Dr Druitt. F.R.C.S.
from the Author

289

8

# LIFE AND DEATH IN OUR MINES.

BY

JABEZ HOGG, F.L.S.,

*Senior Assistant-Surgeon to the Royal Westminster Ophthalmic Hospital; Fellow and late Vice-President of the Medical Society of London; Member of the Microscopical Society, London; etc.*

AUTHOR OF

*A Manual of Ophthalmoscopic Surgery, being a Treatise on the Use of the Ophthalmoscope in Diseases of the Eye; The Microscope, its History, Construction, and Applications; Elements of Natural Philosophy; etc.*

REPRINTED FROM THE "INTELLECTUAL OBSERVER" OF FEBRUARY, 1866.

M.DCCC.LXVI.

# LIFE AND DEATH IN OUR MINES.

By JABEZ HOGG, F.L.S., M.R.C.S., Etc.

Who among us, on taking up a newspaper on the morning of the 23rd of December, 1865, could read the harrowing and heartrending details of the colliery explosion at Merthyr Tydvil without a shudder, and a regret that as yet, with all the increasing scientific knowledge of the day, no remedy had been suggested, no means taken to effectually guard against results of fire-damp in mines? Thirty-four human beings killed, and nearly as many more injured, in this one fatal explosion. It would be well if such calamitous incidents secured the attention of the public to the deplorable fact that the sacrifice of the very large number of 1644 human beings, in the full enjoyment of life, is called for annually in our coal-mines, and arises, as I shall presently show, in the generality of cases, *from preventible causes,* and of these no less than 365, or one per diem, is offered up to that dread spirit of destruction, *fire-damp;* for it has been positively determined by Mr. Holland that the deaths from this deleterious gas alone average one for each day in the year.

The census of 1861 gave 282,474 males as employed in coal-mines; of these, one in 355 annually meets with death by accident of some sort; and during the year 1864, one life was lost in raising every 109,715 tons of coal from the pit. It is true that coal must be had, or the industry of this nation would soon be paralyzed; but must we necessarily pay for it by the annual sacrifice of 1644 hale and hearty fellows? Has science no remedy to offer us that shall be effective in warding off a spirit of evil so dreaded as either fire or choke-damp? This is, indeed, both a serious and momentous question. Before an answer is attempted, we must not lose sight of this important fact, that as long as miners are obliged to employ a lamp, or use a flame of any kind, to illuminate the dark cavern in which they work, surrounded by a dangerous and ever-accumulating gas, which may at any moment be ignited and exploded, so long will they be exposed and subjected to the fearful horrors attending an explosion; and as long as there is "*fire-damp* *below,*" is there a risk that some one act of stupidity or carelessness on the part of a miner will occasion a wholesale slaughter, of it may be some hundreds, of human beings; and so long will the public mind be periodically shocked by the ever-recurring announcement of "*Another colliery explosion, with fearful loss of life, in the 'Reckless' mine.*"

One morning, a year or two ago, we were shocked by reading of the Risca explosion, with the loss of 145 lives at one fell swoop. A still shorter time back, in the model Tredegar mine, noted for the careful management displayed in its working, "a long, rumbling sound" told of twenty-six blackened corpses lying in a heap, and many more half dead, awaiting some daring spirit to save them from the twin destroyer, *choke-damp.* It subsequently appeared that the colliery had been carefully examined only that very morning, and the ordinary means taken to test the presence of fire-damp; some of the inflammable air was found in a "cross-heading in the back-workings," but as there was no great quantity detected, the "*fireman*" thought it a sufficient precaution to put up a "*danger signal,*" whatever that may mean; which it appears was so little regarded that the men quickly followed to their usual work with naked lights. This seems to have been ordinarily permitted even in this model mine; so little are the workmen dismayed by a "*danger signal,*" or rather, so much accustomed are they to the dangers of their daily employment that they become heedless of them; and so, somehow or other, "*the gas was fired.*"

If the officials in charge of the mine care so little for the results as to leave all to blind chance, or next to it, since they consider their duty done after having hoisted a "*danger signal,*" is it to be wondered at that the more ignorant workmen should err on the same side, and blindly walk into the very jaws of death, with an open lamp to light them on their way? Be it remembered, also, that miners are fatalists of the worst kind, implicitly believing that they will not die until their time comes, and that when it does, die they must; and hence they run most foolhardy risks. This very belief, however, makes them courageous even to a fault, for they will face danger most unflinchingly in endeavouring to save fellow-workmen requiring help. And so, with but few exceptions, in a more or less culpable degree, carelessness is at the root of all the sad and terrible disasters attendant upon the firing of a pit.

