

dicating the existence of any attraction between it and the balance, although at times we were disposed to alter our opinion on this point. We do not, however, for a moment doubt the susceptibility of all metallic bodies to become magnetic. In fact, from experiments which we have made, connected, though indirectly, with the present subject, we are quite convinced that every metal may be said to possess a certain degree of inherent magnetism.

In a future part of this paper, we shall produce important evidence of the truth of this theory, at all events, as regards brass, platinum, and silver.

[TO BE CONTINUED.]

*Observations on the Circumstances producing Ignition in Charcoal, in Atmospheric Temperatures.* By Mr. WILLIAM HADFIELD.\*

The spontaneous combustion of charcoal under certain circumstances has been long observed, though it has not excited the attention which it merits; nor would it now, perhaps, have possessed much general interest, had it not been for the serious consequences which may result from its occurrence in some situations. As large quantities of charcoal are used in gunpowder manufactories and in other works, its spontaneous combustion in many places would manifestly endanger, not only much property, but a number of lives. The subject is therefore worthy of attention, since, if the cause could be assigned, the danger might be averted.

Engaged during twenty-five years in a manufactory where charcoal is produced, I have had many opportunities of observing the phenomenon; and I have been induced, by the suggestions of a number of my friends, to lay the amount of my own experience before this Society.

Though I am aware that a very interesting article on this subject was, in January last, published by Col. Aubert in the "*Bulletin des Sciences Militaires*," I shall abstain from any further notice of it, since I wish to confine my present paper to the result of my own observation and experiments.

If twenty or thirty hundred weight of charcoal, in a state of minute division, be put together in a heap, and remain undisturbed, spontaneous combustion generally ensues. The fact has been long known, but no investigation, with the exception of that to which I have referred, has, to my knowledge, been instituted.

Spontaneous combustion does not often take place in what the manufacturers call *round charcoal*; that is to say, in fragments of considerable size; unless when large quantities are laid together, under which circumstances it is not very unusual. In this case, the phenomenon is generally ascribed by the makers to the charcoal not having been sufficiently cooled after its production. This reason is,

\* Read before a meeting of the Literary and Philosophical Society of Manchester, on November 4, 1831; and now communicated by the author.

no doubt, sometimes, but not always, correct. On the contrary, I have known charcoal, which has been freely exposed to the atmosphere for several days, enter into a state of ignition, when, though closely watched, it presented in the interval no appearance of the kind.

In one case, charcoal was loaded in Manchester, and conveyed by a cart to the distance of twenty miles. No combustion appeared during the loading, nor could the carter, though he carefully examined, perceive any indication of it, when, at eleven o'clock, he left it for the night. At five o'clock on the following morning, however, he was called up to save his cart, which he found on fire, and nearly consumed.

This charcoal had been made three days before the accident. Care had been taken that it should be sufficiently cool before it was loaded, as a similar event had previously occurred to the same parties, who ascribed it to the charcoal being too new, when, as they conceived, fire lurked in it unextinguished.

These two instances may, I should think, be accounted for in the following manner:—

When large quantities of charcoal, as in the first example, are laid together, it is evident that the lower parts must be exposed to pressure, and, by the motion of the cart, to friction from the parts above; in this way, therefore, a portion of the charcoal is pulverized, forming a compact mass at the bottom, where it enters into spontaneous combustion.

In the second instance, pressure and friction had still greater influence. The carter, while he was loading, beat down the charcoal with a large hammer, to force it into a smaller compass. Conveyed for twenty miles in a cart, the pieces would rub against each other, and the finer parts would be shaken to a compact mass; and possibly the friction might in this case particularly, produce a degree of heat which would promote the ignition.

Before I proceed to an account of my own direct experiments, I will describe here another instance of spontaneous combustion which occurred casually. About 2000 lbs. weight of charcoal were loaded at Cornbrook, in the cart of Messrs. Williamson & Co., powder-manufacturers of Fernelee, near Buxton. The charcoal had been made several days before, and had lain freely exposed to the open air. No indications of combustion could be perceived. After being taken out of the cart at Fernelee, it was left for the night, and the next day finely pulverized, as a preparation for making gunpowder. It was then thrown into a heap; and no appearance of a tendency to ignite ensued. This was on the Saturday evening; and on Sunday, the building which contained it was observed to be on fire. The fire must have commenced with the charcoal, as every other source of heat was carefully excluded, on account of the gunpowder manufactory.

These, and a number of other accidents which have arisen from the same cause, united with the opportunities which I have possessed

as a manufacturer of charcoal, have led me to take particular interest in the subject.

