XXXVI.—*A Lecture Experiment to Illustrate the Phenomena of Coal Dust Explosions.*

By T. E. THORPE, F.R.S.

THAT the dust which is incidentally formed in the operations of coal getting, and which, therefore, is to be found in greater or less quantity in all collieries, can, under certain conditions, create or augment a colliery explosion, is now very generally admitted. But all mining men are not agreed as to the particular part which the dust plays in the explosion. Some mining engineers and colliery managers are disposed to regard its action as wholly secondary: they believe that it is only in the presence of fire-damp that the coal dust can be ignited by any of the agencies which may initiate an explosion, and that even when ignited its explosive combustion is quickly arrested if the supply of fire-damp ceases. Whilst it is now allowed on all hands that air containing so small a proportion of fire-damp as to be non-explosive may, when mixed with coal dust sufficiently finely divided and containing a sufficiently large amount of combustible matter, become explosive, many engineers and coal mine inspectors of great skill and experience are of opinion that coal dust alone, that is, in the complete absence of fire-damp, may give rise to violent explosions. Indeed, it is very difficult to resist the evidence which has been accumulated by Mr. William Galloway, the Messrs. Atkinson, and others, in support of this view, which derives a *primâ facie* support from the explosions which have been known to occur in flour mills, where, as in the well-known cases of the Annapolis Mills, in America, and the Tradeston Mills, at Glasgow, sparks from the stones have ignited the fine flour or stive dust, and the buildings have, in consequence, been blown down.

Of late years a number of colliery explosions have been investigated with very special care, with the result that, when the conditions under which the catastrophes occurred are considered, it seems impossible to resist the conviction that in some, at least, of these cases, the explosion originated in air absolutely free from fire-damp, and that it was propagated by dust thrown by concussion or vibration into the air of the ways and working places of the mine. So long as dust was present, or could be thrown into the air, so long would the explosive wave continue and gather force. Indeed, there is a gradually growing belief in the mining world that the violent explosions, such as those of Abercarn, Risca, Seaham, and Penygraig, which are found to ramify throughout the pits, and to penetrate into almost every part of them, are to be attributed to coal dust rather than to fire-damp, which latter cause necessitates either the assumption of sudden and simultaneous outbursts of gas over a large area of the mine, and often, too, when there is no other ground for assuming such outbursts; or a state of ventilation such as is never possible in a well regulated pit. It is significant, too, that violent explosions of this class seldom occur in very wet pits, although such pits may, and very frequently do, contain considerable amounts of fire-damp.

It has long been recognised that a large proportion of these accidents are connected with the use of explosives, and more particularly gunpowder, employed in making roadways or in driving headings, or in getting down the coal. In the course of a year a great number of "shots" are fired in a mine, and, for the most part, of course, with impunity. But it occasionally happens, either because the shot is overcharged, or because the tamping or stemming is badly or carelessly done, that the "shot" is blown out, and the explosive spends its energy in driving out the tamping, when there is a violent concussion in the air and a loud report—a mass of flame shoots from the hole—particularly when gunpowder is employed, and the suspended dust ignites, and is consumed with great suddenness. The violent movement of the air dislodges fresh dust from the floor, the roof, and the timbers, and through this the flame is propagated, and continues so long as it is fed with the finely-divided combustible matter.