It must not, however, be supposed that, in the enumeration of losses of life by *fire-damp,* that we fully realize the extent of the evil going on year by year, and, I fear it must be said, in an increasing ratio. The gross total of actual deaths (on the spot) from accidents in and about the coal-mines of Great

Britain in 1864 was 777, being an increase of 20 over the deaths from the same causes in 1863. The following tabular arrangement exhibits at a glance the every-day dangers of miners :—

DEATHS IN 1864. IN THE SHAFT.

| | |
|---|---|
| *From overwinding;* that is, when the engine is not stopped in time, and the tub is drawn over the pulley, and the miners are thrown bodily down the shaft . . . . . . . . . . . . . . . . . | 5 |
| *From falling,* either from the surface, or from part of the way down the shaft, *e.g.*, as where the same shaft works two seams of coal . . . . . . . . . . . | 36 |
| *From breaking of ropes or chains;* that is, the ropes or chains which raise and lower the tubs, cages, etc. . | 9 |
| *From accidents while ascending or descending,* such as from falling off the tub or cage, or being struck by the return tub . . . . . . . . . . . . . . . . | 32 |
| *From miscellaneous accidents in shaft;* such as the catch breaking or being stuck fast, or allowing the tub or cage to go down into the "sump" (a water cistern at the bottom of the shaft) . . . . . . . . . . | 36 |
| *From things falling down the shaft* . . . . . . . . | 25 |
| *From things falling from part of the way down;* as from the side of the shaft, etc. . . . . . . . . . . | 15 |
| | 158 |

IN THE PIT.

*From explosions of fire-damp* . . . . . . . . . 59

We must not omit to mention that deaths resulting from explosions after removal from the pit are not included in these 59. Thus, in 1860 there were 4 deaths from explosion, but 26 other deaths resulted, making actually 30, yet only the 4 were estimated. It has been positively ascertained by Mr. Holland, one of the Royal Commissioners of Mines, that there is one life lost every day throughout the year from explosions alone.

| | |
|---|---|
| *From falls of coal;* that is, falls of detached masses of coal which are imperfectly propped, or which fall before expected . . . . . . . . . . . . . . | 118 |
| *From falls of roof;* that is, falls of stone from the roof or sides of the galleries. These arise from the fact, that the weight of the earth pressing on the pillars left to support the roof sinks them down into the earth, or, as the miners say, "raises the floor," and, in consequence, large masses of stone become detached, and fall unexpectedly . . . . . . . . . | 262 |

| | |
|---|---|
| *From explosions of gunpowder;* that is, gunpowder used for blasting coal, or in making a new roadway in the pit, or raising the roof, etc. . . . . . . . . . | 15 |
| *From miscellaneous accidents;* that is, suffocation, irruptions of gases or of water, falls into water, on the inclined plane, etc. . . . . . . . . . . . . . | 102 |
| | 556 |

ON THE SURFACE.

| | |
|---|---|
| By machinery . . . . . . . . . . . . . . . . | 14 |
| By bursting of boilers . . . . . . . . . . . . | 3 |
| By miscellaneous accidents . . . . . . . . . . . | 46 |
| | 63 |

TOTAL NUMBER OF DEATHS—

| | |
|---|---|
| In the Shaft . . | 158 |
| In the Pit . . | 556 |
| On the Surface . | 63 |
| | 777 actually killed on the spot; but |
| | 867 there were other 867 deaths resulting from accident, making |
| | 1644 1644 actual deaths from accidental causes. |

We cannot altogether overlook or entirely ignore another source of danger to life in mines—one greatly affecting health and shortening life, and thereby increasing what is commonly, but wrongly, spoken of as the *natural death ratio of miners*—namely, the imperfect ventilation of mines. In our northern coal-pits as much care is taken as can be got out of an imperfect system to maintain an interchange of pure air; but in most metal mines this great necessity of life is shamefully and systematically neglected. An eye-witness graphically describes the present condition of a Cornish mine:—

"The only air-engine found working in one big mine was a piston in a rough deal box; a panting short-armed little boy pulled and pushed at the cross handle. The air was close where he worked, and the squirt and its pipes leaked. A long way off, at the 'end,' a very faint puff, which gently bent the flame of a candle for a moment, was the sole result of each violent effort. . . . . Men at work in bad places pant and seem to breathe painfully. Their faces are red or purple; their veins swelled; their brows wet, and begrimed with soot. They seem to labour hard, though their work is not harder than quarrying stones elsewhere. In such places candles flicker and sometimes go out altogether; no puffing or drawing will light a pipe or keep it lighted. There is no laughter, no fun; no busy cheering chatter of active labour; all is silent toil; the carbonic acid is not laughing gas. . . . .

