# THE AIR OF COAL MINES.

The sanitary examination of air has lately attracted more attention than it probably ever has at any former period. The reasons are not far to seek—the close connection now known to exist between vitiated air on the one hand and disease on the other, and the facilities now offered to medical men and others to examine by easier and more improved methods the chemical and physical conditions of air bearing on health. These have undoubtedly led to eager search and much increased information on subjects of great importance to the physician and the general public alike. We have now an abundant literature bearing on the air of houses—one-roomed, two-roomed, and four-roomed—sewers, hospitals, and schools; yet, since the late Dr Angus Smith published his valuable work on *Air and Rain*, in which there are accounts of very long and important experiments on the air of mines, I have not been able to trace any published work on the air of mines. Dr Smith's observations were made in the year 1863, and since then the methods of coal mining, including ventilation, have been completely altered, so that the air of the mine of to-day may be totally different from what he experienced. As I have been born and brought up in a mining district, the subject was one that naturally interested me, and the further fact that for ten years I have been medical attendant to several large collieries has given me facilities for studying it from what may be called chemical and pathological points of view. No reasons are given to explain why the subject should be carefully inquired into, as I presume they are self-evident.

Any one who has read Dr Smith's work will agree with me that the conditions which he found existing in mines were bad. Without entering into any details or discussion as yet into his observations, I simply shall mention that, taking carbonic acid as a test and an example of the state of air found, from 339 specimens taken he got an average of 0.785 per cent. No miner at the present time would be asked to work in such an atmosphere, nor would he if asked. From fifteen to twenty years ago mine air was bad. Improved methods of ventilation were not then in general use, and the law on the subject was not so strictly enforced as now, when not only must there be ample provision for removal of the air, but measurements must be periodically made and entered into a book for the purpose, showing the volume and velocity of the fresh air currents. The test of a candle or a lamp burning is a somewhat rough one, as it is made by the miner. When made in the manner referred to by Smith it is of more value; but the miner's method is a common one, and in "fiery" pits often such a fatal one, that some reference to it may be interesting.

In talking with miners on the subject, they have told me that about twenty years ago sometimes the air was so bad that if the lamp were unaided it would not burn; but by constant attention it might be made to give out a feeble light, and it was frequently the duty of boys, when too young or too small for harder work, to trim the lamps and keep them burning for their fathers or seniors. This is a rude test, but at the same time impresses one with the idea that the air must have been very bad. Judging from my own experiences and sensations, a very short time in a "waste" where lamps would not burn was decidedly unpleasant, and one longed for fresh air in a way hitherto unexperienced. The candle I shall yet refer to when the methods of examination are described.

*Methods of Examination.*—In a purely scientific investigation, other methods might have been selected, but the primary object of the inquiry being to ascertain the relationship between mine air and the miners' healths, some variations are made. It must be further borne in mind by those who have not attempted this sphere for research, that they must be prepared to meet with difficulties in mines which they would not experience elsewhere, such as absence of the light of day, limited space to work in, constrained position, risk, and injury to apparatus used. I am happy to say I cannot add difficulties put in my way, as, from miner to master, every facility was given me in my work. The growth of the microbes in Hesse's tubes was an object to the workmen of great interest and of exaggerated importance, as bearing on imagined diseased conditions attributed to these, in so many cases, harmless organisms.

*Temperature of Mines.*—To the meteorologist, an accurate record of the temperature of mines would doubtless be interesting, and I am not aware any have been made. The difficulties and want of facilities for making them are sufficient reasons, apart from the dangers valuable instruments are liable to in mines. The charts I have made are not valuable to the meteorologist, as they neither show the maximum nor the minimum temperatures, but show the temperatures of the wet and dry bulb thermometers at a fixed hour of the day—namely, 9 A.M. The readings were made by a highly intelligent and conscientious mine inspector, whom I instructed and supervised in the readings. The readings made above ground were made by myself at the same hour of the day, for comparison with the underground thermometers.

*Estimation of Ammonia.*—I am sorry to say this was only an attempt, and which for many reasons had to be given up. The greatest difficulty was the cumbersome apparatus, aspirator and bottles with distilled water, and the long time consumed over the process. The method followed was that of Wanklyn, Chapman, and Smith.

*Determination of Organic Matter.*—There can be no doubt that the estimation of ammonia and albuminoid ammonia is the best test we yet have in obtaining from the amount of these products the amount of organic matter, but from reasons already given this method had to be given up, and the other methods suggested were the varieties of the permanganate process. The method used by Angus Smith was this: A known quantity of air is drawn through a solution of permanganate of potassium of known strength, and the amount of permanganate undecomposed is determined by oxalic acid. This method is open to many objections—viz., complication of apparatus, time needed, and uncertainty of results. The variety of the permanganate method I used is that of Professor Carnelley, to whom I beg to express my great indebtedness for his kindness in giving me copies of his various papers on the air of schools, sewers, &c., and in which the method is described. As this method is not generally known, I shall quote a description of the process from his pamphlet—a reprint from the *Transactions of the Royal Society*, June 10th, 1886.

*Professor Carnelley's Method for determining Organic Matter.*—The principle is reduction of potassium permanganate. The amount is determined colorometrically by comparison with a standard. The solution of permanganate used is of $\frac{N}{1000}$ strength, of which 1 cc.=0.008 milligrammes of oxygen=0.0000056 litre of oxygen at 0° and 760 mm. It is usually kept $\frac{N}{10}$ strength, and diluted as required, about 50 cc. of dilute sulphuric acid being added to each litre of weak solution. The samples of air are collected in well stoppered jars of about 3.5 litres capacity. The jars are filled by pumping out the air contained by bellows, and allowing the air to be examined to flow in. 0.5 cc. of standard permanganate are run into the jar, which is then tightly stoppered and well shaken for at least five minutes. 25 cc. of the permanganate are then withdrawn by a pipette, and placed in a glass cylinder holding about 250 cc. Then 25 cc. of the standard permanganate are run into a similar cylinder; both are diluted up to about 150 cc., and allowed to stand for ten minutes, after which the tints of the cylinders are compared. Standard solution is then run into the decolorised solution from a graduated burette, until the tints of both cylinders are of the same intensity. The amount of solution added from the burette is a measure of the bleaching effected by the known volume of air on half the permanganate. This multiplied by 2 gives the amount. The results may either be expressed in terms of the number of cc. of the $\frac{N}{1000}$ bleached by one litre of air, or by the number of volumes of oxygen, required to oxidise the organic matter in, say, 1,000,000 volumes of air. Example:—25 cc. of solution from a 3.5 litre jar, in which 50 cc. had been used, required 3 cc. of the permanganate to bring it up to the standard, or the whole 50 cc. would have required $3 \times 2 = 6$ cc. This represents the number of cc. of standard permanganate bleached by $3500 - 50$

cc.=3450 cc. of air, consequently $\frac{6}{3.45}$=1.74 cc. is the bleaching effected by one litre of air. But 1 cc. of KMN04=0.0000056 litre of oxygen; ∴ 1.74 cc KMN04=0.0000056×1.74=0.0000097 litre of oxygen is required to oxidise the organic matter in 1 litre of air, or 9.7 vols. of oxygen to oxidise the organic matter in 1,000,000 vols. of air.

The method is highly ingenious, and can be rapidly performed. Some difficulty is experienced at first in matching the tints, and with some samples of mine air no amount of standard would bring the decolorised sample up to its colour. For the purposes to which Professor Carnelley applied this method, it has many things to recommend it; but for the air of mines, those objections to which the permanganate method is liable, render the test unsatisfactory as a test for organic matter; but as a test for organic matter and other impurities co-existing, it is most useful. In mines we have those various substances existing which, as well as organic matter, decolorise the permanganate solution, such as sulphuretted hydrogen, nitrous acid, sulphurous acid, &c., from the combustion of gunpowder, dynamite, and burning of lamps. The results I obtained were very high in many cases, and this I attribute to the presence of these compounds, as well as to the organic matter. Professor Carnelley refers specially to the effect of oil lamps; and in mines where many hundreds are burning during work, it is no surprise that my results are high, even from this cause alone. In Carnelley's experiments he found, before burning of lamps, oxygen per 1,000,000 vols. to be 8.7, while, after, it had risen to 18.1.

*Estimation of Carbonic Acid.*—The method adopted was that of Pettenkofer. The samples were collected in Winchester quarts; and an ordinary pair of bellows, with a tube attached to the spout long enough to reach the bottom of the bottles, was used to fill them with the air desired.

*Estimation of Oxygen.*—The method I have used is that of Franke, of Berlin, and the apparatus is associated with his name—Franke's burette. It consists of a burette graduated into 50 cc., and with a bulb on either end. One end is closed by a stopcock, the other by a plug, on which there is also a stopcock. This plug closes the bulb on one end. Between this bulb and the graduated part of the burette is a stopcock with wide bore. The burette is filled by allowing the air to be examined to stream through it. The two stopcocks are then closed. A quantity of water sufficient to fill the bulb at the end where the plug is inserted is introduced. The burette is then inserted into a tall cylinder of water, till the level of the water in the bulb and the cylinder is the same. The stopcock with wide bore is then opened, and by this means a volume of air at ordinary atmospheric pressure is obtained. The stopcock is now closed, water run out of the bulb, and an alkaline solution of pyrogallic acid is run into the bulb, sufficient to fill it completely. The plug, open, is then inserted, and stopcock closed;

then the stopcock with wide bore is opened, and the absorbing solution is allowed to run into graduated part, where it is gently shaken. The solution is then run back to the bulb, and the stopcock closed. After this the absorbing solution is run out entirely, the bulb washed out with water, finally filled with water, and the plug inserted. The burette is then placed in the tall cylinder of water, and the stopcock with wide bore opened; the height of water in the burette is read off at same water level as of cylinder, and this gives the volume of oxygen per cent. The volume is then calculated for temperature and pressure. I cannot vouch for the accuracy of the instrument, but it is very handy, and at least gives comparatively accurate results.

*Method for Estimation of Micro-Organisms.*—The method of Hesse is by far the best in present use, and this was the one used by me. Koch's own method is useful so far, but the results are not quantitative. When specimens are only desired, and not an idea of the number for a given volume of air, Koch's method is useful, likewise the method of simply exposing plates with nutrient jelly to the air to be examined, or sterilised potatoes, bread, &c.