Colonel Aubert's paper, which I have already alluded to, and an abridged translation of which appeared in Dr. Brewster's Journal for April last, 1831, placed the subject in so striking a point of view, that I came to the determination of making, for my own satisfaction, a few experiments, which I shall proceed to describe.

*Exp't. 1.*—120 pounds of charcoal, slightly pulverized, were put into a flour barrel, and a leaden tube, of an inch and a half in diameter, and fourteen inches long, inserted in the middle, to hold a thermometer. The temperature of the charcoal when put into the barrel was sixty degrees. In two days the charcoal acquired a temperature of seventy degrees; from that time the temperature gradually diminished until, in two days more, it was reduced again to sixty degrees,—the temperature of the surrounding atmosphere. This charcoal was rather old, having been made several weeks, and afterwards freely exposed to the open air.

*Exp't. 2.*—120 pounds of fresh charcoal, pulverized as before, were put into the vessel used in the preceding experiment. The charcoal was then at 70°, and the surrounding air at 62°. In twenty-four hours it had acquired a temperature of 90°; in thirty-six hours, of 110°; and in forty-eight hours more it was down to 70°, as at the commencement.

*Exp't. 3.*—The same quantity of charcoal was taken as in the foregoing experiments: it was quite fresh, and ground into coarse powder. In thirty-six hours the temperature was 130°; it then gradually declined to 70°, when the experiment was given up.

From the preceding experiments I was satisfied that spontaneous combustion would not take place in so small a quantity. I therefore determined to make the experiment upon a larger scale.

*Exp't. 4.*—10 cwt. of new charcoal was finely ground, and put into a hogshead, with a thermometer placed, as before, in a leaden pipe. Several holes were bored in the sides of the hogshead to admit the air. The charcoal, when ground, was 65°; and particular care was taken in examining the charcoal, to see that it was free from ignition. It was put into the hogshead at about ten o'clock in the morning, and at night, its temperature had risen to 90°; the following morning, to 150°; and in the afternoon of the second day, the thermometer stood at 180°.

I was surprised to find at this time that combustion had taken place at about five or six inches from the surface, and about the same distance from the leaden pipe which contained the thermometer, though the temperature, as indicated by the thermometer, was only 180° or 190°.

It may perhaps be proper to remark, that the combustion always takes place *near* to the surface; or, if small charcoal be laid against a wall, the combustion generally begins either at the surface, or close to the wall.

On the 13th of October, 1831, small charcoal was thrown into a heap, which covered about ten feet square, was about four feet deep,

and contained from two to three tons in weight. In three days the temperature had increased to 90°, though it was at first only 57°, being the same as that of the air. On the 19th, it was 150°, and on the 20th, combustion had occurred in several places. Water was thrown upon it, and the combustion was, to all appearance, effectually extinguished; yet, on the 21st, it was again observed to be burning in different parts; and it continued to burn until it was removed and formed into smaller heaps.

The last experiment was the most satisfactory one which has ever come under my notice. The charcoal had been made for at least ten or twelve days before it was put together; and had been lying, during the interval, in small heaps freely exposed in the open air.

I am not aware that any experiment has been made to ascertain the effect of the exposure of the charcoal to pure oxygen gas. A bell glass, of the capacity of two quarts, was filled with oxygen gas previously freed from carbonic acid by washing with lime water. In this vessel was placed a glass dish, containing an ounce of finely pulverized charcoal. The charcoal was left to stand in the oxygen for twenty-four hours, and at the expiration of that time, no trace of carbonic acid was to be found on passing the remaining gas through lime water.

This experiment was three times performed in the same manner, and with precisely the same result.

I have here given a brief and simple statement of the observations and experiments which I have yet made upon this curious and interesting subject. The spontaneous combustion of charcoal is, I apprehend, now fully established: and I have endeavoured, to the best of my ability, to determine some of the circumstances under which it takes place. I have abstained from any theoretical speculations; contented, for the present, to have related the facts which experiments alone have elicited. If in future any new facts should present themselves, I shall be happy to submit them to the Society.

[*Phil. Mag.*

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*Pressure of the Ocean.*

In those accustomed to the Greenland whale fishery, the immense pressure of the ocean cannot but have excited much astonishment and curiosity. In the common method of capturing whales, it is customary to strike them, at first, by a harpoon, an instrument well known to the sailors, with a stock or handle of fir, ash, or hickory, with a line of a very considerable length attached to it; and as soon as struck, the whale generally descends, nearly as quick as a bird, to a very great depth, taking the harpoon along with him, buried to the depth of twelve or eighteen inches in his body, while the other end of the line is particularly coiled in the boat, and veered out by the harpooner with much caution and dexterity. It sometimes happens that the whole of the first boat's line, though no less than 1080 fathoms long, will be taken under water in a very few minutes; and