mr. G. Fowler, in his 'Papers on Coal Mining, says:- "There is, therefore, reason to believe that a proper methodical application of longwall work is most conducive to the safety of mining operations. Whatever may be the value of such adventitious aids as the safety lamp in mining (and no practical miner will ever underrate them), the most important point after all is the regular removal of the gas as it is given off by the coal. The great simplicity of a proper system of longwall work is eminently favourable for the rapidity and regularity of this removal. And it is no small advantage that by this method only can the ventilating currents bear a constant proportion to the gas given off."

Thos. Evans, Esq., Her Majesty's Government Inspector for the Midland district, also speaks with great decision and weight on the same subject. His words are:- "It is worth recording the fact that over 20,000,000 tons of coal have been raised since the last fatal explosion; and during the last two years about 26,700,000 tons were produced for one life lost. The question may be asked: 'How are these results obtained.' In my opinion it is in a great measure due to the system employed in working the coal. For the most part the 'longwall' is the recognised plan. Care is taken to fill with debris all places from which coal has been extracted, so as to make it impossible at any time to have a large accumulation of gas. The ventilation is constantly kept up to the face of the workings, carrying with it any noxious gases emitted from the waste."

Legislation which would lead to an adoption of the longwall system would most certainly conduce to a better state of things in our mining enterprise. As districts, however, vary in the conditions of roof, floor, undercutting, gas, &c., &c., there would require a modification of working detail to suit each, but the broad longwall may be admitted to be generally applicable. This system is gaining more and more friends amongst mining engineers and others concerned, and the time is probably not far distant when the longwall mode of working will be almost universally adopted. One certain fact is that less explosions have taken place under the longwall system than under any other.

With the adoption of this system much of the heavier responsibility of the manager would cease.

At present the colliery manager's responsibilities are graduated according to the system in which he is engaged. In too many cases he is answerable for accidents which, under another system, would not occur. Too frequently he has to contend with risks and contingencies which rise more from radical defect in the mode of working, than from careless discipline or incompetent management. Yet how little is this considered when the manager is summoned for not preventing an inevitable consequence arising from defect of system. Public opinion must, however, be satisfied, and a magistrate's decision is oftener the reflex of that than the balancing of a well-informed and critical judgement.

The Education Act may, in time, tend to minimise the number of accidents, by raising the standard of intelligence amongst the workmen. Education amongst the men will be the strongest possible check on laxity in mining control or managing incompetency.

Miners, as a rule, have little knowledge of the natural laws which affect health, and which influence the sanitary condition of a colliery. Ignorance makes them trustful and they evince a confidence in the management of their mines which has too often been abused. With want of knowledge they cannot be critical, and must, perforce, blindly follow where they cannot see. The growth of technical education, will no doubt remove much of this, and as the miner becomes an intelligent critic, so surely will the standard of management be improved.

VI. - LIGHTING OF MINES AND SAFETY LAMPS, THEIR MERITS AND DEMERITS.

The question of lighting our mines with a good and safe light has for many years been one of great interest.

Since the light of heaven is excluded, some mode of artificial lighting is necessary. Perhaps one more suitable has not been introduced than the primitive candle stuck in a piece of clay, as it can be placed anywhere at will, so as to throw its light on the exact spot which the miner requires it.

But then the naked light is not always safe; and where this is not the case, some other means must be devised to meet it.

It is an old saying that 'Necessity is the mother of invention,' and perhaps few subjects have awakened more the ingenious faculty of inventors than that of lighting fiery mines with safety. Since 1710, in which year we have the first record of a colliery explosion, which, by the way, occurred in Belgium, no less than 400 patents have been taken out for safety lamps and improvements in them.

Perhaps one that will meet every requirement has not yet been invented; at the same time it may be opined that had the men who have distinguished themselves in this line been practically acquainted with the mine and gas phenomena, a thorough safety lamp would have been invented years ago. It is said that many years prior to the discovery of the gauze lamp, many experiments were tried with various contrivances to neutralise the risk arising from firedamp, but it was not until 1814 that any practically utilisable contrivance was discovered.