*Hesse's Apparatus.*—This consists of a glass cylinder about 18 inches long and 22 inches in diameter. At one end a piece of india-rubber sheeting is stretched and firmly bound round the end of the glass cylinder, to prevent air sucking past it. The other end of the glass cylinder is closed with a tight-fitting plug of india-rubber, through which a glass tube passes. From this tube passes a piece of india-rubber tubing to a litre bottle filled with water, and from this bottle to a second litre bottle another tube passes; when not in action this tube is pinched off. Along the bottom of the glass cylinder are 50 cc. of nutrient jelly, solid when cooled. The cylinder rests on a tripod stand similar to those used by photographers. The nutrient jelly, india-rubber caps, tubing, cylinder, &c., are sterilised in the usual manner by steaming in a steriliser repeatedly, and the tubes with their layers of jelly are kept sufficiently long before using to see that there is nothing growing on them. When we wish to operate, the india-rubber sheeting is perforated by a heated needle or pin, making a very small hole, and the pinchcock is screwed slack; water passes slowly from the upper to the lower bottle, and when it is empty a litre of air has been supposed to pass into the cylinder, and to deposit its contained microbes. As many litres of water as desired can be run out simply by reversing the position of the bottles. When the air is very foul, one litre will be sufficient, as the colonies otherwise would be too close and run into each other. When the operation is over, sterilised india-rubber caps or pieces of cotton wool, also sterilised, are bound over the ends of the Hesse tube, and it is then placed in an incubation chamber or other suitable place. After a week or ten days the colonies may be counted. At one time the glass cylinders were used, with a coating of jelly all round the interior; but this is difficult to obtain, and in practice it is found that the microbes gravitate and settle on the layer on the bottom of the tubes. The method of Hesse is very elegant, and has many advantages; from the length of the surface of the jelly exposed, separate colonies form, often giving pure cultivations, and their growth can be studied as on a glass plate, and inoculations can readily be made in the usual manner. There are undoubtedly objections, some of which apply to all bacterial methods, and others, which apply specially to this one in particular, struck me, and I have not heard it referred to by any other observer. It is this: Although you run off a litre of water, and although the capacity of the glass cylinder is also about a litre, it does not follow that a litre of air has been drawn from the outside. The first half of the air contained in the glass cylinder may be removed, but after that, or even before it, the air from the outside and the air inside diffuse and commingle, so that a mixture of these will be aspirated out, and in consequence a litre of sample air will not be tested. There can be little doubt about this, so that as a quantitative test the method is defective. Another objection is that you cannot be sure all microbes are deposited. True, we find in practice that the colonies are found in greatest abundance at the end furthest from the aspirator, and gradually diminishing inwards. Tyndall's researches bring out this point, and if we directed the beam of an electric light into one of those tubes, doubtless we should find floating particles long after we expected. Notwithstanding these objections, the method is the best we have, and likely to remain so for some time.

*Methods of Ventilation.*—An inquiry regarding the condition of the air of mines would be incomplete without reference being made to the methods adopted to secure purity. Ventilation implies two conditions; removal of impure, and the substitution of pure, air; and those conditions may be obtained either by, first, natural methods, such as by the action of winds, changes produced by alterations in temperature or pressure, or by the diffusive tendencies of gases; secondly, artificial methods. We have such examples as the action of fires, fans, jets of steam, steam pipes, &c. The principles of these, however, are not different from natural methods. In the cases of those mines which came under my notice, the variety of artificial methods adopted was the fan method applied on the principle of propulsion. Whether the propulsion method or the vacuum method is the better I cannot decide, and this point falls more under the consideration of mining engineers. In the *Transactions of the Mining Institute of Scotland* there are interesting papers on the subject, which, however, leave one undecided on a point which is worth clearing up. For this purpose experiments were made; but as these were not made under exactly similar conditions, they are not comparable, and the tests applied were rather to ascertain the differences in volume of air passed through the mine by the propulsion and vacuum methods, as well as the power of steam engine needed in either case, than the actual chemical condition of the air of the mine under those two different processes. I would therefore suggest that to determine which method of the two is better, not only the volume but the chemical nature of the air should be determined. Of the fans ordinarily used the Guibal, Waddle, and Pelzer are most highly spoken of.

At one time fires were very commonly used, and these were either at the bottom or the top of a shaft. In the former all the heat was utilised to diminish the density of the air, and in consequence a larger volume was discharged, but there was a great danger to the mine from the fire itself; but great volumes of air can be discharged by this method, and I have read accounts of 200,000 to 400,000 cubic feet per minute being discharged by a ventilating furnace. I have not had any experience of ventilation by jets of steam or compressed air. By Act of Parliament all mines in which twenty men or upwards are employed must have two shafts. Usually one of these is used for conveying pure air into the mine and the other for removal of the impure. The former is called the downcast and the latter the upcast. If there is only one shaft, by dividing it into two by means of a partition called a mid-wall, extending from the mouth of the shaft to the bottom, a downcast and an upcast are secured, and a fan or ventilating furnace is placed in connection with one or other. The sectional area of these shafts and the working capacity of the fan determine the volume of air that can be passed into the mine either by the plenum or vacuum methods. The distribution of the air through the mine is a question of mining detail, and the completeness of this determines very much the efficiency of the system. Formerly one main gallery or passage was used to carry the air completely round the workings, but nowadays it is split up by branches to the different workings, and this is a great improvement. If from any reason the main air current was interrupted, the whole workings beyond this point were deprived of air; but by splitting up the current this great objection is removed. It is recommended that splitting of the main air current should commence as near the bottom of the downcast shaft as possible, and should finish as near the bottom of the upcast as possible, splits of air far in the interior of the workings having comparatively little effect in increasing the quantity of air (Atkinson *On Gases met with in Mines and Ventilation*).

To carry out the process of splitting, mechanical devices, such as double doors, stoppings, bratticing, are needed, which require no further reference from me, being details belonging to the duties of mining engineers. In practice the mechanical details involve a great amount of skill, and the success of all methods of ventilation depends upon the manner in which these complicated details are carried out. However efficient a ventilating fan may be, or powerful the motive power, the combined efforts may be defeated by defective stoppings or injudicious splittings, or other defects of the various ingenious methods used. I can only speak of the various mines I have personally examined, and the experience obtained so far has been expressed by the results of the numerous chemical examinations made. The conclusions drawn from these have been already stated, and showed the generally satisfactory state of air. What now remains is to show from actual measurements by the anemometer the quantity of air passed into those mines which were examined by me.

*Volume of Air measured by Anemometer.*

| | | Section Area of Course. |
|---|---|---|
| Cubic feet per minute . . | 14.345 | — |
| Moderately deep mine . . | 14.784 | — |
| ,, ,, . . | 12.730 | — |
| ,, ,, . . | 13.065 | — |
| ,, ,, . . | 9.900 | — |
| ,, ,, . . | 8.000 | — |
| ,, ,, . . | 7.590 | — |
| Deep mine . . . . | 50.400 | 16 × 7 |
| ,, . . . . . | 50.624 | — |
| ,, . . . . . | 51.520 | — |
| ,, . . . . . | 52.080 | — |

*In the following Table the effect of Underground Stables will be shown as regards $CO_2$ Oxydisable Matter and Micro-Organisms.*

| Carbonic Acid per 1000 | Oxygen per 1,000,000 | Microbes per Litre. | Remarks. |
|---|---|---|---|
| 2.175 | — | Countless | In stables |
| 0.489 | — | — | Near bottom |
| 0.610 | — | — | Past stables |
| — | — | Sixteen points | Near stables |
| — | 35 vols. | — | — |
| — | Matchless | Countless | In stables |
| 1.757 | 16 | — | Front of stables |
| 1.778 | 20 | — | Past stables |
| 2.205 | 27 | — | Front of stables |
| 2.595 | 32 | — | Past stables |
| 2.111 | 30 | 150 moulds, 50 bacteria | Stables |
| 1.454 | 10 | Numerous moulds | ,, |
| 1.675 | Matchless | 30 moulds, 30 bacteria | 1 horse in stable |
| 1.280 | 50 | — | Outside stables |
| 2.586 | Matchless | — | 24 ponies in stables |
| 2.630 | 60 | — | Ponies in stables |
| 2.209 | 45 | — | Beyond stables |
| 2.796 | 30 | — | Stables full |
| 3.025 | 60 | — | 12 ponies in stables |
| 2.404 | — | — | Stables |
| 7.000 | — | — | Stables in upcast |
| 7.8 | — | — | — |
| 1.15 | — | — | Front of stables |
| 2.4 | — | — | Past stables |

*Table showing effect of Distance.*

| Carbonic Acid per 1000 | Oxygen per 1,000,000 | Microbes per Litre. | Remarks |
|---|---|---|---|
| 0.489 | — | — | Near bottom |
| 0.610 | — | — | Further in |
| 1.085 | — | — | 150 yards in |
| 2.55 | — | — | 2000 ,, |
| 2.59 | — | — | ,, ,, |
| 1.906 | — | — | ,, ,, |
| 1.339 | — | — | ,, ,, |
| 2.112 | 34 | — | 1700 ,, |
| 2.868 | 25 | — | 1900 ,, |
| 0.964 | 11 | 25 | 100 ,, |
| 1.641 | 13 | 30 bacteria, 10 moulds | 400 ,, |
| 1.822 | 50 | — | — |
| 1.637 | 60 | — | 700 yards in |
| 3.286 | — | 20 | 1500 ,, |
| 1.604 | — | 24 | 1000 ,, |
| 1.470 | — | — | 500 ,, |
| 7.000 | — | — | Temperature, 70° F. |
| 4.209 | — | — | 1500 yards in |
| 2.00 | — | — | 1000 ,, |
| 1.187 | Matchless | — | 100 ,, |
| 1.653 | 33 | — | ,, ,, |
| 5.182 | 40 | None | Temperature, 70° F. |
| 1.656 | 33 | — | 100 yards in |
| 3.025 | 60 | — | Stables |
| 1.912 | 22 | 14 bacteria, 2 moulds | 1000 yards in |
| 1.266 | 32 | — | 100 ,, |
| — | 52 | — | 400 ,, |

It will be noticed how much the quantities vary in these tables, but the stables referred to were in four different pits, some situated in the downcast and some in the upcast shaft, and different depths in each. The effect will be seen by the increase of carbonic acid when the air is in the stables or past the stables. The organic matter is also increased by the stables, and micro-organisms I have invariably found to be enormously increased when the samples were taken in the stables. A suggestion naturally follows that, when possible, stables should be placed in the upcast shaft, as the air from the stables when in the downcast shaft must undoubtedly diffuse all over the mine, and vitiate it seriously. More attention should be directed to keep the stables as clean and sweet as possible by having impervious floors, and by the use of a liberal supply of water to sweep out impurities. More litter has been found to have a good effect in improving the air, probably by absorbing ammonia.