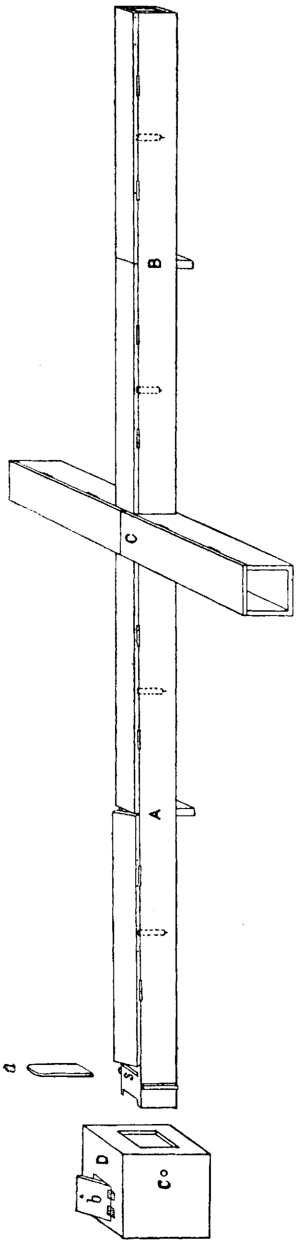
A blown out or overcharged "shot" may then produce an explosion, either by igniting an explosive mixture of gas and air, which, by the concussion, raises a cloud of dust, which, in its turn, burns with explosive violence; or the flame of the shot may directly ignite the dust without the intervention of fire-damp.

For some years I have been in the habit of illustrating the general phenomena of a dust explosion to my class by means of an apparatus devised on the principle of that adopted by Mr. Galloway in his experiments at Llwynpia.

It consists of a long, narrow box, A and B, made in two pieces, which together are 12 feet in length and 5 inches deep and 5 inches wide externally. Each length of the longer box fits into the sides of a similar box C, 6 feet long, which serves as a cross gallery, and illustrates how the explosion may travel through all parts of the pit so long as it is fed with dust. The boxes are open at both ends, and fitted at the top with lids attached by strong hinges and hasps. They are strengthened across the top by cross-pieces, and should be strongly made, best of 1-inch oak, and should be put together with screws. At one end of the longer box is a well-fitting shutter or slide *a*, working through a slot *s*, and in grooves at the sides. This end of the long box is inserted into one side of the quadrangular box D, 9 inches square, which is also fitted with a lid *b* at the top. At *c* is a small hole, through which can be inserted a caoutchouc tube from a gasometer filled with marsh gas or coal gas. A graduated bell-jar, furnished with a stopcock and suspended in a wider jar containing water, is, on the whole, the most convenient arrangement for delivering such an amount of the gas into the box as will form an explosive mixture with the air contained in it.

A small quantity of coal dust is then strewed on the bottom of the boxes, along their entire length, and the lids are fastened down by means of the hasps. To illustrate the direct action of the blown out shot, the barrel of a small pistol, charged with a blank cartridge, is inserted through the lid *b*. On firing the cartridge the dust cloud, consequent on the explosion, is ignited, and a flame, often several feet in length, is projected from the further end of the box.

To imitate the effect of a local explosion of fire-damp, the wooden shutter *a* is dropped down through the slot *s*. The quantity of gas, either marsh gas or coal gas, required to make an explosive mixture (determined by previous trial) is then delivered through the hole *c*, the lid *b* being of course closed. On drawing out the shutter *a*, and thrusting a lighted taper either through the slot *s* or through the hole *c*, the explosion instantly creates a cloud of coal dust, which, by its violent ignition, raises a continuous cloud along the whole length of the box through which the flame is propagated,


B
C
A
a
S
D
C
b

and is driven out at the further end, often to a distance of 4 or 5 feet. The success of the experiment seems to depend upon the nature of the coal dust and the character of the initial explosion. Some dusts do not readily rise by the concussion, and the flame travels only a comparatively short distance along the box. The hygrometric state of the air and of the dust also seems to affect the result. In order to obtain the dust in the proper state of subdivision, it must be sifted through very fine muslin or passed through a wire sieve made of the finest gauze.