"The death-rates per 1000 between certain ages are as follows :—

| Ages. | Cornish people above ground. | Northern colliers. | Cornish men under ground. |
|---|---|---|---|
| 35 to 45 | 10 | 10 | 14 |
| 45 to 55 | 15 | 17 | 34 |
| 55 to 65 | 24 | 24 | 63 " * |

Is so lamentable a death-rate to be longer permitted to pass unheeded?

Now comes the important question, What has science done to ameliorate this long list of dangers to the miner? But before we enter upon the consideration of this question, it will be necessary to comprehend quite clearly the *nature and properties of fire-damp.*

First, the gas is light, and therefore rises to the upper part of a gallery in a mine, and remains in that position, unless in exceptional cases. It is inflammable, burning with a luminous flame, and in its combustion forming water and carbonic acid, the latter being the "choke-damp" of the miner. A mixture of fire-damp and air, containing six per cent. of the gas, burns quietly; if the quantity of the combustible element be increased to seven per cent., the mixture explodes feebly; the most destructive explosion taking place when ten and a half parts of fire-damp are mixed with eighty-nine and a half of air. Fire-damp, fortunately, requires a high temperature to ignite it, and by its combustion produces a still higher one; consequently it singes off the hair, burns the skin, sets fire to garments, and at times even sets fire to coal; hence we occasionally hear of mines being on fire. The gas has a peculiar odour, which, however, varies considerably; in some mines it has a faint smell of alcohol, in others of tar, and again in others it has a fœtid odour not unlike fennel. For experimental use it is readily procurable, being eliminated when a mixture of equal parts of acetate of potash, caustic potash, and quick lime is strongly heated. It occurs naturally as a result of the decomposition of vegetable matter contained in the mud

* J. F. Campbell's *Frost and Fire*, vol. i., page 55.

of stagnant water, such as rivers, ponds, marshes, etc.; hence its name marsh-gas.

A common cause of explosions, not often explained or even thought of, may be found in the variations of the pressure of the atmosphere, as indicated by the barometer. The gas having collected in a "Goaf," is retained there by the high pressure indicated by the barometer—suddenly the barometer falls, the mass of gas expands, and some unfortunate workman, not knowing what has happened, walks into the danger with a naked light, thereby exploding it may be acres of gas.

Until the beginning of the present century, the only means of ascertaining the accumulation of fire-damp to a dangerous extent was at the almost certain risk of igniting the whole; while the dim light afforded by the *steel-mill* was the only one with which a dangerous atmosphere could be approached; and even with this, there was the actual danger of the sparks given off inflaming the gas. In 1812, the insufficiency of the then existing arrangements was made painfully apparent by the Felling Colliery explosion; the fact of a pit judiciously worked, and, as was supposed, adequately ventilated, being subjected to so extensive a calamity as to cause the loss of three-fourths of the large staff of workmen employed in it, led many to make the most earnest endeavours to devise some remedy for the evil. The first recorded invention in this direction was a lamp devised by Dr. Clanny, said to be capable of being burnt in an explosive atmosphere: this consisted of an arrangement for blowing the air to support combustion through a column of water, and for permitting the escape of the heated air through the same medium. Sir Humphrey Davy then turned his attention to the subject, and found, while pursuing his remarkable "researches on flame," which afterwards led to the invention of the *Safety Lamp*, that no explosion could be produced in a mixture of air and fire-damp passing through a narrow tube, owing to the cooling influence exerted by the tube upon the gas, and that the narrower the tube, the shorter was the length required to produce this protective effect.

Flame is well understood to be, in all ordinary cases, a luminous envelope, which forms a limiting surface between the unburned combustible within and the supporter of combustion without. Hemming's safety tube for the oxyhydrogen blowpipe depends for its efficacy upon the cooling influence which the metallic tubes or channels exert upon the burning jet. The heat of the flame is in this way prevented from passing backwards, and causing the explosion of the mixed gases in the reservoir.

It is well-known in the laboratory, that, by using wire gauze, we may easily cut off the upper part of a flame, the unburned gases being reduced in temperature below the point required for ignition; and if we employ a piece of gauze with about 400 meshes to the square inch, the conducting power of the metal is sufficient to cool the flame below the point of ignition, even though the wire itself may become red-hot. In a similar manner the gas above the gauze may be kindled, and the flame will not pass through to that below.