In the last Mines Act a clause occurs by which it is ordered that stables must be ventilated by a current of air passing round them. This, in the interests of the ponies, is satisfactory; but if the stables were better constructed and kept cleaner, the effect on the general conditions of the air would be beneficial.

These samples were taken from different mines. The shallow ones are the first on the list. The general effect will be seen in the almost uniform increase in the carbonic acid as the distance from the bottom of the downcast increases. In shallow pits the air at the bottom of the downcast is very good indeed, but in the deep pits I never found a sample as good as in a shallow one, as was to be expected. The oxydisable matter varies, but there are so many substances which act on the permanganate that the effect must be variable. The micro-organisms do not seem to follow any fixed rule, as in one very bad sample as regards $CO_2$ there were none, and the next time I made an examination of the same air I got about twenty bacterial points per litre. Stagnation of air and high temperature are favourable circumstances to their growth, but the presence of horses or men is more so.

*Table showing Relationship of $CO_2$ Oxygen per 1,000,000 Vols. and Microbes.*

| Carbonic Acid | Oxygen per 1,000,000 | Microbes per Litre |
|---|---|---|
| 1.397 | 42 | 214 moulds, 10 bacteria |
| 2.111 | 30 | 150 ,, 50 ,, |
| 5.812 | — | 63 ,, |
| — | 20 | 41 ,, |
| 1.267 | — | 26 ,, |
| 0.820 | — | 16 ,, |
| 0.811 | — | 25 ,, |
| 2.175 | — | Countless |
| 2.562 | — | 6 ,, |
| 2.303 | — | 5 ,, |
| 8.790 | — | 0 ,, |
| 2.630 | 60 | — |
| 2.209 | 45 | — |
| 2.796 | 30 | — |
| 1.187 | Matchless | — |
| 2.856 | 39 | — |
| 1.352 | 15 | — |
| 1.912 | 22 | 16 ,, |
| 5.182 | 40 | 0 ,, |
| 2.628 | 30 | 28 ,, |
| 0.964 | 11 | 25 ,, |
| 1.454 | 10 | Countless |
| 1.675 | Matchless | 30 moulds, 30 bacteria |
| 2.063 | 34 | 17 ,, |
| 1.641 | 13 | 10 ,, 30 ,, |
| 3.286 | — | 20 ,, |
| 1.604 | — | 24 ,, |
| — | Matchless | Jelly liquid |
| 6.000 | — | 5 moulds, 4 bacteria |
| 7.000 | — | 4 ,, 111 ,, |
| 7.000 | — | 5 ,, 20 ,, |
| 1.912 | 22 | 2 ,, 14 ,, |
| 2.628 | 30 | 4 ,, 24 ,, |
| 2.4 | — | 25 ,, |
| 2.517 | — | — |
| 1.358 | — | — |
| 2.872 | — | — |
| 2.832 | — | 4 moulds, 10 bacteria |
| 2.4 | — | — |
| 1.15 | — | 3 bacteria |
| 4.445 | — | 3 moulds, 20 bacteria |

In the following table the carbonic acid is alone estimated, and the samples do not represent the condition of mines, seeing that they were collected in "wastes," upcast shafts, and generally where no work was going on. The effect of barometric depression was noted on several occasions; samples were collected always at the same place in a mine, and compared with samples collected when the barometer was steady or standing high.

| Carbonic Acid | Remarks | Carbonic Acid | Remarks |
|---|---|---|---|
| 5.812 | Made in waste, no current, lamps dim | 3.286 | 1500 yards from bottom of shaft |
| 3.811 | In mine after explosion of blasting powder | 7.000 | Barometer rising after fall |
| | | 4.579 | Low barometer |
| 3.4 | Upcast shaft | 4.8 | ,, ,, |
| 3.5 | ,, ,, | 7.581 | ,, ,, |
| 4.066 | ,, ,, | 7.261 | Barometer rising after severe fall |
| 4.012 | ,, ,, | | |
| 11.050 | Taken in mine where fatal case had occurred | 6.999 | Barometer rising after severe fall |
| 3.025 | In stables with 12 ponies in | 5.182 | Barometer high |
| 5.182 | In foul shaft 1500 yards in | 20.000 | Air passing from burning seams |
| 3.377 | — | | |
| 6.000 | Bottom of upcast shaft | 80.000 | Air in mine closed for burning seam |
| 7.000 | ,, ,, | | |

*Table showing Per-centage of Oxygen.*

| Oxygen per cent. | Remarks | Oxygen per cent. | Remarks |
|---|---|---|---|
| 20.3 | Sample taken 1500 yards from downcast | 20.6 | Sample 500 yards from downcast |
| 20.2 | Sample taken 1000 yards from downcast | 20.0 | Sample 1000 yards in, temperature 70° F. |
| 20.6 | Bottom of pit | 18.0 | Stythe from burning coal |
| 20.3 | Stables in pit | 20.4 | 1500 yards from downcast |
| 20.4 | 50 yards from bottom | 19.9 | Outside stables in upcast pit |
| 20.3 | ,, ,, | 19.4 | Inside ,, ,, |
| 20.1 | Bottom of upcast shaft | 19.1 | 1000 yards in upcast, temperature 70° F. |
| 19.8 | Stables in upcast pit, temperature 68° F. | 18.9 | 1000 yards in upcast, temperature 70° F. |
| 20.4 | Sample 1500 yards from downcast | 4.0 | In this sample there was 80 per cent of $CO_2$. Seams on fire and section built up |
| 20.6 | Sample 1000 yards from downcast | | |

*Results Compared.*

| Carbonic Acid per cent. | Oxygen per 1,000,000 volumes | Oxygen per cent. | Situation | Authority |
|---|---|---|---|---|
| 0.181 | 30 | — | Shallow mines . . | — |
| 0.219 | 39 | 20.40 | Deep mines . . | — |
| — | — | 20.26 | ,, . . | Smith |
| 0.785 | — | — | — | ,, |
| 0.10 | — | — | Barracks . . . | Chaumont |
| 0.216 | — | — | Schools . . . | Endeman |
| 0.245 | — | — | ,, . . . | Weaver |
| 0.112 | — | — | One-room house . . | Carnelley |
| 0.099 | — | — | Two ,, . . | ,, |
| 0.077 | — | — | Four ,, . . | ,, |
| 0.186 | — | — | School . . . | ,, |
| 0.123 | — | — | ,, . . . | ,, |
| 0.133 | — | — | Factory . . . | ,, |

*Table showing Average of Results.*

| | Per cent. |
|---|---|
| Carbonic acid in moderately deep mines .. ... | 0.181 |
| Carbonic acid in deep mines over 100 fathoms ... ... | 0.219 |
| Oxygen in deep mines ... ... ... .. ... | 20.40 |
| Oxygen required to oxidise 1,000,000 volumes of air— | |
| Moderately deep mines ... ... ... .. | 30 |
| Deep mines ... ... ... ... ... ... | 39 |

These are exceptionally high results, and they do not represent the average condition of mines. In the case of the last estimation, which gave 80 $CO_2$ per 1000 volumes of air, the sample was taken from a mine which had been purposely closed for a month or two, and as nearly hermetically as possible, so as to keep damp off a burning seam by using up the oxygen and developing carbonic acid. In practice this method alone is found sufficient. Before the place was opened I warned the workmen of the danger of going in. Lights went out at once when introduced. No one ventured in; but still it was possible to collect the samples I got, from the fact that a current of fresh air passed up to the door which closed up the mine. The bottles were introduced through this and emptied of their contained water—the only method applicable in this case.

This sample, which shows 11.050 per 1000, had a history attached to it, as in the place where it was collected an hour before a man had succumbed to the poisonous gases given off from the burning seam referred to. The air here smelt of the combustion of coal, paraffin or naphtha being the most apparent. The quantity of carbonic acid, though large, doubtless did not cause death; but as there would be carbonic oxide as well, the cause of death was not far to seek. Lamps burnt well enough, and this would probably be assisted by some marsh gas given off from the burning coal. The effect of these gases on individuals is peculiar; some men were overcome at once, others were not very susceptible.

As I accompanied the rescue party with the hope that artificial respiration might not be too late to restore the man, I can speak from experience of the effect produced.

The action of the heart was increased—not from the excitement of the situation, I believe, as I again experienced this on a second visit—some slight oppression of breathing and giddiness, and a tightness over the forehead as long as I remained in the fonl place. There was not much else to be felt, but on reaching the fresh air there were very marked giddiness, weak, fluttering action of the heart, and almost syncope, followed by severe headache and thirst. The experience of others was similar, with pain in the loins and loss of power in the limbs, and, in those overcome, unconsciousness and vomiting on return to consciousness. These symptoms look like poisoning by carbon disulphide, and no doubt this is present in the stythe from the burning coal. In regard to the relationship that exists between barometric conditions and the presence of explosive gases in mines, it is usually stated that with a low barometer there is danger of explosions ; but there is as much with a variable condition of the barometer, and especially with a rise subsequent to a low barometer. The mines I have examined are not fiery, hence I could not trace any relationship such as the above ; and as there is no very good method of examining carburetted hydrogen accurately, I cannot speak regarding this connection. But assuming that carbonic acid gas might be used as an indicator of other gases, I have examined the quantities of carbonic acid at a fixed place in a mine under those varying conditions referred to, and I certainly found that with a low barometer, or with a rising one, I got much larger quantities present than when the barometer was steady or high. At the place I selected for testing the point, the quantity of carbonic acid usually found was from 3 to 4 volumes per 1000 with a low barometer, or with a rising one after a fall I got from 5 to 7 volumes per 1000. This part of the subject demands further attention, and which I hope yet to give it.