In that year, Dr. Clanny submitted his invention to the Royal Scientific Society, and in support of the necessity for the adoption of a safety lamp, stated that over 200 lives had been lost during the year by explosions, leaving 300 women and children unprovided for. Amongst those interested in mining, both here and abroad, the need of a protected light was greatly felt, as explosions were increasing yearly, with heavy loss of life and property.

Dr. Clanny's invention was therefore tried, but was found too cumbersome and expensive, the flame having to be supplied with air propelled with a pair of bellows through a thin layer of water. In 1815, Sir Humphrey Davy made his wonderful discovery of the gauze lamp, his experiments leading up to the discovery being based on the conductivity of metal in carrying off the heat arising from the combustion of gas within the lamp. Smiles, in his 'Life of George Stephenson,' states that Stephenson brought out his lamp a few weeks prior to Davy, and that had he have introduced it to the notice of some of the learned societies he would have been equally honoured with Davy.

Stephenson's experiments were tried with tubes of varying diameters, which ultimately led up to the discovery that flame would not pass through those of a certain diameter. This diameter is now fixed at about 1/56th 4th of an inch, or 784 apertures per square inch.

In 1835, it was proved before a Royal Commission that more persons had lost their lives in the eighteen years succeeding the introduction of the Davy lamp than the eighteen years preceding the invention.

When the lamp was undergoing experiment in the presence of Sir Humphrey Davy and others, on being subjected to a gas test, the gas was exploded outside the gauze, on which Davy, addressing those present, said:- "Now, gentlemen, you see the nature of the danger to which you are exposed in using the lamp, and I caution and warn you not to use it in any such places without the shield." Unfortunately, with the adoption of the shield the explosions did not cease, but increased, despite improvements in safety lamps and the introduction of better apparatus for ventilating mines.

From time to time, as a terrible disaster happened from an explosion, and public interest awakened into sympathy for the sufferers and the bereaved, parliamentary regulations were made and enforced for the better and safer working of mines, resulting eventually in the Act of 1872, the observance of which has been attended with a steady diminution in the loss of life, principally, however, from miscellaneous, or the more strictly preventable accidents. For the past 23 years, that is from 1856 to 1878 inclusive, no less than 5,556 lives have been lost by colliery explosions, during which period of time 2,404,917,538 tons of coal have been raised. The last three years have shown a rapid increase. In 1876, 47 explosions occurred, resulting in the loss of 99 lives; in 1877, explosions 49, loss of life, 349; and in 1878, explosions 31, loss of life, 586. But the total loss of life from various causes for 1878 is 1,413, as against 1,208 for the preceding year.

For the present year a good number of lives have been lost already.

It is somewhat singular in an experimental and scientific age like the present that no perfect means of working safely in fiery mines has been discovered. The nature and properties of the various gases found in mines are well-known. The influences quickening or diminishing their generation have become simple matters of fact, but beyond the exercise of vigilance and discipline on the part of officials, and the use of imperfect safety lamps by the workmen, there is as yet no barrier between a pit's company and a fearful disaster. One fruitful cause of the outflow of gas and consequent explosions is the changes that take place in atmospheric pressure. No less than three-fourths of the explosions during the above period of 23 years are supposed to have originated from this cause alone. Of late, many experiments have been made with safety lamps, in which they have been subjected to currents of gas travelling at varying velocities. The result of these has, however, been to prove that the perfect safety lamp is not yet introduced to the working of mines, and that those in use are rather pictures of safety than realities. For how frequently have they been depended upon as a safeguard, and proved but a deadly weapon cherished in the hands of the bearer. It is to be feared that colliery managers have to too great an extent thought that a workman could go anywhere with a lamp, so long as it would burn.

The gauze lamp has been relied on until it has become nothing but darkness in light, and so far from being safe, recent experiments have shown that the wind at certain velocities will pass the flame through the gauze.