Sir H. Davy, in the construction of his miner's lamp, beautifully adapted these principles, so that the miner might carry on his work without allowing the flame to come in contact with the surrounding atmosphere. The wire gauze used in the construction of these lamps contains from 700 to 800 meshes in the square inch. In a strong current of air, the heated gas may be blown through even this fine gauze before its temperature is sufficiently lowered to prevent an explosion; but, of course, such an occurrence might be easily guarded against. The lamp itself is merely an ordinary oil lamp, inclosed within a cylinder of this fine wire gauze; it is provided with a double top, and a crooked wire, which passes up tightly through a tube traversing the body of the lamp, for the purpose of trimming the wick without the necessity of removing the wire case. When such a lamp is introduced into an explosive mixture, the flame is seen gradually to enlarge as the proportion of the gas increases, until at length it fills the entire gauze cylinder; when the gas is greatly in excess, the lamp is entirely extinguished; if it be withdrawn from the mixture while the cylinder appears full of flame, the wick is rekindled. Whenever this pale, enlarged flame is seen, the miner should withdraw; for although no explosion may be looked for while the gauze is sound, yet at a high temperature the metal rapidly oxidizes, and then easily breaks into holes. In such a case, a single aperture of sufficient size determines a fatal explosion.

The means employed for detecting *fire-damp* are few and simple. The viewer or his deputy inspects all the working places in a coal-mine before the men are allowed to begin work, and with his Davy lamp determines whether it is safe for the men to use naked lights, or whether they are to employ the safety lamp. In the latter case, the lamps are securely locked; but even then the men will at times suck the flame through the wire gauze to light their pipes, and by this selfish act they hazard their own lives, as well as that of their fellow-workmen.

In the viewer's trial, he reduces the flame of his lamp to about the size of a horse-bean, and then slowly raises it into the suspected atmosphere, carefully watching the flame. If there be three per cent., a pale blue cap overhangs the flame;

if more than five, but less than seven per cent., the flame elongates in proportion to the quantity; if more than seven, but less than fifteen per cent., the lamp explodes (that is, the gas within the gauze) with less or greater violence; if the mixture contains more than fifteen or sixteen per cent. of fire-damp, it burns quietly; and if more than this, it is unable to support combustion, and the lamp is extinguished. In former times these trials were made with a naked candle, and an explosion commonly told of the presence of the gas: and even with the Davy lamp in competent hands, these trials are not actually safe, as is evidenced by the report lately made by Mr. J. J. Atkinson, Inspector of Mines in the Durham district, wherein he gives in detail two instances of explosions through the gauze of Davy lamps, which were found in a perfect condition even after the explosions.

One of these explosions took place at Newbottle colliery, "through two workmen unexpectedly opening a communication between the Margaret pit and the Jane pit workings at that colliery, on the 8th of April, 1864, the latter pit having been abandoned for about sixty years, and the shaft closed up, after an explosion. On opening the communication, gas came out of the old workings with considerable force, and the workmen ran away, leaving their safety lamps behind. Very soon a slight explosion took place, and the coal was set on fire, and that part of the workings had to be closed off for some time, in order to extinguish the fire. When the fire was extinguished, and the place was again reached, strange to relate, both safety lamps were found to be in good order. They were common Davy lamps." It appears that there are also precautions required before using a new Davy lamp. The wire, at the time of its being drawn out, is lubricated with oil, to enable it to pass through the steel die that regulates its size, and it is found that it retains on its surface a thin film of this oil, even after it has been woven into gauze, If, therefore, a new lamp be taken into an explosive mixture, the ignition and combustion of that mixture heats the gauze to redness, and the oil volatalises, and ignites the fire-damp outside the lamp. These, and other important facts, have recently received the fullest investigation at the hands of Mr. Atkinson, who, we hope, will collect them into a paper, and publish the same for the benefit of mankind.

To fully comprehend, then, the advantages and disadvantages of the Davy lamp, we will take them *seriatim*:

1st. The fire-damp will explode through the gauze of a perfectly constructed lamp.

2nd. The lamp goes out if taken into a very impure atmosphere, and this happens in cases where light is absolutely necessary to the saving of life, or where there are urgent works to be conducted in an atmosphere which will support life for a short time, but where the Davy lamp will not burn. On this ground it is to be hoped that a means will be found of using the electric light in some way or other, either in Dumas' form, or in that of the diver's lamp.

3rd. The Davy lamp may be, and indeed, as we have already seen, often is, opened by the miner, even after it has been locked by the viewer, either to light his pipe, or to obtain more light, for the gauze sadly obstructs light.

4th. It may easily be extinguished by a current of air, or by a drop of water falling from the roof of the gallery.

5th. If the lamp be tilted on one side the oil is liable to run over the gauze; and in such a case, as not unfrequently happens, it causes an explosion.