*Micro-Organisms in Coal Mines.*—Hesse's process is useful, both as a convenient method for collecting and estimating the number of colonies in a given quantity of air. We are also enabled to observe any special features in the growth of these colonies, and from them further to make pure cultivations when so desired. The conditions of growth in the air of mines are totally different from those found above ground—viz., the absence of sunlight, the presence of excessive moisture, and the different chemical nature of this underground atmosphere.

I have already stated that I did not find a uniform connection between impurity of air and quantity of organisms found. There seem to be various modifying circumstances contributing to these results. Where the current of air was strong there were usually few colonies found, and when the air was stagnant, colonies were abundant. The presence of men and horses has a very great influence in affecting both the numbers and kind of colonies, increasing the former and varying the kind ; where there were neither horses nor men, usually there was a crop of moulds; where men and horses were near, bacteria were found.

*General Description of Microbes found.*

A. Sample made at upcast shaft, very foul air. The forms were mainly torulæ, mycelial filaments, bacilli subtiles, and some cocci. Number of colonies, 26.

B. Bottom of downcast. Torulæ and mycelial forms alone. Number of colonies, 15.

C. Upcast ; bacilli, torulæ, and mucors.

$D^2$. Upcast in deep mine, very foul air. 5 penicillia, 4 bacteria.

$E^2$. Stables in upcast, air very bad. Moulds 10, bacteria 110.
Slides—bacilli, torulæ, and micrococci.
Cultivations—1. Orange yellow in jelly.
2. Pure white.
3. ,,
4. Yellowish.

$F^2$. Bottom of upcast, foul air. Bacteria 20, moulds 5.
Slides—micrococci, torulæ, and bacilli.

$G^2$. Stables in downcast pit. 25 penicillia glauca.

$H^2$. 1000 yards from downcast. 24 colonies.
In 10 slides ; bacilli, micrococci.

$I^2$. 1500 yards from downcast. 20 colonies.

$K^2$. 1000 yards in. 24 points.

F. Sample made in stables.
In 10 slides there were bacilli, cocci, torulæ, and mycelial forms. Colonies countless.

G. Sample taken 1000 yards from downcast. No work going on. Fans stopped.
In six slides there were mostly bacilli. 6 colonies in tube.

H. Same place as G.
In 5 slides : torulæ, micrococci, and a few bacilli. Colonies 5.

I. Sample taken in waste.
$CO_2$. 8 volumes per 1000. Lamps would scarcely burn.
Slides : mostly penicillum glaucum. Colonies 62.

J. 1000 yards from downcast. Colonies 12, bacterial moulds 8.
Slide 1 : Micrococci in clusters and chains, in jelly, pale straw colour, forming a very deep cut into jelly.
Slide 2 : Large micrococci, bright orange in colour.
Slide 3 : Micrococci, jelly liquid. Other slides : torulæ chiefly.

K. Sample near stables. 16 colonies in all, 4 of these moulds.
In 9 slides : micrococci and a few bacilli.

L. Samples in stables.
Slides : torulæ, micrococci, and bacilli.

M. Same place as L. Cocci, torulæ, and bacilli.

N. Made in stone mine, blind end, so little current two men working. Temperature 59° F. 41 colonies.
In 17 slides : bacilli, torulæ, cocci, and mycelial forms.

P. Sample 200 yards from downcast. 60 moulds, 4 bacterial growths.
Slide 1 : Long broad bacilli arranged in clusters show spores ; others, cocci and torulæ.

Q. 500 yards from downcast. 8 moulds and 4 bacteria.

R. Made in stables. Colonies countless.

S. Bottom of pit. No work going on for four days ; fan not going. Moulds 214, bacteria 10.
Slide 1 : Mycelial growth.

Slide 2 : Torulæ and bacilli, bright orange growth in tube cultivation.
Slide 3 : Pinkish growth in jelly, long bacilli at ends.
Slide 4 : Micrococci, white growth in jelly.
Slide 5 : Large micrococci, bright yellow growth in jelly.
Slide 6 : Orange growth in jelly, large micrococci.

T. Made in stables. Moulds 150, bacteria 50.
Slide 1 : Impure mycelia and micrococci.
Slide 2 : Micrococci, pearly white growth in jelly.
Slide 3 : Micrococci or torulæ, straw coloured growth in jelly.
Slide 4 : Jelly liquefying micrococci.
Slide 5 : Large micrococci, orange growth in jelly.
Slide 7 : Large bacilli like bacillus anthracis, jelly liquid.
Slide 9 : Straw coloured growth, cup-shaped and yellow in colour, micrococci.
Slide 10 : Micrococci, jelly liquid.

U. Made in stables. Moulds countless.

V. Sample opposite stables in pit. 150 fathoms deep near downcast. 25 colonies.
Slides : Bacilli and micrococci.

W. Stables of deep pit. Moulds 3, bacteria 30.
Slides : Bacilli, torulæ, and mucor growths.

X. Near downcast pit. 17 colonies.
Slides : Micrococci, torulæ, and bacilli.
Cultivations four in number.

Y. Sample 400 yards from downcast. 10 moulds, 30 bacteria.
Slides : Micrococci, torulæ.
Cultivations seven in number.

$A^1$. Sample made in *cul-de-sac* 1000 yards from downcast. Moulds 4, bacteria 24.
Slides : Nearly all micrococci.
Cultivations—1. Pearly white growth on surface, forming a ring round a central growth.
2. Delicate pink in jelly.
3. Liquefying.

$B^2$. 1000 yards from downcast. Temperature 60° F. 14 colonies. Bacilli and micrococci.

$C^2$. 1500 yards in. No growth at all.

$D^2$. Made in upcast. 5 penicillia, 4 bacteria. Micrococci.

$E^2$. Stables in upcast. Moulds 10, bacteria 110.
Slides 8 in number, showing bacilli, torulæ, and micrococci.
Cultivations—1. Impure.
2. Pure white growth in jelly, small round cocci.
3. Same as No. 2.
4. Yellow growth, cocci in clusters and chains.

$F^2$. Bottom of upcast. Bacteria 20, moulds 5.
In 10 slides : Micrococci, torulæ, and bacilli.

$H^2$. 1000 yards from downcast. 24 points.
10 slides : Mostly micrococci, some show bacilli.

$I^2$. 100 yards from bottom of downcast. 4 points.
Slides show micrococci and mycelial forms.

$K^2$. Sample in stables. 30 penicillia, 20 bacteria.
8 slides : Mostly micrococci and bacilli.

*Underground Temperature.*—I have already mentioned the plan that was adopted, and that the results are not intended to be at all strict meteorological records, but simply to show, as near as possible, the average temperature of a mine at a fixed time of the day. The thermometers, wet and dry bulb, were put in the air-way, through which the air coming from the surface had travelled 1000 yards. The observations began in September, 1887, and terminated January, 1888.

*Peculiarities of Records.*—The highest temperatures recorded were on September 9th, when 55° F. was indicated at the thermometer above ground; in the mine the temperature was 55.5°. The lowest temperature above was on December 22nd, 25°; in the mine on that day the temperature was 53°. The smallest difference between the temperatures above and below occurred on September 9th, when the temperature in the mine was only half a degree higher than above ground. The greatest difference was on December 22nd, when the temperature was 28° higher below than on the surface. The highest temperature in the mine was 55.5°. The lowest temperature in the mine was 53°, and this temperature was recorded on twenty-one consecutive days, showing an extraordinary uniformity of temperature. The greatest difference below was 2.5°. The greatest difference above in two consecutive days was 14°, while below it was only 1°. The relative humidity below varied from 93° to 100°; practically the air is nearly always saturated. This excessive humidity is certainly not desirable from a sanitary point of view; but I do not know any bad consequence to the health of the miners. The uniformity of temperature is certainly favourable; there are not the great vicissitudes of temperature as above ground, nor the biting blasts.

It is a fact well known that ponies an' horses soon improve in condition in mines; their coats shine in a way which can only occur with much grooming above ground, and which they certainly do not get below; and in spite of hard work I have known ponies to be twenty years below ground, and at a time when the ventilation was very bad and the working hours longer than now. The chart showing the whole range of temperature from September to January will be found at the end of this report.

*In the following Tables the Temperatures of Wet and Dry Bulb Thermometers on the Surface are compared with the Readings below at a Distance of about 1000 yards from Bottom of Pit.*

