Vein-matter mined in the rooms was permitted to slide from them into cars standing in the level below. More or less dense dust-clouds necessarily followed ; and when one of these clouds was sufficiently dense, if it then enveloped an open light, a flash followed. Several men were in this way burned ; but none seriously. Such flashes always produced watery blisters upon their victims. Glass lanterns offered a remedy ; but dust soon coated the glasses. Following the invariable ways of unrestrained miners, these car-loaders risked the danger of open lights. These they would place at a distance greater, as they supposed, than the dust-cloud would roll, and they would then open the chute and permit the grahamite to descend, almost flowing like water, from the room into the car below.

A few weeks after the explosion of February 9th, the writer stood near the car-loaders' lamps when a car was being loaded in level 4. He saw the dust-cloud extending unpleasantly near to the lamps, which stood upon the floor of the level, and observed it to roll onward until it reached a lamp full 30 feet distant from the column of falling grahamite. Immediately a flash followed, so brilliant and complete that one might have judged it due to gunpowder-dust disseminated through the air.

An unsuccessful attempt was made to recover the details of a grahamite dust-flash which occurred in the waters of New York harbor, perhaps in 1871. While a cargo was being discharged, a workman in the hold of the barge attempted to light his pipe by means of a match. Agitation of the grahamite had afforded the sufficiently dense dust cloud, and a flash resulted. The flash was reported to be unusually vigorous ; or more likely it was so regarded because the observers were unused to such occurrences.

The reader is now in possession of all information known to us as bearing upon the explosion of February 9th, and almost necessarily he must anticipate our conclusion as to its cause.

We are compelled to assume that the blast pulverized, and immediately decomposed into coke and inflammable gas, a great deal of the dry vein-matter ; these assumptions are imperative. The remainder follows easily from what is known of the behaviour of mixtures of marsh-gas and air.

The first effect was a burning of the air in room B, as proved by blackening of the side-walls and the adhesion to them of coke formed from the dust which had lain upon them. Expansion of heated gases could occur in two directions. Toward the open air there was but little fuel to feed the flame; and it ceased in level 6, because no dry dust was found there. Inward, every surface supplied its store of dust whereby ignition was led downward through the airway next west from room B. Once in level 4, the dust so abundant there was freely converted to gases which burned vigorously. After reaching and passing the two men 30 feet west of the airway, there was a cessation. We supposed it was due to the resistance of the air-cushion offered in that direction to the widely expanding gases. The line of least resistance was toward the open air, in which direction ignition was propagated to the portal of the level. The hot gases there encountered that abundance of air necessary to form with the mixtures which were explosive, and the result has been stated.

No explosion occurred within the mine, because the requisite volumes of air and gas were nowhere present. That is to say, there was at no point as much as eight volumes of air to one volume of explosive gas, if each had been measured at the same temperature.

Coke found within the mine was, of course, a product of destructive distillation, and it was the best of evidence as to what had occurred. Moreover, its abundance about the pit-head demonstrated that a great deal of grahamite dust had been swept along the level to the open air ; in a hot state it had been projected thence upon all opposing objects. The Executive Committee of the Company's Directory, of whom Mr. Enoch Pratt alone survives, attempted to find a remedy against the future occurrence of dust-explosions. They had the advantage of good advisers, among them Dr. D. K. Tuttle, a chemist, now of the United States Mint, at Philadelphia. But they could suggest nothing better than to dampen the dust by means of small jets of water thrown from pipes secured within the mine, a method suggested by the fire-protection pipes in the cotton-duck mills of Mr. William E. Hooper, at Woodberry, near Baltimore.

The precaution actually taken was to put no more blasts in the vein-matter, and to fire none in the side-walls, except when the mine contained no men. Even these precautions at length failed ; the east mine suffered an explosion which much injured it, and in connection with which four men assumed risks which cost them their lives.