We must not, however, lose sight of the fact, that in spite of the disadvantages just enumerated, the Davy lamp has proved of very great value to the miner. First, in the detection of fire-damp in pits, and then in giving sufficient light for the miner to work in an atmosphere containing a considerable amount of an explosive gas. Many changes and alterations have been from time to time proposed for the purpose of overcoming some of the objections above mentioned, but hitherto all the proposed fancied improvements have ended in disappointment and vexatious failure. A somewhat important lamp is offered in Dumas' electric light for the purpose of working mines with safety. This lamp consists of an induction coil, enclosed in a box, with a tube of uranium glass about a foot long in the front. The positive and negative platinum points are introduced, one at one end, and the other at the other, a vacuum is then produced in the tube; by turning a small screw the current passes from point to point, and produces the well-known electric light. The light is much inferior to that of the Davy lamp; indeed, it is only just sufficient to enable the miners to grope their way about. The whole affair is unfortunately cumbrous and expensive (costing about £10), and therefore not likely to be brought into general use, at least in its present form. Danger is, however, reduced to a minimum, because in the event of fracture of the glass tube, the vacuum is destroyed, the air rushes in, and the lamp is immediately extinguished.

We may then conclude that all mere mechanical contrivances for shutting off the gas from the source of illumination have proved failures, and altogether inadequate to grapple with the difficulties to be dealt with in mines; and therefore science has been driven to look in another direction for the means of lessening the dangers attendant upon mining. Mr. George F. Ansell, of the Royal Mint, lately invented a most delicately sensitive "Indicator," whereby he is able to detect the smallest appreciable quantity of fire-damp in a mine. This is undoubtedly a step in the right direction.

As in the case of the safety lamp, Ansell's Fire-damp Indicator is the practical application of a natural law, that of DIFFUSION. Dr. Priestley first noticed the phenomenon which has since been more fully developed by Berthollet and Dobereiner in 1825, and by Graham still more recently, who evidently sought out and explained the law which governs the diffusion of gases, and which law may be thus popularly explained :— When two different gases, as atmospheric air and fire-damp, for example, are brought into contact with each other, they have a tendency to mix; and whilst this mixing is taking place, the atoms of each gas travel at a certain speed peculiar to that gas, which speed remains the same under all circumstances. Another peculiarity is, that the speed of a gas remains the same whether it is passing into space or intermixing with another gas, and whether it is passing through a porous substance or an open tube. Mr. Ansell practically applies these facts to the detection of fire-damp; and since his indicator enables him to ascertain the exact percentage of this or other deleterious gases, the application is of the very highest importance and value, not only for coal and metal mines, but wherever subterranean works of any kind have to be carried on, for it readily indicates the presence of the deadly choke-damp, if in any poisonous amount. It is also capable of being made equally useful for the detection of coal-gas in houses and large buildings, as theatres, railway tunnels, and the proposed subways in our streets; or in the holds of ships, where foul air or fire-damp often collects. It may be stated, *en passant,* that a short time since the newspapers gave an account of one ship lying at Liverpool, and another at Sunderland, having suffered great damage, attended with loss of life, by the explosion of an unsuspected accumulation of marsh gas in their holds. In well-sinking, and various other branches of mechanical art, it is capable of being turned to most valuable account for the preservation of human life.

Many of the phenomena attendant upon the mixing of gases are so novel and interesting, that we cannot quite pass them over without a few observations; and for the better elucidation of our subject it will be as well that we should briefly notice some of the more important. The laws which govern the movements of mixed gases are of a totally different character to those which operate upon mixed fluids. The latter are invariably arranged in strata, or layers as it were, and in exact accordance with their specific gravities, the lightest finding its way to the surface, and the heaviest sinking to the bottom of the vessel in which they are placed. From this fact it is concluded that no chemical action is exerted in order to effect their incorporation, and that by the force of gravity alone each liquid assumes its relative position. With respect to gases, which also vary in density to a very considerable extent, no such separation takes place. If chlorine, the specific gravity of which is thirty-six times as great as that of hydrogen, be placed in one of two distant vessels, and be allowed to communicate by means of a long tube, the hydrogen, or the lighter gas, being placed uppermost, the heavier chlorine will, in the course of a few hours, find its way into the upper jar, as may be seen by its green colour, whilst the hydrogen will pass downwards into the lower jar, and ultimately the two gases will be found to be equally intermixed throughout, and when once mixed, there is no disposition to separate again, however long they may remain at rest together. The rapidity with which this *diffusion* occurs varies with the specific gravity of the gases; and, contrary to what might be generally supposed, the more widely the two gases differ in density, the more rapid is the process of intermixture. In the earliest investigations into this very interesting subject, a very simple apparatus was employed, which was nothing more than a plain cylindrical glass tube, ten or twelve inches in length, and one inch in diameter. It was closed at one end by a porous plate of plaster of Paris, graphite, or any dry porous substance, and was then termed a *Diffusiometer*.