| Month. | Above. | | | Below. | | | Difference. | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Above. | | Below. | |
| | Dry Bulb. | Wet Bulb. | Rel. Hum. | Dry Bulb. | Wet Bulb. | Rel. Hum. | Temp. | R. H. | Temp. | R. H. |
| | ° | ° | | ° | ° | | ° | | ° | |
| Sept. 8 | 54.0 | 49.0 | 69 | 55.0 | 54.0 | 93 | ... | ... | + 1.0 | +24 |
| ,, 9 | 55.0 | 54.0 | 93 | 55.5 | 54.5 | 93 | ... | ... | + 5.0 | ... |
| ,, 10 | 48.0 | 46.3 | 86 | 55.0 | 54.0 | 93 | ... | ... | + 7.0 | + 7 |
| ,, 11 | 49.3 | 48.7 | 93 | 55.0 | 54.7 | 93 | ... | ... | + 5.7 | ... |
| ,, 12 | 49.0 | 48.0 | 93 | 55.0 | 54.2 | 93 | ... | ... | + 6.0 | ... |
| ,, 13 | 45.3 | 43.0 | 85 | 55.0 | 54.0 | 93 | ... | ... | + 9.7 | + 8 |
| ,, 14 | 49.0 | 47.5 | 86 | 55.0 | 54.0 | 93 | ... | ... | + 6.0 | + 7 |
| ,, 15 | 47.0 | 45.5 | 86 | 54.5 | 54.0 | 93 | ... | ... | + 7.5 | + 7 |
| ,, 16 | 47.7 | 46.5 | 93 | 55.0 | 54.5 | 93 | ... | ... | + 7.3 | ... |
| ,, 17 | 52.0 | 50.1 | 86 | 54.5 | 54.0 | 93 | ... | ... | + 2.5 | + 7 |
| ,, 18 | 48.3 | 46.5 | 86 | ... | ... | ... | ... | ... | ... | ... |
| ,, 19 | 49.0 | 47.0 | 86 | 54.5 | 54.0 | 93 | ... | ... | + 5.5 | + 7 |
| ,, 20 | 48.3 | 47.0 | 93 | 54.0 | 53.3 | 93 | ... | ... | + 5.7 | ... |
| ,, 21 | 49.4 | 48.5 | 93 | 54.5 | 54.0 | 93 | ... | ... | + 5.1 | ... |
| ,, 22 | 50.5 | 49.0 | 86 | 54.0 | 54.0 | 100 | ... | ... | + 3.5 | +14 |
| ,, 23 | 50.0 | 49.1 | 93 | 55.0 | 54.3 | 93 | ... | ... | + 5.0 | ... |
| ,, 24 | 48.0 | 47.5 | 86 | 54.5 | 54.3 | 93 | ... | ... | + 6.5 | + 7 |
| ,, 25 | 51.7 | 51.0 | 93 | ... | ... | ... | ... | ... | ... | ... |
| ,, 26 | 53.2 | 53.2 | 100 | 54.0 | 54.0 | 93 | ... | +7 | + 1.3 | ... |
| ,, 27 | ... | ... | ... | 54.5 | 53.5 | 93 | ... | ... | ... | ... |
| ,, 28 | 41.0 | 40.0 | 92 | 54.5 | 53.0 | 93 | ... | ... | +12.5 | + 1 |
| ,, 29 | 48.5 | 48.3 | 100 | 54.0 | 53.5 | 93 | ... | +7 | + 5.5 | ... |
| ,, 30 | 50.0 | 48.0 | 86 | 54.0 | 53.5 | 93 | ... | ... | + 4.0 | + 7 |
| Oct. 1 | 45.3 | 45.0 | 100 | 54.0 | 53.5 | 93 | ... | +7 | + 8.7 | ... |
| ,, 2 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| ,, 3 | ... | ... | ... | 54.0 | 53.7 | 100 | ... | ... | ... | ... |
| ,, 4 | 46.0 | 44.5 | 86 | 54.0 | 53.5 | 93 | ... | ... | + 8.0 | + 7 |
| ,, 5 | 46.5 | 45.3 | 93 | 54.0 | 53.5 | 93 | ... | ... | + 7.5 | ... |
| ,, 6 | 49.0 | 48.0 | 93 | 54.0 | 53.5 | 93 | ... | ... | + 5.0 | ... |
| ,, 7 | 45.0 | 44.5 | 92 | 54.0 | 53.5 | 93 | ... | ... | + 9.0 | + 1 |
| ,, 8 | 40.0 | 39.0 | 92 | 54.0 | 53.0 | 93 | ... | ... | +14.0 | + 1 |
| ,, 9 | 38.5 | 37.5 | 91 | ... | ... | ... | ... | ... | ... | ... |
| ,, 10 | ... | ... | ... | 53.5 | 53.0 | 93 | ... | ... | ... | ... |
| ,, 11 | 35.0 | 33.3 | 80 | 53.5 | 53.0 | 93 | ... | ... | +18.5 | +13 |
| ,, 12 | 34.0 | 32.0 | 79 | 53.0 | 53.0 | 98 | ... | ... | +19.0 | +14 |
| ,, 13 | 40.0 | 38.0 | 84 | 53.0 | 52.5 | 93 | ... | ... | +13.0 | + 9 |
| ,, 14 | 39.0 | 37.0 | 84 | 53.0 | 52.5 | 93 | ... | ... | +14.0 | + 9 |
| ,, 15 | 36.5 | 34.3 | 82 | 53.0 | 52.5 | 100 | ... | ... | +16.5 | +18 |
| ,, 16 | 38.0 | 36.0 | 83 | ... | ... | ... | ... | ... | ... | ... |
| ,, 17 | 36.0 | 35.0 | 91 | 54.0 | 53.0 | 93 | ... | ... | +18.0 | + 2 |
| ,, 18 | 46.7 | 46.0 | 93 | 54.0 | 53.0 | 93 | ... | ... | + 7.3 | ... |
| ,, 19 | 46.0 | 44.0 | 86 | 54.0 | 53.5 | 93 | ... | ... | + 8.0 | + 7 |
| ,, 20 | 48.8 | 46.0 | 79 | 54.0 | 53.5 | 93 | ... | ... | + 5.3 | +14 |
| ,, 21 | 36.3 | 35.0 | 91 | 54.0 | 53.0 | 93 | ... | ... | +17.7 | + 2 |
| ,, 22 | 42.0 | 40.0 | 84 | 54.0 | 53.0 | 93 | ... | ... | +12.0 | + 9 |
| ,, 23 | 48.0 | 47.5 | 100 | 54.0 | 54.0 | 100 | ... | ... | + 6.0 | ... |

| Month. | | Above. | | | Below. | | | Difference. | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Above. | | Below. | |
| | | Dry Bulb. | Wet Bulb. | Rel. Hum. | Dry Bulb. | Wet Bulb. | Rel. Hum. | Temp. | R. H. | Temp. | R. H. |
| | | ° | ° | | ° | ° | | ° | | ° | |
| Oct. | 24 | 34.0 | 31.0 | 72 | 53.0 | 52.5 | 93 | ... | ... | +19.0 | +21 |
| ,, | 25 | 33.5 | 31.0 | 78 | 53.5 | 53.0 | 93 | ... | ... | +20.0 | +15 |
| ,, | 26 | 40.0 | 37.0 | 77 | 53.0 | 53.0 | 100 | ... | ... | +13.0 | +23 |
| ,, | 27 | 49.0 | 49.0 | 100 | 54.0 | 53.0 | 93 | .. | +7 | + 5.0 | ... |
| ,, | 28 | 46.0 | 44.0 | 86 | 54.0 | 53.0 | 93 | ... | ... | + 8.0 | + 7 |
| ,, | 29 | 40.3 | 40.0 | 100 | 54.0 | 53.0 | 93 | ... | +7 | +13.7 | ... |
| ,, | 30 | 38.2 | 37.2 | 91 | ... | ... | ... | ... | ... | ... | ... |
| ,, | 31 | 40.1 | 39.9 | 100 | 54.0 | 53.0 | 93 | ... | +7 | +13.9 | ... |
| Nov. | 1 | 43.7 | 41.0 | 78 | 54.0 | 53.5 | 93 | ... | . | +10.3 | +15 |
| ,, | 2 | 43.0 | 41.5 | 84 | 54.0 | 53.0 | 93 | .. | .. | +11.0 | + 9 |
| ,, | 3 | 41.5 | 40.0 | 100 | 53.0 | 52.5 | 93 | ... | +7 | +11.5 | ... |
| ,, | 4 | 37.3 | 37.0 | 100 | 53.0 | 52.5 | 93 | ... | +7 | +15.7 | ... |
| ,, | 5 | ... | ... | ... | 54.0 | 52.0 | 93 | ... | ... | ... | ... |
| ,, | 6 | 43.0 | 43.0 | 100 | ... | ... | ... | ... | ... | ... | ... |
| ,, | 7 | 43.0 | 43.0 | 92 | 54.0 | 53.0 | 93 | ... | ... | +11.0 | + 1 |
| ,, | 8 | 44.0 | 44.0 | 100 | 54.0 | 53.0 | 93 | ... | +7 | +10.0 | ... |
| ,, | 9 | 41.1 | 41.0 | 100 | 54.0 | 53.0 | 93 | .. | +7 | +12.9 | ... |
| ,, | 10 | 36.0 | 35.0 | 91 | 54.0 | 53.0 | 93 | ... | ... | +18.0 | + 2 |
| ,, | 11 | 39.1 | 39.0 | 92 | 53.0 | 53.0 | 100 | ... | ... | +13.9 | + 8 |
| ,, | 12 | 37.5 | 36.0 | 91 | 53.0 | 53.0 | 100 | ... | ... | +15.5 | + 9 |
| ,, | 13 | 37.5 | 36.1 | 91 | ... | ... | ... | ... | ... | .. | ... |
| ,, | 14 | 34.0 | 33.0 | 89 | 54.0 | 54.0 | 93 | ... | ... | +20.0 | + 4 |
| ,, | 15 | 28.0 | 27.0 | 93 | 53.0 | 53.0 | 100 | ... | ... | +25.0 | + 7 |
| ,, | 16 | 34.0 | 33.8 | 100 | 53.0 | 53.5 | 100 | ... | ... | +19.0 | ... |
| ,, | 17 | 39.5 | 37.0 | 84 | 53.0 | 53.0 | 100 | ... | ... | +13.5 | +16 |
| ,, | 18 | 35.0 | 34.0 | 90 | 53.0 | 53.0 | 100 | ... | .. | +18.0 | +10 |
| ,, | 19 | 36.0 | 35.8 | 100 | 54.0 | 53.0 | 93 | ... | +7 | +18.0 | .. |
| ,, | 20 | 35.0 | 34.0 | 90 | 54.0 | 54.0 | 100 | ... | ... | +19.0 | +10 |
| ,, | 21 | 36.2 | 36.0 | 100 | 54.0 | 53.0 | 100 | ... | ... | +16.8 | ... |
| ,, | 22 | 39.0 | 39.0 | 100 | 53.0 | 53.0 | 100 | ... | ... | +14.0 | ... |
| ,, | 23 | 36.5 | 35.0 | 91 | 54.0 | 53.0 | 93 | ... | ... | +17.5 | + 2 |
| ,, | 24 | 34.0 | 33.5 | 100 | 53.0 | 53.0 | 100 | ... | .. | +19.0 | ... |
| ,, | 25 | 36.0 | 35.0 | 91 | 53.0 | 52.5 | 100 | ... | ... | +17.0 | + 9 |
| ,, | 26 | 48.0 | 47-0 | 93 | 53.0 | 53.0 | 100 | ... | ... | + 5.0 | + 7 |
| ,, | 27 | 40.5 | 39.0 | 100 | 53.0 | 53.0 | 100 | ... | ... | +12.5 | ... |
| ,, | 28 | 36.5 | 36.0 | 100 | 53.0 | 53.0 | 100 | ... | ... | +16.5 | ... |
| ,, | 29 | 32.0 | 31.5 | 100 | 53.0 | 53.0 | 100 | .. | ... | +21.0 | ... |
| ,, | 30 | 33.0 | 32.5 | 100 | 53.0 | 53.0 | 100 | ... | ... | +20.0 | ... |
| Dec. | 1 | 47.0 | 46.0 | 93 | 53.0 | 53.0 | 100 | ... | ... | + 6.0 | + 7 |
| ,, | 2 | 45.0 | 45.0 | 100 | 53.0 | 53.0 | 100 | ... | ... | + 8.0 | ... |
| ,, | 3 | 45.1 | 45.1 | 93 | 53.0 | 53.0 | 100 | ... | ... | + 7.9 | + 7 |
| ,, | 4 | 35.0 | 35.0 | 100 | 53.0 | 53.0 | 100 | ... | ... | +18.0 | ... |
| ,, | 5 | 35.0 | 35.0 | 100 | 53.0 | 53.0 | 100 | ... | ... | +18.0 | ... |
| ,, | 6 | 41.0 | 40.0 | 92 | 53.0 | 52.5 | 100 | ... | ... | +12.0 | + 8 |
| ,, | 7 | 31.5 | 31.0 | 100 | 53.0 | 53.0 | 100 | ... | ... | +21.5 | ... |
| ,, | 8 | 32.5 | 31.5 | 100 | 53.0 | 53.0 | 100 | ... | ... | +21.0 | ... |
| ,, | 9 | 34.0 | 34.0 | 100 | 53.0 | 53.0 | 100 | ... | ... | +19.0 | ... |
| ,, | 10 | 27.0 | ... | .. | 53.0 | 52.0 | 93 | ... | ... | +26.0 | ... |
| ,, | 11 | 25.0 | ... | ... | ... | ... | .. | .. | ... | ... | ... |
| ,, | 12 | 29.0 | ... | ... | 53.0 | 52.5 | 100 | ... | ... | +24.0 | ... |
| ,, | 13 | 40.0 | 39.0 | 92 | 53.0 | 53.0 | 100 | .. | ... | +13.0 | + 8 |
| ,, | 14 | 35.0 | 34.5 | 100 | 53.0 | 53.0 | 100 | ... | ... | +18.0 | ... |