Notwithstanding the numerous and careful experiments that have been made with all kinds of safety lamps, it is still difficult to determine how explosions occur, although no defective lamps may be found. Now, it is well-known to practical men that breaks in the roof, floor, and sides are not perpendicular, that on the contrary they are more or less slant or oblique. When blowers occur the gas is discharged through many of these oblique openings at the same time. Then, as a lamp is hanging or being carried in an upright position across the slant or oblique stream of gas, which are rejected with great force and velocity, the jets impinge against the flame and at once propel it through the gauze, thus igniting the mixture of firedamp outside.

Again, a lamp may be hanging up and an accumulation of gas take place around it, and eventually explode inside the lamp, burning while it can gain oxygen to support it. The gauze being of thin iron wire is easily heated to a red heat and so ignites the gas outside.

Ignition by propulsion through the gauze may also occur when a boy or man is carelessly swinging his lamp in his hand until unnoticed it becomes red hot and explodes the gas outside. Again, a workman or unskilled overman may be trying working places, cavities or high breaks in the roof, the mixture he is testing may be at the most violent explosive point, when just as he touches the gas he may slip or fall. Or gas may be rarely seen in the mine and the fireman timed in the testing, and while doing so draw his lamp down quickly out of the gas, and cause the flame to pass the gauze. Then, a blown-out shot has been known to cause the explosion. A door also may be left open and the wind rushing by a near cut may increase to such a forcible velocity that fine inflammable dust may be carried through the gauze to the flame, become incandescent, and carry an ignitable temperature to a small proportion of gas outside, which the pressure of the cloud of dust has rendered highly explosive. Then, ignition may be communicated outside a lamp gauze, if the top of it has become dusty and the lamp receives a slight shock which shakes the dust into the flame and causes a small stream of fire to pass outside.

Again, a common evil is frequently practised in road-men and others re-lighting the lamps when they have gone out in the workings, either from falling over or falling down, and the gauze having become smeared with oil, they are taken again into the workings in this state; then, if contacted with an explosive mixture, the flame is at once brought to the outside.

Again, a lamp may be carried across jets of gas issuing from the floor, and quickly become red-hot.

Experienced men in fiery mines are, however, able to test gas with perfect safety, and will explode the fiery mixture in their lamps over and over again.

The Stephenson is the safest lamp with which the writer is practically acquainted, but in this the gauze is a source of weakness and danger.

It will be clear to everyone that when gas explodes, it expands with great rapidity and force.

When the Stephenson lamp is put into firedamp, the gas passes through the gauze around the glass cylinder. On being exploded it depends on the force of the mixture and the condition of the lamp whether the mixture is exploded outside the gauze by the forcible and rapid expansion of the ignited gas inside, as flame with a certain force will pass the gauze.

Another danger in the Stephenson lamp is that of the gauze being too short, so as not to cover the air-holes in the brass rim at the bottom of the lamp. Or it may be split by the brush being forced into it when undergoing cleansing.

Then, the gauze may be pressed at the bottom by a per-son carrying it, so that the gauze will break contact with the brass. This may occur when a miner is passing on a small airway, and clutches his lamp tightly round the gauze to prevent its being extinguished. A wire may become displaced or broken, and render the lamp no better than a naked light.

In two lamps experimented upon by the writer, and which allowed the flame to pass in explosive mixtures, it was found that one gauze was too short, and the other split at the bottom. This led to further experiments or testing of the ordinary run of lamps used, and the author ventures to assert that, if put under test, ten per cent. of the lamps ordinarily used would explode. This will probably seem an astonishing assertion when one defective lamp in ten thousand may cause a terrible calamity.

The tendency to splitting in gauzes exists in all lamps when they become old and friable, but it has perhaps been made sufficiently clear that a faulty lamp is not needed to cause an explosion. But how much greater is the risk magnified by the prevalence of defects in existing types of the safety lamp.

Then, an additional danger arises from the reckless tampering of some of the men with their lamps. A few personal experiences will illustrate this. The writer once saw a man hold the bolt of the common lock with his teeth, while he turned round the lamp, thus unlocking it, afterwards taking off the top and lighting his tobacco. Another threw up the glass cylinder of the 'Georgie' lamp and placing his pipe close to the gauze sucked the light through. The same thing can also be done with a 'Clanny,' by enlarging the flame and drawing or sucking through above the glass.