For class demonstrations, lycopodium powder, or the spores of club moss (*Lycopodium clavatum*), used by pyrotechnists, and for the production of theatrical lightning, is a very good and cleanly substitute for coal dust, which, by its ignition, always makes a somewhat unpleasant smoke; moreover, it almost invariably happens that portions of caked or charred dust are projected on to the table or about the lecture room. The spores of the club moss have a composition more nearly approaching that of lignite than that of coal. From analyses made by Miss E. G. Hagerty in the laboratories of the Royal College of Science, 100 parts of the air-dried spores contain—

Carbon.	Hydrogen.	Nitrogen.	Oxygen.	Ash.
68·09	9·79	1·22	18·90	2·00

With this substance, all the characteristic phenomena of a dust explosion may be readily and easily observed. Indeed, the use of lycopodium powder allows of many of these phenomena to be investigated with more ease and certainty than when coal dust itself is employed. For example, the track of a colliery explosion is now traced by the peculiar manner in which the caked or charred dust is lodged or thrown on to the pit props, timbers, or other objects in the path of the explosive wave or air rush, and it is by following up these indications that the point of origin and cause of the explosion can frequently be ascertained. The charred dust is found to be lodged in greatest proportion *behind* the obstacle, and not on the face presented to the advancing air current. The cause of this is easily explained by the formation of eddies, which drive in the dust to the rear of the object. This phenomenon may be readily illustrated in the arrangement described, by inserting small pegs of wood along the bottom of the box, when it will be found, after the explosion, that the lycopodium has been swept away in a regular and symmetrical manner before the face of the peg, and heaped up at its rear.

It is well known that a colliery explosion, and, particularly, a dust explosion, increases in violence as it progresses. At its point of origin the evidences of disturbance are often comparatively few; lamps, tools, clothes, &c., are frequently found in the position in which they have been left by their owners, whereas, hundreds of yards away, the signs of havoc and destruction are on every hand; stoppings, screens, and brattices are blown down, wagons are hurled together, and, in some cases, every shred of clothing, even to the clogs or shoes, has been stripped from the bodies of the men. The gradually increasing violence of the explosion is well illustrated by the increasing areas of clear space before the pegs, as the flame travels to the end.

It has been frequently noticed that inflammable or readily ignitable substances are left untouched or unconsumed by the flame which traverses the ways of the mine: *e.g.*, the powder in the bottles or canisters used by the men, although freely exposed, and in the neighbourhood of the shot holes, is often unburnt. If little heaps of fine powder are placed at intervals along the box in the track of a dust explosion, it will be found that they are rarely fired. Small pieces of touch-paper are seldom ignited, and then only near the open end of the box where the flame is strongest. Gun-cotton, however, is ignited in all parts of the track.

It has been asserted that in a colliery explosion the rush of air is frequently so violent, and the consequent diminution of pressure in parts so great, that the occluded fire-damp may actually be drawn from the face of the coal, and thereby feed, so to say, the explosion. It would appear from the evidence published in the First Report of the Royal Commission on Explosions from Coal Dust in Mines that this so-called "Suction Theory" is held by many colliery managers. So far as I know, the only experimental proof of it hitherto advanced is cited in a paper by Mr. G. C. Greenwell, F.G.S., published in the *Transactions of the Manchester Geological Society*. I am indebted to Mr. Greenwell for a sketch of the apparatus he employed. It consisted of a box, closed at one end and open at the other, about 3 feet long. At right angles to this box, and opening into it, was a second and smaller box, fitted with a valve, on which the pressure of the outer air could act. On firing a shot at the closed end of the longer box, the violent rush of air towards the open end dragged out more or less of the air from the box placed at right angles, and the valve was driven inwards. This, of course, is what might have been expected. The lateral current acts as in the injector or in the "spray producer," or as in the case of the current of coal gas emerging from the jet of the Bunsen lamp. By means of a manometer constructed on the same principle as that by which I demonstrated some years ago (Trans., 1877, i, 627) the area of low pressure, near the jet of a Bunsen lamp, when the gas is turned on, and, in consequence of which air is driven in through the holes at the base, I have sought to gain evidence of the existence of a diminution of pressure along the sides of the gallery during the course of a dust explosion. The manometer was placed at different parts of the apparatus during successive explosions, but there was not the slightest indication of such a diminution; on the contrary, there was always a strong pressure against the sides and top of the box, exactly opposite to that which the suction theory requires.