Fig. 2 is a distorted diagram of a vertical section of the east mine, at February 25, 1873. There are no existing records from which a scale-drawing might be constructed ; and unfortunately the writer has not clear memories of the distances involved. However, we shall not be seriously in error if we accept these assumptions ; Distance between east and west portals of the two parts of the level, 1,800 feet, length of cavern in level, 3,350 feet, and height of it, 40 feet ; the distance from airway to the closed end of the level is important, perhaps, and yet the writer cannot recall what it was—it may have been 30 feet, or even somewhat more.

It should be stated, that the back of the east part of level 1 was mined-material, about 300 tons, which rested upon boards supported by timbers upheld by the two side-walls.

About the closed end of level 1, the road-way had to be widened by means of blasts in the side-walls. Shortly after 10 o'clock in the morning of the date last mentioned, a shot was ready to be fired there, near *e* of the figure.

Blasts were invariably charged and fired by the mine captain's helper, and nearly always they were discharged when the mine contained him only. But occasionally, as in this instance, when but few men were at work, noon or evening was not waited for, but those few men were notified to leave the mine while a shot was fired. So in this instance they were notified, and the notice was repeated. The two men who were mining down the back of level 3, about the point *g*, twice replied that they would take the risks of any accident. The car-loader in level 1 was ordered to leave, but instead of doing so concealed himself in some timbering (a battery) about the point *n* in the back of the level. All the above was learned later from the man who fired the shot. The four men mentioned were all who were at the time in the east mine.

After the captain's helper had ignited the fuse of the shot in the side-wall of the level near *e*, he walked east to about *s*, a point in the level at which the north side-wall had been cut away that cars might there pass each other. He passed under the car-loader who had concealed himself, and for whom he was on the lookout, but did not observe him.

A mine-explosion resulted, fully as violent as those which occur at fiery coal mines. Cars which had stood in level 1 were shot in complete wreck out of its portal, and onwards far into the valley of McFarland's Run. Some timbers took a similar course, notably an oak board which was driven through an irregular track and which landed at last upon the opposite hills of the valley, more than 500 feet distant from the level-portal.

In the ravine of Mine Run, at the portal of level 3, there was another explosion which did no little damage to the pit-head structures. At *c* a crater was formed, and from it were thrown what we judged to be 40 tons of earth and stone, A tree which had stood there was thrown at least 50 feet, and being a mountain hemlock of complete growth, it afforded some measure of the energy which had formed the crater. According to my present memories, the latter was 14 feet deep. Its figure was tha of an inverted flat cone.

The helper who fired the shot was found wandering in the level, burned and mentally deranged, but otherwise uninjured. During lucid intervals which preceded his death, he told us the story of the accident, as he alone knew it ; of his warnings to the men, and of his having seen the level filled with bluish flame as it approached him.

After several hours of labor, the car-loader was dug out from under a pile of hot vein-matter which had fallen into the level when its supporting timbers were swept away. The two men who had remained at *g*, level 3, bore no marks of injury whatever, no burns and no abrasions ; yet both of them had been killed. We judged they had died of asphyxia, or because of the pressure which had existed in the level at the moment the crater was formed.

The already-mined grahamite which had formed the back of level 1, had, in part, fallen into the level when its timber supports were swept away. It was ignited and it afforded a troublesome fire to deal with. By throwing upon it water from pipes led into the level, we were able to shovel it into cars and thus remove it from the mine.

The writer is aware that this second explosion may be explained by use of the theories now held of coal-mine explosions—that it was a result of fire-damp and dry-dust as well. There was a sort of gas-trap where ignition began, and, possibly, there was another in the roof of the cavern in level 3, even if surface water did drip at times through it. But, as fire-damp had not been observed, and as it was not essential to the explosion, it seems more rational to regard this as having been a dust-explosion simply.

In the paper published in 1873, and already cited, while relating the characteristics of grahamite, Professor Fontaine says :

"The fine dust produced by handling the mineral, is capable, when very dry, of inflaming from an open lamp. This has led to two accidents from explosion. The dry dust having caught fire in the lower levels, the gaseous products became mixed with air in the upper works and exploded."