| Month. | | Above. | | | Below. | | | Difference. | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Above. | | Below. | |
| | | Dry Bulb. | Wet Bulb. | Rel. Hum. | Dry Bulb. | Wet Bulb. | Rel. Hum. | Temp. | R. H. | Temp. | R. H. |
| | | ° | ° | | ° | ° | | ° | | ° | |
| Dec. | 15 | 36.0 | 35.0 | 91 | 53.5 | 53.0 | 100 | ... | ... | +17.5 | + 9 |
| ,, | 16 | 41.0 | 41.0 | 100 | 53.0 | 53.0 | 100 | ... | ... | +12.0 | ... |
| ,, | 17 | 37.0 | 35.0 | 83 | 53.0 | 53.0 | 100 | ... | . | +16.0 | +17 |
| ,, | 18 | ... | .. | ... | ... | ... | .. | ... | .. | ... | ... |
| ,, | 19 | 30.0 | ... | ... | 53.0 | 53.0 | 100 | ... | ... | +23.0 | ... |
| ,, | 20 | 34.0 | 33.0 | ... | 53.0 | 53.0 | 100 | .. | ... | +19.0 | ... |
| ,, | 21 | 30.0 | 30.0 | ... | 53.0 | 53.0 | 100 | ... | ... | +23.0 | .. |
| ,, | 22 | 25.0 | 25.0 | ... | 53.0 | 53.0 | 100 | ... | .. | +28.0 | ... |
| ,, | 23 | 28.0 | ... | ... | 53.0 | 53.0 | 100 | .. | ... | +25.0 | ... |
| ,, | 24 | 34.0 | 32.0 | 79 | 53.0 | 53.0 | 100 | ... | .. | +19.0 | +21 |
| ,, | 25 | ... | ... | .. | ... | ... | .. | ... | ... | ... | ... |
| ,, | 26 | 34.0 | 33.5 | 100 | 53.0 | 53.0 | 100 | ... | ... | +19.0 | ... |
| ,, | 27 | 31.5 | 31.0 | 100 | 53.0 | 53.0 | 100 | ... | ... | +21.5 | ... |
| ,, | 28 | 36.5 | 35.0 | 91 | 53.0 | 53.0 | 100 | ... | ... | +16.5 | + 9 |
| ,, | 29 | 30.0 | ... | .. | 53.0 | 53.0 | 100 | ... | ... | +23.0 | ... |
| ,, | 30 | 33.0 | 32.0 | 89 | 53.0 | 53.0 | 100 | ... | ... | +20.0 | +11 |
| ,, | 31 | 31.0 | 31.0 | ... | 53.0 | 53.0 | 100 | ... | ... | +22.0 | ... |
| Jan. | 1 | 31.5 | 31.5 | ... | .. | ... | ... | .. | ... | .. | ... |
| ,, | 2 | 29.0 | 29.0 | ... | ... | ... | ... | ... | ... | ... | ... |
| ,, | 3 | 33.0 | 32.0 | ... | ... | ... | .. | ... | ... | ... | ... |
| ,, | 4 | 46.0 | 45.0 | .. | 53.5 | 53.0 | 100 | ... | ... | + 7.5 | .. |
| ,, | 5 | 40.0 | 40.0 | 100 | 54.0 | 53.0 | 93 | ... | +7 | +14.0 | ... |
| ,, | 6 | 36.0 | 35.5 | 100 | 53.5 | 53.0 | 100 | ... | ... | +17.5 | ... |
| ,, | 7 | 40.2 | 40.0 | 100 | 54.0 | 53.5 | 100 | ... | ... | +13.8 | .. |
| ,, | 8 | 48.0 | 48.0 | 100 | ... | ... | ... | ... | ... | ... | ... |
| ,, | 9 | 47.0 | 46.8 | 100 | 54.0 | 53.5 | 100 | ... | .. | + 7.0 | ... |
| ,, | 10 | ... | ... | .. | 54.0 | 53.5 | 100 | ... | ... | .. | ... |

*In the following Tables, Readings of Wet and Dry Bulb Thermometers on Surface are compared with Readings made at the Bottom of Pit.*

| Month. | | Above. | | | Below. | | | Difference. | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Above. | | Below. | |
| | | Dry Bulb. | Wet Bulb. | Rel. Hum. | Dry Bulb. | Wet Bulb. | Rel. Hum. | Temp. | R. H. | Temp. | R. H. |
| | | ° | ° | | ° | ° | | ° | | ° | |
| Jan. | 11 | 44.0 | 43.5 | 100 | 54.0 | 53.5 | 100 | ... | ... | +10.0 | ... |
| ,, | 12 | 33.5 | 33.0 | 89 | 53.5 | 53.0 | 93 | ... | ... | +20.5 | + 4 |
| ,, | 13 | 35.0 | 34.5 | 100 | 53.5 | 53.0 | 93 | ... | +7 | +18.5 | .. |
| ,, | 14 | 35.0 | 34.5 | 100 | 54.0 | 53.5 | 100 | ... | .. | +19.0 | ... |
| ,, | 15 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| ,, | 16 | 35.0 | 34.5 | 100 | 44.5 | 44.0 | 92 | ... | +8 | + 9.5 | ... |
| ,, | 17 | 33.0 | 32.5 | 100 | 41.0 | 40.5 | 100 | .. | .. | + 8.0 | ... |
| ,, | 18 | 33.5 | 33.0 | 89 | 42.0 | 41.0 | 92 | .. | ... | + 8.5 | + 3 |
| ,, | 19 | 24.0 | 24.0 | 100 | 38.0 | 37.5 | 100 | ... | ... | +14.0 | ... |
| ,, | 20 | 32.5 | 32.0 | 89 | 40.5 | 40.0 | 92 | .. | ... | + 8.0 | + 3 |