In the primary application of the tube it was filled with hydrogen over a mercurial trough, a sheet of gutta-percha for the moment covering the porous plate, and rendering it more slowly permeable. On the removal of the gutta-percha gaseous diffusion through the pores of the plate immediately took place, and during the process the mercury rose in the tube to a height of six or seven inches, thus showing the force with which the impenetration of the atmospheric air is effected. Mr. Ansell's ready mode of showing this is very simple, inasmuch as he demonstrates it with ordinary coal-gas. He takes a piece of glass tubing about one inch in diameter, covers one end with a piece of tile or plaster of Paris, and fills it with coal-gas. This is supported in a jar of water, when the water immediately begins to rise in the tube, and will continue to do so in opposition to gravity, until in the course of a few minutes it stands three or four inches higher inside the tube than the surface of the fluid in the outer vessel, in consequence of the coal-gas passing out through the pores of the plaster of Paris much more rapidly than air can pass in. In the case where different gases are mixed, and then introduced into the diffusion tube, each preserves the rate of diffusion peculiar to itself. If, for instance, hydrogen and carbonic acid be mixed and placed in the diffusion tube, the hydrogen passes out with much greater rapidity than the carbonic acid, and a partial mechanical separation of two gases differing in density may thus be effected. The rate of diffusion is, as might be expected, accelerated by a rise of temperature; for by heat all gases are rendered specifically lighter.

The rapid passage of gases through the minute pores of the plates is a remarkable phenomenon, and one which is thought to fully demonstrate the molecular theory of bodies; but still more remarkable, the infinitesimal particles of gaseous bodies find their way quite as rapidly through such substances as *india-rubber*, etc., which neither microscopical nor chemical examination had heretofore shown to be porous. Upon submitting the very finest pellicle of india-rubber to the highest powers of the microscope it presents a perfectly homogeneous appearance, and no pressure, however carefully applied, will force a fluid through its minute pores; nevertheless, gases pass readily through it.

The process of *diffusion* is one which is continually going on, and playing an important part in the atmosphere which surrounds us, as well as in the various parts of nature. The beautiful and regular movements of the fluid particles which we watch with so much interest in the Vallisneria, Anacharis, etc., are doubtless a result of the law of *diffusion*. Accumulations of gases unfitted for the support of animal and vegetable life, are by its means silently and speedily dispersed: even respiration itself could not be long maintained, were it not for the process of diffusion, which rapidly displaces that which has been rendered unfit for the support of life, and at the same time draws downwards and into the lungs a fresh supply of purer, better, and specifically lighter air.

Enough has now been said to convey a clear idea of the singularly beautiful phenomenon of the diffusion of gases, and light the way to a more exact comprehension of Mr. Ansell's *fire-damp and gas indicator*.

Carburetted hydrogen, either heavy, in the form of olefiant gas, or light as marsh or coal-mine gas (in both cases lighter than air), diffuses readily through air, as we have already shown; and upon this is founded Mr. Ansell's beautiful method for detecting its presence.

It was represented to this gentleman that *fire-damp* would become comparatively harmless if its presence in a mine could be made known by a signal in the manager's room above-ground; the essential condition being, that such means should be entirely self-acting. In September, 1862, Mr. Ansell visited some coal-mines in the Midland district, for the purpose of ascertaining the conditions to be met, and was conducted to a portion of a pit known to be pretty tolerably charged with an explosive mixture. The gas caused a peculiarly helpless feeling to come over him, and "his head had an extraordinary light feeling"—so much so, that it occurred to him, that if his head had been made of india-rubber, he could have brought away some of the gas; in his own words, "his head appeared to be filled with fire-damp." On his return home, an india-rubber balloon his child was playing with, attracted his attention, and he thought he might turn this plaything to account; this thought was elaborated, and associated with a law just spoken of, and uppermost in his mind—namely, that of osmose, or diffusion.

Before his next visit, he had not only thought out this happy idea, but had provided himself with the simple apparatus shown in Fig. 1, consisting of an india-rubber balloon, bound round the centre with a linen band, secured in the manner shown in the woodcut, between the foot-board, F, and the moveable arm, C. By the expansion of the balloon, the arm, and a lever, D, are raised, and a spring bell, E, fixed above, liberated and set in motion.

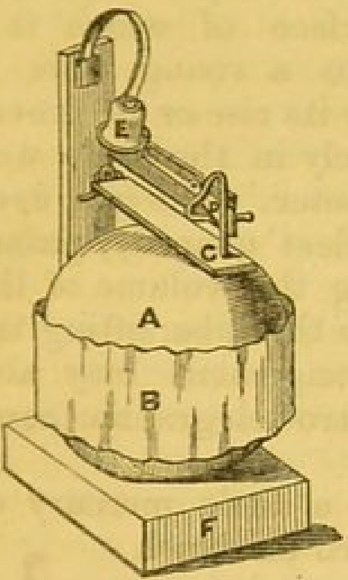

FIG: 1.