This mention is but the briefest statement of bare fact ; yet it has this additional interest—it seems to have been the first printed announcement of a purely mine-dust explosion.

Nineteen years after the conclusions reached by us in the early summer of 1871, while reading in the library of the British Museum, the writer saw, for the first time the paper printed by Faraday and Lyell in Janurary, 1845.* It was a report made by them to the British government upon the Haswell collieries explosion of the year previous ; a report written in parts by each of them, as is clearly indicated in the text. Faraday wrote :

"In considering the extent of the fire for the moment of explosion, it is not to be supposed that fire-damp is its only fuel ; the coal-dust swept by the rush of wind and flame from the floor, roof and walls of the works would instantly take fire and burn, if there were oxygen enough in the air present to support its combustion."

They found upon the mine-timbering "coke gradually increasing in thickness," as they "neared the place of ignition ;" coke which, they believed, had resulted from partial combustion of coal-dust so abundant in the mine. The report continues :

"There is every reason to believe that much coal-gas was made from this dust in the very air of the mine itself by the flame of the fire-damp, which raised and swept it along ; and much of the carbon of this dust remained unburned only for want of air.'

Thus Faraday announced what has come to our present belief regarding fire-damp explosions in coal-mines.

In a Royal Institution lecture,* Professor Abel took for his subject the dust-explosions which then had become so numerous in wheat and rice-mills. The lecturer stated that such explosions had, "prior to 1872, appeared enveloped in mystery, until their probable cause was indicated by an Austrian observer." Referring to the paper of Faraday and Lyell, printed in 1845, the lecturer continues, "ten years later, M. de Souich, an eminent French mining-engineer, published as original" work which sustained the deductions of those writers. Professor Abel added, "Later on M. de Souich extended his inquiries into the part played by coal-dust in mine-explosions.'

After an ordinarily diligent search, made in the library of the British Museum, and in the Peabody Library at Baltimore, the present writer must say, that he failed to find records of any work done by the Austrian observer of Abel, or of M. de Souich. Several recent writers mention both of them, but nobody has cited the places of their communications.

*Nature, xxvi., 19, given April, 1882.

The Blast Furnace.*

By E. C. Potter.

Raw iron, or "pig iron" as it is commonly called, is produced by deriving from iron ores (oxides of iron) the metallic iron they contain in their composition. Stated briefly, this is accomplished by exposing the ores to the chemical action of carbonic oxidide, formed by the combustion of coal or coke, which, by taking up the oxygen of the oxides of iron, leaves the metalic iron free. In addition to this, the earthly impurities of the ores have to be dealt with in a manner to be explained later.

The apparatus in which this process is carried on is known as a blast furnace, so called because the ordinary combustion of the fuel is augmented and accelerated by forcing into the furnace by mechanical means large volumes of air. This air, delivered into the furnace under high pressure, is known as "the blast." As indicated above, the materials to be dealt with in the operation, are, first, the ore ; second, the fuel, by whose combustion we obtain the active element in the reduction of the ore, carbonic oxide (this fuel is a more or less pure carbon in the shape of charcoal, coke or anthracite coal) ; third, a material technically called a "flux" is required, whose office is to remove the earthy impurities of the ores. For this purpose limestone is usually employed. The way in which this is accomplished is rather an intricate chemical reaction, but stated as simply as possible the action is as follows :—The principal earth associated with the ore is common clay, or silicate of aluminum, as it is chemically called. This material, as everyone knows, is quite infusible, and hence impossible to remove by the mere application of heat. It is a chemical fact, however, that by the addition of lime to the silicate of aluminum, forming the double silicate of lime and aluminum, this double silicate being quite fusible and being lighter than the metallic iron floats upon its surface, and is thence drawn off in a manner to be indicated later.

This is, briefly, the office of the flux. These three materials together with the air blown into the furnace are all that are required to carry on the operation of smelting pig iron. I mention the air, as that is not by any means as insignificant a feature

*Phil. Mag., iii., xxvi., 16