But there is no difficulty in unlocking these lamps, for almost anything will do. False keys, nails with a nick filed at the end to fit the bolt, a bit of wire bent in the form of a pair of tongs and held together, small pieces of wood capped with wire, small nails, pick points, &c., &c. All these and other contrivances for opening lamps have fallen under the writer's observation.

Few people are aware of the strong temptation there is for miners to unlock their lamps for the purpose of re-lighting them where naked lights are prohibited except at the bottom of the pit.

It is customary where there are ten or twelve men at work in a company to have two spare lamps, but no one has the right to the use of these except the contractors. A man working by the piece and getting out his lamp is under the necessity of going perhaps a mile or more to the pit bottom, where he has probably to wait another fifteen minutes while the lamp goes up to be re-lit. Very frequently the lamp is again extinguished by the shock of the cage when it drops in the bottom, and the lamp has to be sent back again to the surface.

The writer has known men to be away from their working places for an hour and a half, and has experienced the same thing himself.

Very often the Journey to the bottom had to be made in the dark or in the company of the gang lads. So great an evil was this and so great the money loss to the men that it was a common practice to unlock and light each other's lamps, and men whose lamps have been extinguished would even put out the lights of several others so that all might be concerned in the keeping the secret.

Another risk, arising more from the regulations affecting the use of lamps than the lamps themselves, is the rigid system of fines enforced for defective gauzes whether they be the result of ordinary wear and tear, accidental damage or culpable carelessness. After the writer had used lamps for about six or eight months he noticed two broken wires in his gauze which he was pleased to show the lampman and so avert further risk. The latter observed that the wires were badly worn and thin, but nevertheless fined him a shilling. Men have been known to work with broken and displaced wires for a long time, as they knew that discovery would result in a fine, whatever the cause might be. It may be thought these experiences of the writer are more imaginary than actual. They admit, however, of easy proof.

It has been said that one false step may lead to moral destruction how true also this is of the management and regulations respecting the use of lamps. An unjust system of fining deters the men from reporting a defect which may lose their lives, a want of spare lamps in a stall's company leads to reckless tampering, with its accompanying liabilities.

The evils that exist in the gauze lamps may be further illustrated by a few notes from a series of experiments made on safety lamps by the Committee of the North of England Institute, as follows:-

(1.) By revolving a Davy safety lamp in certain mixtures, not only of ordinary coal gas and air, but also of the less explosive pit gas and air, at certain velocities, the external gas will be ignited. (2.) In a mixture of coal gas and air, the gas has been ignited by a lamp revolving at a great velocity, but the gauze of which has not attained a red heat, thus proving that in this experiment the flame passed through the gauze, and was not ignited by the gauze itself attaining high temperature. (3.) In mixtures where there is a great excess of gas in the proportion of one to five of air, the explosive force is very slight, the flame, which is of a yellow colour, passes sluggishly over the box (in which the experiment was made), and the explosion is prolonged. Where the air is more abundant (in proportion of one of gas to eight of air, or thereabouts) the colour of the flame is blue, and the explosion is violent and rapid. (4.) The lowest velocity at which the flame passed was 13 ft. per second. Further experiments were made in which a current of air and gas of known proportions and velocity were caused to impinge upon a lamp at rest, proving conclusively the exact velocity of current required to cause an explosion. The general results are thus stated: An inflammable mixture of pit gas and air, moving at the rate of eight feet per second against a stationary Davy lamp without a shield will explode. The addition of an ordinary shield to a Davy lamp is of little benefit. When the shield fits closely, and extends from the top to the bottom of the gauze, it affords some protection, but still at a velocity of 12 ft. per second, the flame passes. A Clanny lamp under similar circumstances will explode in a mixture passing at 9 ft. per second. A Stephenson lamp will explode at 9 ft. per second. In some experiments the flame passed the Stephenson lamp before the glass was in any way injured, and in one experiment the glass was clearly observed to break after the lamp had fired the mixture, and was being withdrawn into the cold air for examination. A Museler lamp passed the flame as easily as a Davy lamp, viz., at 8 ft. per second. The Williamson lamp, a recent invention, which is a kind of combination of the Stephenson and Clanny, resembling in appearance very much the latter lamp, but having an additional glass cylinder inside, is not so liable to explosion at high velocities as the lamps above mentioned. Mr. Galloway, speaking of these mysterious explosions which sometimes occur in an unvitiated atmosphere, believes that the sound wave originated by a blown out or heavily charged shot, in passing through a Davy safety lamp burning in an explosive mixture, would carry the flame through the meshes of the wire gauze, by virtue of the molecules of the explosive gas. A number of experiments on a small scale wore organised by him at the cost of the Royal Society, and it was proved that the sound wave did cause a passage of the flame through the meshes of the wire gauze of both Clanny and Davy lamps. This trial was made in a large sewer, and shots fired from a pistol charged with fifty-nine grains of gunpowder at a distance of 109 ft. from the lamps under trial, the air round the lamps being charged with coal gas to an explosive point. The flame of the lamps was passed through the wire gauze by the sound wave and exploded the mixture.