This first experiment was so near to perfection, that all subsequent improvements in the form of the apparatus partake more of the nature of scientific refinements than that of a positively necessary departure from the original conception, as may be readily seen upon comparing Fig. 1 with the latest adopted form shown in Fig. 2.

Fig. 2, *a*, is a small balloon of india-rubber, filled with atmospheric air, bound round the middle with a band of linen, to prevent lateral expansion. This is placed under the lever, *b*, resting on a stand, F, where there is a screw to adjust the bag of air to a proper height. When adjusted, the balloon presses lightly upon the lever, *b*. If this arrangement be placed in an atmosphere containing but a small percentage of carburetted hydrogen, this gas passes through the india-rubber by diffusion, and, of course, expands the balloon. In expanding this the lever is raised; and by the arrangement shown at *c*, the ratchet wheel is released, and the cord and weight, *d*, liberated; and by the fall of the latter down the pillar, a bell is rapidly and re-

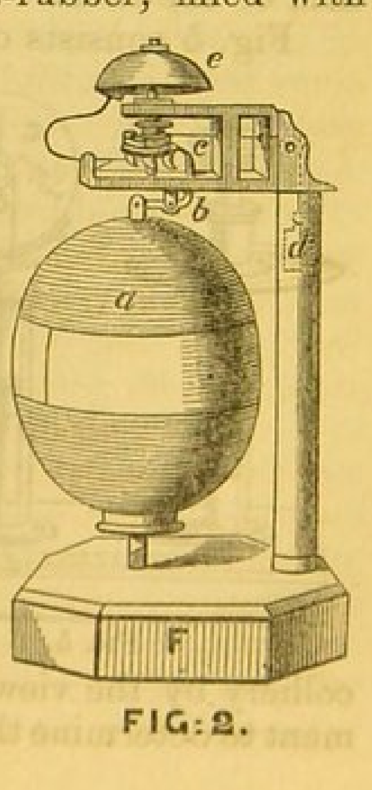

FIG: 2.

peatedly rung. By the same forms of apparatus connection may be made and broken with a voltaic battery, or a magneto-electric machine put in motion, and a telegraphic signal given at the surface of the mine, either in the office or in any convenient place.

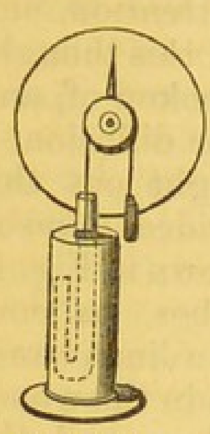
FIG: 3.

Fig. 3 is another form of instrument. A U-shaped tube, longer in one arm than in the other, and having the short arm provided with a bulb, is passed through the bottom of a porous battery cell, and cemented securely; then the open end of the cell is closed by a disk of wood, and cemented on by sealing-wax. The tube is partially filled with mercury, on the surface of which is a floating weight attached to a string, this is carried over a pulley, and by its rise or fall moves an index upon a dial, precisely in the same way as an ordinary wheel barometer. The gas, even when it exists in the smallest quantity, passes into the porous cell, and thus increasing the volume of the enclosed air, it presses the mercury up into the tube, lifting the float, and moving the index. This arrangement may also be used to ring a bell, or to establish electro-telegraphic communication.

Fig. 4 is a glass U-tube, containing a little mercury or coloured water. This is fixed upon a board on which is a scale graduated by experiment. Over one arm of the tube is fixed a porous plate. This is then carried into the colliery, and the percentage of gas in the air is shown by the rise of the fluid in the open arm of the tube.

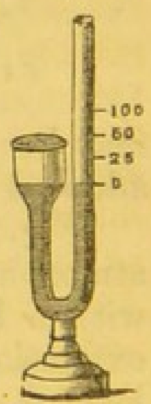
FIG: 4.

Fig. 5 consists of, A, a porous tile, secured into a glass vessel, B, which is connected with a U-tube, having some mercury in it. The arrangement is then made as in the former case, so that the index is moved the moment diffusion takes place.

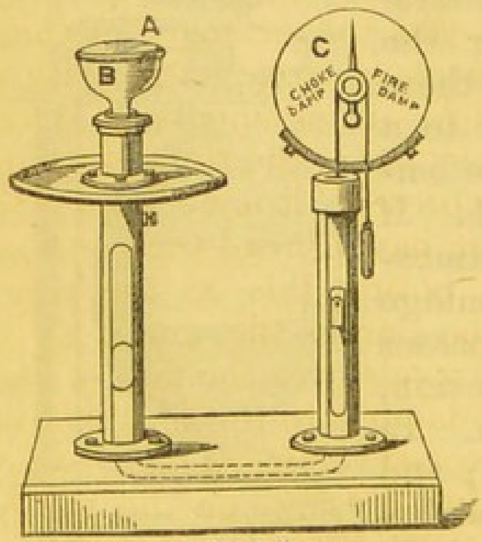

FIG. 5.