| Month. | | Above. | | | Below. | | | Difference. | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Above. | | Below. | |
| | | Dry Bulb. | Wet Bulb. | Rel. Hum. | Dry Bulb. | Wet Bulb. | Rel. Hum. | Temp. | R. H. | Temp. | R. H. |
| | | ° | ° | | ° | ° | | ° | | ° | |
| Jan. | 21 | 42.0 | 41.0 | 92 | 44.0 | 43.5 | 100 | ... | ... | + 2.0 | + 8 |
| ,, | 22 | ... | ... | ... | ... | .. | ... | ... | .. | ... | ... |
| ,, | 23 | 44.5 | 44.0 | 92 | 47.0 | 46.5 | 100 | ... | ... | + 2.5 | + 8 |
| ,, | 24 | 46.0 | 45.0 | 93 | 48.0 | 47.5 | 100 | ... | ... | + 2.0 | + 7 |
| ,, | 25 | 47.0 | 46.0 | 93 | 48.0 | 47.5 | 100 | .. | ... | + 1.0 | + 7 |
| ,, | 26 | 38.0 | 37.0 | 91 | 45.0 | 44.0 | 92 | ... | ... | + 7.0 | + 1 |
| ,, | 27 | 33.0 | 32.0 | 89 | 42.0 | 41.0 | 92 | ... | ... | + 9.0 | + 3 |
| ,, | 28 | 28.0 | 27.0 | ... | 38.0 | 37.0 | 91 | .. | ... | +10.0 | ... |
| ,, | 29 | ... | ... | ... | ... | ... | ... | .. | | ... | ... |
| ,, | 30 | 31.0 | 30.0 | ... | 38.0 | 37.0 | 91 | ... | ... | + 7.0 | .. |
| ,, | 31 | 32.5 | 31.5 | 89 | 40.5 | 40.0 | 92 | .. | ... | + 8.0 | + 3 |
| Feb. | 1 | 29.0 | 28.0 | ... | 39.0 | 38.0 | 92 | ... | ... | +10.0 | .. |
| ,, | 2 | 31.0 | 30.0 | ... | 38.0 | 37.5 | 100 | ... | ... | + 7.0 | ... |
| ,, | 3 | 38.0 | 37.0 | 91 | 39.0 | 38.5 | 100 | ... | ... | + 1.0 | + 9 |
| ,, | 4 | 41.0 | 40.0 | 92 | 46.0 | 45.5 | 100 | ... | ... | + 5.0 | + 8 |
| ,, | 5 | ... | ... | ... | ... | .. | ... | ... | ... | ... | ... |
| ,, | 6 | 42.0 | 41.0 | 92 | 49.0 | 48.0 | 93 | ... | ... | + 7.0 | + 1 |
| ,, | 7 | 38.0 | 37.0 | 91 | 48.0 | 47.5 | 100 | ... | ... | +10.0 | + 9 |
| ,, | 8 | 44.0 | 43.0 | 92 | 49.5 | 49.0 | 93 | ... | ... | + 5.5 | + 1 |
| ,, | 9 | 38.0 | 37.0 | 91 | 45.0 | 44.5 | 100 | .. | ... | + 7.0 | + 9 |
| ,, | 10 | 35.0 | 34.0 | 90 | 44.0 | 43.5 | 100 | ... | ... | + 9.0 | +10 |
| ,, | 11 | 31.0 | 30.0 | ... | 42.0 | 41.5 | 100 | ... | ... | +11.0 | ... |
| ,, | 12 | ... | ... | ... | ... | .. | ... | ... | ... | ... | ... |
| ,, | 13 | 32.0 | 31.0 | 87 | 42.5 | 42.0 | 92 | ... | ... | +10.5 | + 5 |
| ,, | 14 | 30.0 | 29.0 | ... | 40.5 | 40.0 | 92 | ... | .. | +10.5 | ... |
| ,, | 15 | 30.0 | 29.0 | ... | 40.5 | 40.0 | 92 | ... | ... | +10.5 | ... |
| ,, | 16 | 28.0 | 27.0 | ... | 39.0 | 38.5 | 100 | ... | ... | +11.0 | +13 |
| ,, | 17 | 32.0 | 31.0 | 87 | 40.0 | 39.5 | 100 | .. | ... | + 8.0 | +13 |
| ,, | 18 | 34.0 | 32.0 | 79 | 42.5 | 42.0 | 92 | ... | ... | + 8.5 | +13 |
| ,, | 19 | 33.0 | 32.0 | 89 | 41.5 | 41.0 | 92 | ... | ... | + 8.5 | +11 |
| ,, | 20 | 33.0 | 32.0 | 89 | 42.0 | 41.5 | 100 | ... | ... | + 9.0 | +13 |
| ,, | 21 | 32.0 | 31.0 | 87 | 41.0 | 40.5 | 100 | ... | ... | + 9.0 | +13 |
| ,, | 22 | 32.0 | 31.0 | 87 | 41.0 | 40.5 | 100 | ... | ... | + 9.0 | ... |
| ,, | 23 | 31.0 | 30.0 | ... | 40.5 | 40.0 | 92 | ... | .. | + 9.5 | ... |
| ,, | 24 | 32.0 | 31.0 | 87 | 41.0 | 40.5 | 100 | ... | ... | + 9.0 | +13 |
| ,, | 25 | 28.0 | 27.0 | ... | 39.5 | 39.0 | 92 | ... | ... | +11.5 | ... |
| ,, | 26 | ... | ... | ... | ... | ... | .. | ... | ... | ... | ... |
| ,, | 27 | 37.0 | 36.0 | 91 | 46.0 | 45.5 | 100 | .. | ... | + 9.0 | + 9 |
| ,, | 28 | 36.0 | 35.0 | 91 | 45.5 | 45.0 | 93 | .. | ... | + 9.5 | + 2 |
| ,, | 29 | 34.0 | 33.0 | 89 | 44.5 | 44.0 | 92 | ... | ... | +10.5 | + 3 |
| March | 1 | 35.0 | 34.0 | 90 | 44.5 | 44.0 | 92 | ... | ... | + 9.5 | + 2 |
| ,, | 2 | 33.0 | 32.0 | 89 | 43.0 | 42.5 | 100 | ... | ... | +10.0 | +11 |
| ,, | 3 | 32.0 | 31.0 | 87 | 41.0 | 40.5 | 100 | ... | .. | + 9.0 | +13 |
| ,, | 4 | . | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| ,, | 5 | 31.0 | 30.0 | ... | 39.0 | 38.5 | 100 | ... | ... | + 8.0 | ... |
| ,, | 6 | 37.0 | 36.0 | 91 | 44.5 | 44.0 | 92 | ... | ... | + 7.5 | + 1 |
| ,, | 7 | 45.0 | 44.0 | 92 | 45.0 | 44.5 | 100 | ... | ... | .. | + 8 |
| ,, | 8 | 46.0 | 45.0 | 93 | 45.0 | 44.5 | 100 | +1 | . | ... | + 7 |
| ,, | 9 | 47.0 | 46.0 | 93 | 48.0 | 47.5 | 100 | ... | ... | + 1.0 | + 7 |
| ,, | 10 | 47.0 | 46.0 | 93 | 48.0 | 47.5 | 100 | ... | ... | + 1.0 | + 7 |
| ,, | 11 | ... | ... | ... | ... | .. | .. | ... | ... | ... | ... |
| ,, | 12 | 29.0 | 28.0 | ... | 40.5 | 40.0 | 92 | ... | ... | +11.5 | ... |

| Month. | Above. | | | Below. | | | Difference. | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Above. | | Below. | |
| | Dry Bulb. | Wet Bulb. | Rel. Hum. | Dry Bulb. | Wet Bulb. | Rel. Hum. | Temp. | R. H. | Temp. | R. H. |
| | ° | ° | | ° | ° | | ° | | ° | |
| March 13 | 31.0 | 30.0 | ... | 42.0 | 41.5 | 100 | ... | .. | +11.0 | ... |
| „ 14 | 29.0 | 28.0 | .. | 40.0 | 39.5 | 100 | ... | ... | +11.0 | ... |
| „ 15 | 29.0 | 28.0 | ... | 41.0 | 40.5 | 100 | ... | ... | +12.0 | ... |
| „ 16 | 27.0 | 26.0 | ... | 39.0 | 38.5 | 100 | ... | ... | +12.0 | ... |
| „ 17 | 26.0 | 25.0 | .. | 39.0 | 38.5 | 100 | ... | ... | +13.0 | ... |
| „ 18 | ... | .. | ... | ... | ... | ... | ... | ... | ... | ... |
| „ 19 | 35.0 | 34.0 | 90 | 41.5 | 41.0 | 92 | ... | ... | + 6.5 | + 2 |
| „ 20 | 34.0 | 33.0 | 89 | 41.0 | 40.5 | 100 | ... | ... | + 7.0 | +11 |
| „ 21 | 39.0 | 37.0 | 84 | 46.0 | 45.5 | 100 | ... | ... | + 7.0 | +16 |
| „ 22 | 40.0 | 39.0 | 92 | 47.5 | 46.0 | 93 | ... | .. | + 7.0 | + 1 |
| „ 23 | 38.0 | 37.0 | 91 | 45.0 | 44.5 | 100 | ... | ... | + 7.0 | + 9 |
| „ 24 | 41.0 | 40.0 | 92 | 46.0 | 45.5 | 100 | ... | ... | + 5.0 | + 8 |
| „ 25 | ... | .. | ... | ... | ... | ... | ... | ... | ... | ... |
| „ 26 | 40.0 | 39.0 | 92 | 44.5 | 44.0 | 92 | .. | ... | + 4.5 | + 3 |
| „ 27 | 42.0 | 41.0 | 92 | 46.0 | 45.5 | 100 | ... | ... | + 4.0 | ... |
| „ 28 | 41.0 | 40.0 | 92 | 54.0 | 43.0 | 92 | ... | ... | + 3.0 | + 8 |
| „ 29 | 43.0 | 42.0 | 92 | 45.0 | 44.5 | 100 | ... | ... | + 2.0 | + 8 |
| „ 30 | 42.0 | 41.0 | 92 | 43.0 | 42.5 | 100 | ... | ... | + 1.0 | + 8 |
| „ 31 | 41.0 | 40.0 | 92 | 42.0 | 41.5 | 100 | ... | ... | + 1.0 | + 8 |
| April 1 | ... | ... | .. | ... | ... | ... | ... | ... | ... | ... |
| „ 2 | 43.0 | 40.0 | 78 | 42.0 | 41.5 | 100 | +1 | ... | ... | +22 |
| „ 3 | 42.0 | 40.0 | 84 | 42.0 | 41.5 | 100 | ... | ... | .. | +16 |
| „ 4 | 43.0 | 41.0 | 84 | 43.0 | 42.0 | 92 | ... | ... | ... | + 8 |
| „ 5 | 45.0 | 43.0 | 85 | 43.0 | 42.5 | 100 | +2 | ... | ... | +15 |
| „ 6 | 48.0 | 47.0 | 93 | 45.0 | 44.5 | 100 | +3 | ... | ... | + 7 |
| „ 7 | 46.0 | 44.0 | 86 | 45.0 | 44.5 | 100 | +1 | ... | ... | +14 |
| „ 8 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| „ 9 | 41.0 | 39.5 | 92 | 44.0 | 43.5 | 100 | ... | ... | + 3.0 | + 8 |
| „ 10 | 45.0 | 44.0 | 92 | 46.0 | 45.5 | 100 | ... | ... | + 1.0 | + 8 |
| „ 11 | 47.0 | 43.0 | 73 | 47.0 | 46.5 | 100 | ... | ... | ... | +27 |
| „ 12 | 48.0 | 43.0 | 67 | 45.0 | 44.5 | 100 | +3 | ... | ... | +33 |
| „ 13 | 47.0 | 45.0 | 86 | 47.0 | 46.5 | 100 | ... | ... | ... | +14 |
| „ 14 | 46.0 | 44.0 | 86 | 47.0 | 46.5 | 100 | ... | ... | + 1.0 | +14 |

*Opinions regarding Miners' Occupation.*—In endeavouring to ascertain what are the opinions regarding the effect of the conditions of employment peculiar to miners, it is found that reference must be made to periods about twenty-five years back, so that these are not likely to apply to the conditions of the present time, owing to circumstances which have been already referred to.