Mr. Logan, in his recent lecture on the Northern Coal-field, speaking on the subject of safety lamps, said, “It was not until 1815 that Sir Humphry Davy brought his lamp to perfection, and, notwithstanding that it is not under all circumstances a perfectly safe lamp, it has not as yet been improved upon. There are, of course, a number of other lamps besides the Davy, but a perfectly safe lamp remains to be invented”. Mr. Arnold Lupton, M.I.C.E., in his introductory lecture of the present session of the Coal Mining Department of the Yorkshire College, Leeds, said in respect to the prevention of colliery accidents, “There is no doubt that what is wanted is an absolutely safe safety lamp which will give a good light. This has not as yet been invented; when it has, it will be a great step forward.”

Joseph Dickinson, Esq., one of Her Majesty’s Inspectors of Mines, says, in his report to Government, “many of the so-called safety lamps, including the Davy, are unsafe in explosive currents.”

The writer has found no difficulty in passing the flame through more than one thickness of gauze, and utterly condemns the use of gauze lamps.

A DESCRIPTION OF THE WRITER’S IMPROVEMENTS IN THE SAFETY LAMP.

The writer has no desire to undervalue or disparage the endeavours made by inventors to combat the miners’ deadliest enemy, for he would rather bare his head and bow with reverence before a statue of these men than before those of the greatest warriors that ever lived.

Being practically acquainted with mining and the use and abuse of safety lamps, the writer has long seen the need of a better form of safety lamp, which, while being so sensitive as to be self-extinguishing in an explosive mixture, should be so strong outwardly as to be proof against ordinary accidents, and also have a lock which should be practically unpickable.

The results of his thoughts and labours have nearly, if not altogether, attained these objects. The construction of his lamp is as follows. In general appearance it is of the Clanny type. In place of the gauze ordinarily used, thin, but strong metallic dome is substituted. Inside this tube or dome, another thin tube is placed, having a perforated copper cap, to which is closely fitted an ordinary gauze cap. The inner tube is held in position by the glass. The glass is secured in its place by a gauze drum, or ferule, which faces airholes in the rim of the gallery. To the neck of the gallery the oil vessel is fastened in the usual manner. By the application of the outer metallic shell or dome, the vulnerable part of the lamp. i.e., the gauze, is effectually protected. At the same time, perfect sensitiveness is secured by limiting the passages for the entrance of gases. Ventilation is also obtained through the same passages so long as the air is pure, the heated air and results of combustion passing through the copper and gauze caps, and so on through the airholes at the top of the dome.