There are many other forms which might be given to this apparatus. Indeed, Mr. Ansell has completed one of a most portable description, which is about the size of an old-fashioned watch. It can, therefore, be carried into the colliery by the viewer, in his pocket, and employed at any moment to determine the amount of dangerous gas present in the air.

When diffusion has been completed, that is, when the air within and without the porous septum has become of the same character, the index retires to zero, and remains at that point until there is a change in the mixed airs or gases; but if then the air be purified, the index travels back from zero, showing purification. To restore the instrument to its normal condition, so that it will be ready for use in *any* atmosphere, nothing more is necessary than to place it for a few minutes in an atmosphere which is free from carburetted hydrogen.

If it be desired to give instant notice to the men at work, or to the people above ground from the working places, he uses a porous battery cell, which, with a small column of mercury, gives warning in a few seconds of a sudden irruption of fire-damp. The action of the instrument is so immediate, that, unless seen, it would appear to be incredible; it is, nevertheless, trustworthy and certain. Supposing the atmosphere which has caused the indication to remain unaltered, then the instrument empties itself by effusion, and the indicator returns to the original zero, and remains at that point until the mine is ventilated, when the indicator retires from zero, thus indicating the purification of the dangerous place. These remarks also apply to the pocket aneroid about to be explained.

The instruments above spoken of are intended to give warning alone; but if it be desired for the information of viewers, inspectors, owners, and others, to ascertain the amount per cent. of fire-damp present in the air of mines, Mr. Ansell varies the form of his apparatus, the most convenient form for that purpose being that of a small aneroid barometer for the waistcoat pocket. The mercurial barometer, when fitted with the necessary accompaniments, affords very satisfactory results, as also does a column of mercury not representing a barometer. As regards the aneroid barometer, he removes the brass back, and replaces it by a piece of porous tile, the ordinary biscuit-ware of Wedgewood. The instrument so completed, with a few additional and simple mechanical arrangements, may be used as an ordinary aneroid barometer; but at the time of using it, to tell the amount of fire-damp present, it is necessary to close the valve by a small screw. Then having read the point at which the barometer stands, and noting this as the zero, remove a brass cap which protects the porous tile, and if there be any fire-damp present, the hand travels over the face of the dial, because the diffusion of the fire-damp into the chamber of the aneroid barometer causes an increased volume, which, being obliged to occupy a fixed space, makes pressure on the partly exhausted chamber within that space, and thus causes the hand to move over the face of the dial, indicating unfailingly the amount per cent. of explosive gas. In round numbers, 1 per cent. of gas is equal to ·01 inch, and 10 per cent. of gas to ·10 inch on the aneroid barometer. The following results have been obtained in the presence of experienced miners by the Aneroid Indicator:—

The aneroid indicated 1·5 per cent. of fire-damp. The Davy lamp gave no indication.

The aneroid indicated 3·0 per cent. of fire-damp. The gas could be detected by the Davy lamp, which gave a small pale blue cap of flame.

The aneroid indicated 6·0 per cent. The Davy lamp did not explode, but its flame elongated greatly.

The aneroid indicated 8·0 per cent. The Davy lamp exploded feebly.

The aneroid indicated 10·0 per cent. The Davy lamp exploded fiercely.

In the words of a competent critic, "It is impossible to conceive a more refined application of science than this, nor one that will be found of greater practical utility, as indicating the presence of fire-damp in collieries, before it becomes dangerous from accumulation."

A few last words as to the grave responsibility which attaches to mine owners. That coal owners should hesitate, or decline to employ, Ansell's Fire-damp Indicator, seems to arise either from gross ignorance, or a sordid desire to secure the economical working of their mines, regardless of the lives and health of those employed within them. It appears to me that every instance of a frightful rate of mortality, such as we have seen associated with mining, is a just subject for legislative interference. Whenever evidence is adduced that the death-rate among workpeople engaged in any employment habitually exceeds a certain maximum, which the legislature would have no real difficulty in fixing, I think it only reasonable to demand that every such undertaking should be held illegal after fair notice and opportunity of amendment has been given. That those who derive their riches from the labour of the poor man should be compelled to use for his protection every means which science can devise, or, failing this, that they shall be held as legally responsible as railway companies are for the lives and limbs of those who suffer from their negligence.

While this paper has been passing through the press, another appalling accident has occured, in the Highbrook Colliery. On the 23rd January 30 men and boys were in a moment ushered into eternity by an explosion of fire-damp.

HARRILD, PRINTER, LONDON.