In Sir John Simon's *Public Health Reports,* published by the Sanitary Institute of Great Britain, we have the benefit of his unrivalled experience of the causes that act in producing disease over long periods in England and Wales; and on page 37 in vol. ii. we find the following remarks on the effect of occupation on the health of miners:—"The miner, like the indoor operative, often spends his day in an ill-ventilated workplace. But the non-ventilation from which he suffers is associated in its existence and in its consequences with conditions special to the subterranean employment, and far more complex than those which belong to the non-ventilation of common workplaces. The air in which he works is air which, for his safety's sake, ought pre-eminently to be ventilated; for in most cases, not only the exhalations of human labour, but gases indigenous of the mine earth, or gases from gunpowder burnt in rock-blasting, tend incessantly to gather round him at his work as an atmosphere quite unfit for respiration." Further, the report goes on to say:—"The air in ill-ventilated mines must be very greatly more impure than the air of ill-ventilated above-ground places, so considerable must be its defect of oxygen, so considerable its excess of carbonic acid, not only must it be insufficient, often almost urgently insufficient, for healthy respiration. And the same air, besides being chemically insufficient for respiration, also carries with it into the miners' lungs more or less irritant material—material which, though the air were ever so well oxygenated, would itself tend to produce bronchitis—namely, soot, grit, and the acid fumes of combustion."

Sir John goes on to discuss the conditions of health experienced in miners: bronchitis, asthma, phthisis, and cardiac disease, with the exception—and a very important exception—of the miners of Northumberland and Durham. It was found that they did not suffer from any diseases special to their employment, or in excess of other workmen. The explanation given of these striking exceptions is that these two northern counties had good ventilation in their mines. Sir John further quotes the good effect of sufficient ventilation in some Welsh mines, where the miners were reported by the manager, by the surgeon, and by some of the men themselves, to be nearly exempt from miners' asthma. Quotations might be made of opinions given by other writers, but these are generally founded on Simon's report, and the point seems to be abundantly proved that, twenty-five years ago at any rate, the air of mines was bad, and the effect on the health of the miners was correspondingly bad.

In the succeeding tables facts of considerable importance are brought out. In the parish of Beath we have a mean death-rate from phthisis for both sexes of 1.33 for 1000 living. For males for the same year the mortality was 1.01, and for females 1.72. If occupation had any effect in causing an increased mortality in miners, then we should have expected a higher mortality amongst males than females. But the opposite is the case, and this in a population where adult males are almost entirely miners. The general condition of the parish is not at all favourable to a low mortality from phthisis, the soil being stiff clay, as a rule, and very wet, marshy in many places, and liable to be swept by cold winds, there being very little shelter either from trees or hills. The housing is also indifferent, and overcrowding prevails to a considerable extent. These conditions might be expected to lead to a higher death-rate from phthisis, even without the influence of occupation. When we compare the phthisis death-rate with other places, we find, from Farr's statistics, that in years 1850-54 there was a mean mortality from phthisis of 2.811, in 1855-57 a mortality of 2.683, and in years 1857-63 a mortality of 2.574; and in Scotland, from 1858 to 1861, a mortality of 3 per 1000, for Leith 2 per 1000, and for Glasgow 4 per 1000 living.

It will at once be seen that these rates exceed very much the death-rates from phthisis in an almost purely mining district. Although we have thus a low mortality from phthisis, of course it might be that the effect of occupation might show itself in increased deaths from other causes. A reference to other tables will show that for the same periods as already given, the mortality from all causes given in the mean was 15.79 per 1000 living, and this, of course, is a tolerably low mortality. Comparing this rate with the rate for all England for twelve periods, we find that the rate of the latter exceeds this by about 4 deaths per 1000. Coming to the last column, we have the mean age at death of miners, and the average for twelve years we find is 43.1. In the list of deaths I found that one miner died at the age of 86, one at 74, another at 73, and several at 69; and those men were miners when the conditions of occupation were much more unfavourable than those experienced at the present day.

*Deaths in Parish of Beath from Phthisis from year 1876 to 1887, according to Sex. Total Mortality. Mean Age at Death.*

| Year. | Deaths per 1000. Phthisis: Males. | Deaths per 1000. Phthisis: Females. | Deaths per 1000. Phthisis: Both Sexes. | Per 1000 Deaths. All Causes. | Miners. Mean Age Deaths. |
|---|---|---|---|---|---|
| 1876 | 1.213 | 0.991 | 1.113 | 16.6 | 43.5 |
| 1877 | 1.555 | 0.999 | 1.283 | 18.1 | 43 |
| 1878 | 0.375 | 0.461 | 0.412 | 17.6 | 37.3 |
| 1879 | 0.723 | 0.443 | 0.597 | 10.3 | 47.2 |
| 1880 | 0.349 | 1.691 | 0.956 | 15.1 | 40.5 |
| 1881 | 1.677 | 2.031 | 1.837 | 16.5 | 32.8 |
| 1882 | 1.62 | 1.592 | 1.592 | 15.5 | 53 |
| 1883 | 1.567 | 2.042 | 2.042 | 17.6 | 39.6 |
| 1884 | 0.000 | 1.147 | 1.147 | 15.4 | 51.7 |
| 1885 | 0.584 | 1.113 | 1.113 | 14.4 | 48 |
| 1886 | 1.147 | 1.698 | 1.698 | 14 | 49.7 |
| 1887 | 1.398 | 2.272 | 2.272 | 18.4 | 41.1 |
| Mean for 12 years | 1.01 | 1.72 | 1.33 | 15.79 | 43.1 |

*Average Annual Rate of Mortality to 1000 living from Phthisis in England for Three Periods.*

| Years. | Lung Diseases. | Phthisis. | Increase. |
|---|---|---|---|
| 1850-54 ... ... | 2.769 ... | 2.811 ... | — |
| 1855-57 ... ... | 3.103 ... | 2.683 ... | 0.206 |
| 1857-63 .. ... | 3.809 ... | 2.574 ... | 0.097 |

*Rate from Phthisis in Scotland.*

| Years. | Scotland. | Leith. | Glasgow. |
|---|---|---|---|
| 1858-61 ... ... | 3 ... | 2 ... | 4 |

*General Considerations and Conclusions.*—From comparison of the state of air in coal mines with that in one-room houses, schools naturally ventilated, and manufactories, it will be admitted that it is wonderfully good. The problem of mine ventilation is a difficult one, but by the use of fans it has been solved to a certain and large extent. It would not be easy, if possible, to ensure that the air of mines would be as pure as the air above ground, as so many causes are co-operating to vitiate mine air—respiration and excretions of men and horses; combustion of powder, oil, and tallow; the exudation of gases peculiar to the various minerals met with in mines; and the decomposition of wood. To keep the products of all these in moderation, a large and ever-moving volume of air must pass in and out of the mine. The sectional area of the air shaft would have to be much larger than present uses demand, if the impurities were to be reduced to the quantity found in pure air, but the present system might, to my mind, be much improved by attention to some points which have struck me in the present inquiry, and which I now venture to suggest to those concerned.

The miner spends about one-third of each day in the mine, and we may assume that about one-third of his excreta pass into the mine, and there remain as a source of pollution for an indefinite time. Horses are at all times in the mine, and their excreta are constantly polluting the air, and this cannot, even partially, be avoided. The evil produced by the former might be diminished by the use of some form of earth closet, small coal or coal dust taking the place of earth. The receptacles could be removed daily or weekly, according to circumstances. This proposal may not strike a coal owner or manager as being practicable, but it is very simple, and to a certain extent it would diminish the difficulties and the cost of ventilation. As regards pollution by horses, it is not convenient always to have stables in the upcast shaft, but for the sake of the air they should be; for the sake of the horses the stables are better in the downcast, as where the stables are in the upcast pit experience proves that they do not live so long as in the downcast. Wherever the stables are, means should be taken to purify them; impermeable floors which can be washed out with water, lime-washed walls, and careful attention to daily cleaning out of litter, would all help to solve the problem of ventilation.

Natural means should assist artificial. Thus, if the mouth of the upcast shaft were bell-shaped, and by a weather-cock arrangement made so as not to face the wind, its aspirating action would assist the fan instead of rather opposing it, as it does with the present system; and in the case of the downcast a sail or brattice might be so arranged as to promote the down current. Further, in the case of the downcast, all sources of vitiation should be removed from near its mouth, such as tar, oil, paraffin, &c., and there should be no chance of currents passing from the furnace holes down the shaft.

*The Work of the Miner and its Effects.*—Twenty years ago air was very bad in mines; ventilation was almost unknown, and the hours were very long. Nowadays the air is generally good; ventilation is efficiently carried on, and hours of work are short. The miner works hard whilst at his work, but he has short hours and many holidays. In the tables of statistics I have shown that phthisis, contrary to general opinion, is not a common disease amongst miners, and my own everyday experience for ten years in a large mining population supports this. In fact, I know of no disease peculiar to miners, or any disease in excess existing amongst miners. I have also consulted many other medical men practising amongst colliers, and their opinion coincides with my own. In conclusion, I have to state, as my belief, that the conditions connected with miners' occupation are as favourable to health as those in the occupation of any other workmen, and this opinion is borne out by the vital statistics quoted.

In Plate XVIII. is a record of temperature shown diagramatically.

The thermometers, two in number, were placed—one at the bottom of a downcast shaft, 100 fathoms deep, and the other at the bottom of the upcast, also 100 fathoms deep. The temperatures of the downcast are shown by black lines, and those of the upcast by red lines.

The points of importance to be noted are the most remarkable uniformity of the temperatures of the air in the upcast shaft, more striking even than those given where the thermometer, 1000 yards from the bottom of the downcast, is compared with the one on the surface.

The wet-bulb readings in connection with the readings of this table are not given in the chart, but the air of the upcast is almost invariably saturated.

From a mining engineer's point of view, those readings, I might suppose, are important in reference to the supposed relationship between changing conditions of temperature above ground and the occurrence of explosions below. And my experience, so far as these records go, is that variations of the temperature above ground, whether in the case of a rise or a fall, make no appreciable difference on the temperature 1000 yards from the bottom of the downcast; and in the case of the upcast, where the air has passed all through the ramifications of the underground workings, there is also no appreciable relationship. As far as atmospheric temperature is concerned, I think, therefore, it is not a factor to be considered as influencing explosions of gases.

As the air of mines in this district is also nearly always saturated, this must add to diminished risks of explosions from gases and coal dust.

This method of investigation, in my mind, offers a wide field, and an important one, and those who have facilities for such work would be rewarded by making careful barometric and thermometric observations on the surface and comparing them with similar observations made below, especially in "fiery" districts.

At some future time I propose experimenting to ascertain *what distance from the bottom of the downcast* is necessary to give practically an unvarying, or only slightly varying, temperature.

Another probably important subject, upon which we have no information, is the electrical condition of the mine atmosphere in relation to the occurrence of explosions.