The following is the locking arrangement. A small cylinder is fitted at the aide of the oil vessel, having a piston rod, or bolt which passes through and projects above the rim of the oil vessel. This rod or bolt is held up by a spring, after the principle of a cornet valve. When the top of the lamp is screwed on to the bottom, the piston bolt becomes inserted in a recess in the upper neck of the lamp, which comes opposite to the bolt at the moment of contact of both parts of the lamp. Thus, a perfectly safe locking is secured. For the purpose of unlocking, a hollow screw is fitted in the side of the cylinder, which can be withdrawn only so far as to permit a small hole in the side of the hollow screw becoming accessible to an air pump. When it is desired to draw down the bolt and unlock the lamp, the hollow screw is partly withdrawn and inserted in the mouth of the air-pump, by one stroke of which the air is exhausted, and by a simultaneous turn of the upper part of the lamp the two parts are disconnected.

The advantages claimed for the lamp are as follows

1. A good light.
2. The blaze or flame cannot be drawn or forced through the lamp.
3. It cannot be burst by any mixture of firedamp, at any velocity, however great.
4. In gas, the flame never leaves the wick, thus guarding against a common source of danger.
5. It is sensitive to gas, thereby permitting very delicate tests.

6. It is self-extinguishing in an explosive mixture.

7. It will stand a greater current of air than any other lamp without flickering.

8. It cannot be tampered with or unlocked without the pneumatic apparatus.

9. The lock is selfacting, thus saving much time in a mine using lamps exclusively.

10. Economy of time in unlocking.

11. Economy of time in cleaning and repairs.

12. Great strength.

13. The outer shell becoming pricked with a pick point, or otherwise cut through, does not endanger the lamp, there being an inner tube which protects the flame.

14. The glass is secured by flanges at top and bottom, which only allow it to crack in an upright position when subject to accident.

15. It is so arranged as to burn any kind of mineral or vegetable oil.

16. The lamp is so practically constructed as to meet every requirement of the miner's labour.

A shield reflector has also been applied by the writer to the lamp, by the use of which a much higher power of light can be thrown on any required spot.

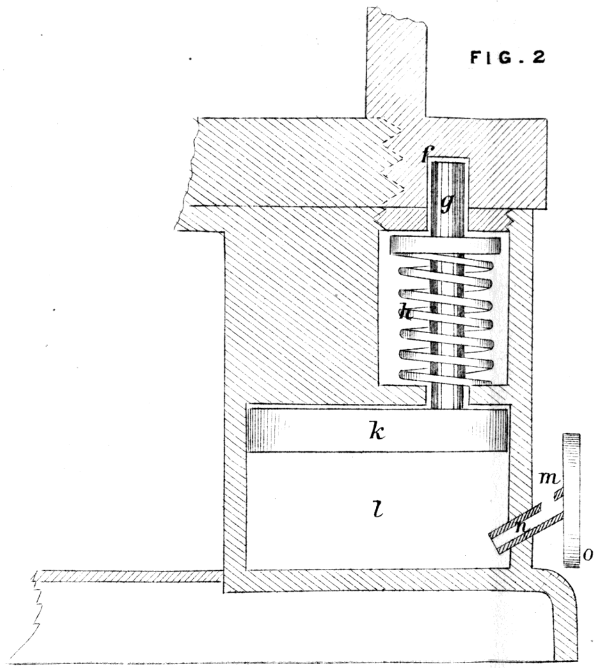
The writer hopes it will not be thought he has treated this all-important subject too lengthily. His apology is the admitted need there is for a thorough consideration and discussion of the matter, so that if possible some pressure may be put upon the legislative powers to deal with it more effectually than hitherto.

DESCRIPTION OF DRAWINGS.

FIG 1 - A is a gauze cap, fitted over the perforated copper cap b, which is secured on the iron or other metallic tube d d; C C is a brass or other metallic cylinder or outer shell securing the vital parts of the lamp. B is a row of small perforated holes, round the outer shell or cylinder, to pass a current of air between the two shells. e ~ is a gauze drum or glass ferule, through which the air passes to feed the flame.

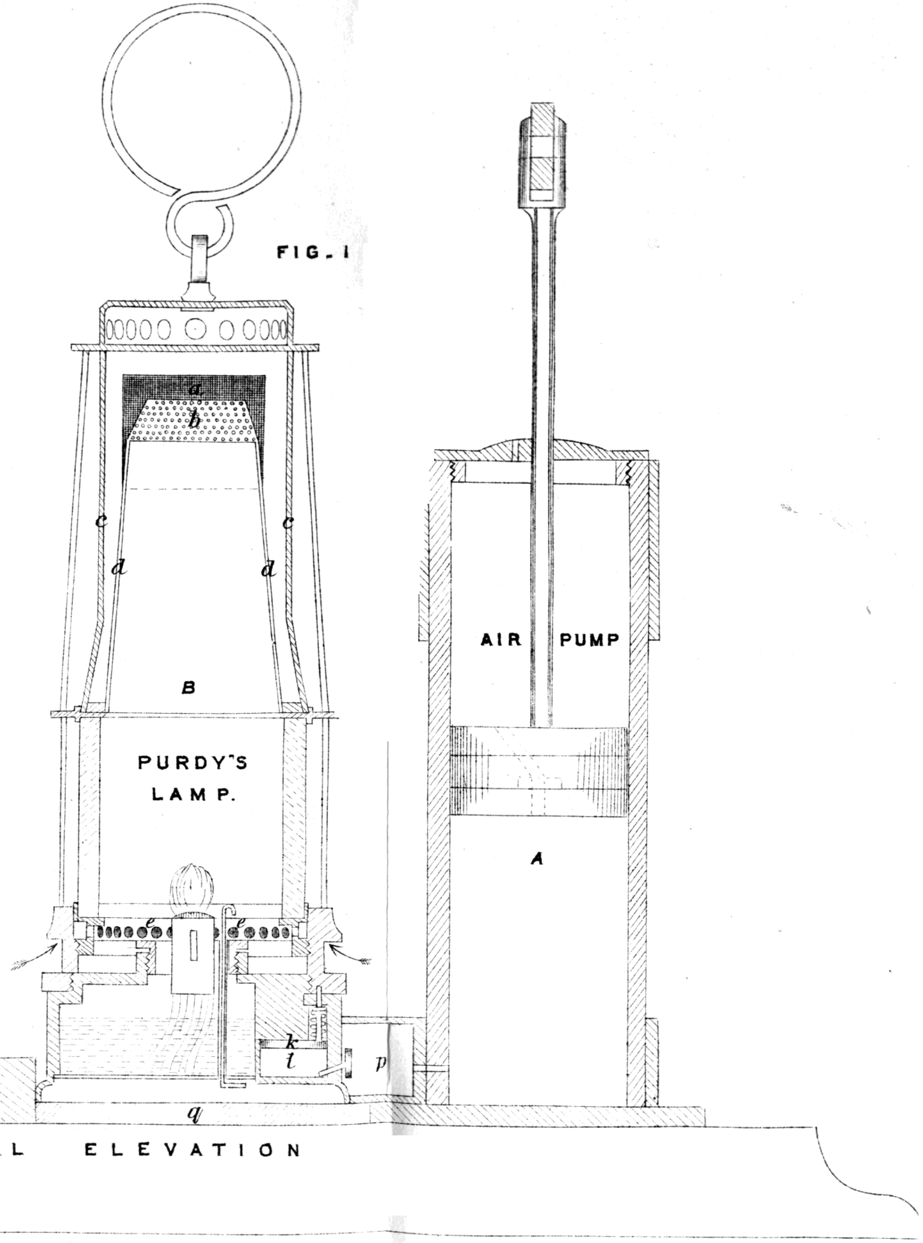
In **FIG**. **2**, F is a recess in the rim of the lamp to receive the bolt or piston rod g; h is a spiral spring coiled on the piston rod; k is the piston working in the cylinder, or air chamber 1; m is a hole in the hollow screw through which the air is exhausted; n is a bulge on the inside of the screw, which prevents it from being taken out; 0 is a button on the screw which screws up tightly to side of the lamp; A is a vacuum made by the air pump; P is the mouth of the pump faced with india-rubber; Q is an india-rubber pad.

FIG. 2



SECTION OF LOCK (*ENLARGED*)

FIG. 1



CAM

SECTIONAL ELEVATION