XXXIX. Experiments and observations on the manufacture of malleable iron directly from the ore

D. Mushet Esq.

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21. To discover in what state (with respect to electricity) the vapour was, I used the apparatus represented by the annexed sketch, of which the upright A B is of glass covered with sealing-wax, and all the rest, except the bottle of the electrometer, is of metal. In thirteen trials with cinders of pit-coal, the electrometer diverged P. seven times; four times it opened and closed again before I could determine which state was produced, and twice it did not diverge at all.

22. In seven trials with marble, the electrometer diverged N. three times; three times it lost all its divergence before I could determine in which state it diverged, and once it did not diverge at all.

In the two last experiments, the electrometer retained its divergence so short a time, that I was obliged to hold an excited tube in one hand, while I dropped the hot substance into the water with the other, to be ready in time to determine the state produced by the vapour.

XXXIX. *Experiments and Observations on the Manufacture of Malleable Iron directly from the Ore.* By D. MUSHET, Esq. of the Calder Iron Works *.

IN a former communication I took occasion to remark that a variety of processes had been followed out, endeavouring to form a good quality of bar iron with coak-pigs and pit-coal; but as these had been attended with little or no alteration of principle, the results had been nearly similar. In no case has an uniform quality of bar iron been produced, able to cope for all uses with the superior marks of Sweden and Russia.

At this day, assisted by a variety of facts chemical and philosophical, we yet remain in comparative ignorance of what constitutes the real difference in point of quality betwixt home-made iron and that imported from foreign markets. We acknowledge with pain and humiliation our dependence on other countries for our steel-iron, and it is with regret that we see every industrious exertion made to obviate this dependence foiled by the nature of our fuel, or the defective qualities of our ores.

Those who have voluntarily made an offer of their time and abilities for the service of their country, in promoting a thorough knowledge of the principles of our manufactures, could not engage in a subject fraught with more important

* Communicated by the Author.

consequences. An accurate chemical analysis of the various states and qualities of British manufactured iron, accompanied by a similar development of the component parts of the foreign fabrics, would prove an interesting contrast, and could not fail ultimately of producing infinite advantage to that department of labour.

I shall not, at present, enter into an investigation of the probable reasons which constitute this difference, but confine myself to a succinct account of several processes in which I have obtained malleable iron, often superior to the common run of British manufacture. In contemplating these manipulations followed out in the large way, I uniformly found that, although some fabrics possessed comparative excellence, yet that all were deficient in obtaining a quality of iron equal in appearance and fracture to the foreign.

In all these processes it was evident that if the contact of pit-coal, considered as a more impure fuel than wood, was hurtful to the quality of the iron, then all our bar-iron would be so injured, as all of it is manufactured either in contact with such fuel, or the flame of it, or both. The point therefore wished to be gained was the making of bar-iron without bringing the metal, while in fusion, in contact either with the flame of pit-coal, or with the ignited coaks. My first crude attempt was in 1794 with crucibles and roasted ironstone. I conceived that by introducing just as much charcoal of wood as would remove the oxygen of the ore, that malleable iron would be the result. Experiment, in some measure, justified this conjecture: but a want of uniformity in the result proved the fallacy of this mode of operating. When the temperature was moderately raised, I found the iron partially separated, and, in a malleable state, entangled amongst the earths of the ore: but, when a higher degree of heat was brought on, the greatest part of the iron was found precipitated in the form of a button. The iron in this state was malleable: but so excessively red-short as to be incapable of drawing at any shade of heat beyond faint red.

In varying these experiments, and using a greater proportion of charcoal than usual, I was surprised to find, that after a long and violent heat no part of the iron had entered into fusion. The pieces of iron-stone were firmly connected together, possessed of the original acuteness of angle and fracture. Their appearance and surface was dark and metallic, and, upon attempting to part them, I found them attached to each other by a species of metallic fibre, which twisted repeatedly before breaking. This was a species of welding I had never before witnessed. I found the whole mass sufficiently

ciently metallic upon the surface to receive a considerable degree of polish from a file. The interior of each piece, from the want of a sufficient dose of heat, remained in a soft, easily pulverised form, perfectly magnetic, and burning with great rapidity when strewed in the flame.

The apparent advantages which seemed to result from this chance discovery were sufficient to induce me to perform, during the course of three or four years, several hundred experiments. In the prosecution of this subject, I soon abandoned the use of iron-stones. It was found requisite to use them in a roasted state; and even afterwards, when heated in contact with charcoal for three or four days, it was with the greatest difficulty that the process of malleability could be made to penetrate to the centre without a general and premature fusion, which was always carefully to be avoided. When raw iron-stone was used, it was difficult to prevent it from entering into fusion, and separating its iron in the state of minute globules of crude iron. Having thus satisfied myself of the precarious results obtained in this process by the use of iron-stones, I had recourse to Cumberland ore, as a fit substitute, and my expectations in it were not disappointed.

I shall simply state the methods which I ultimately followed to produce bar-iron in this process with the use of pit-coal and charcoal of wood. Having prepared a small furnace with an oblong cavity, surrounded with a sufficient number of holes to admit the heat all round, I introduced 50 to 60 lbs. of Cumberland iron ore reduced to pieces of nearly 3 ounces weight each. This was mixed with a sufficient quantity of clean dust produced in the charring of coal. The ore was surrounded by a layer nearly $2\frac{1}{2}$ inches thick, and this last of all was covered with a layer of moist sand 2 to 3 inches thick. The fire was maintained at a temperature of nearly 100° of Wedgwood for 36 to 48 hours, according to circumstances. It was then allowed to cool gradually. Upon examination, the pieces of ore were frequently found attached to each other so firmly as to require considerable force to part them. They filed, and were, when the cementation was continued long enough, malleable throughout. The ore, thus prepared, was piled up in a flat broad shallow crucible with a loose top, and placed in a furnace heated with the flame of pit-coal. A welding heat was brought on the whole mass, which was then carried to the hammer: the first blow destroyed the crucible, and the ore was shingled into a bloom at the first heat.

In this way excellent iron was produced. Its fracture was
light

light blue, fibrous, and tearing considerably in groups. It possessed, however, a slight degree of red-shortness when very highly heated. It formed with equal facility horse-shoes and nails of the most delicate structure. The produce of the raw ore never exceeded 47 per cent., and commonly was from 43 to 45. Iron of a more pure fracture was obtained by piling the ore upon a flat cake of fire-clay or sand-stone. As the welding heat penetrated the mass, part of the earth and unmetallized particles of iron were reduced into fusion, and run off into the furnace. The produce, however, in iron was reduced as low as 37 per cent. This reduction of metal, no doubt, arose from the greater surface exposed in this way than when the balling pot was used.

To obviate this, and, at the same time, insure an equal quality of iron, the piles were heated in the same furnace with the gas of coaks, and the flue of the furnace nearly shut up; so that the circulation of air was much smaller, and the heat, though equally great, yet more attenuated. This produced a better quality of iron than any of the former ways, but at a greater expense of fuel.

However suitable this iron was for the common uses of the smithy, it was found to form but a very indifferent quality of steel by cementation. The whole of it became in some degree laminated, and incapable of standing great fatigue; and the red-shortness, which before faintly marked the bar iron, was now considerably increased when in the state of steel.

In varying this process of making bar iron, quantities of the prepared ore were thrown upon the top of a small finery fire, charged with soft coal coak, and sunk to the bottom. The metallic mass was found connected, and so much purified as to afford iron of a clear fracture, but the produce was diminished to 28 and 30 per cent. from raw ore.

The same ore, however, sunk in a small fire of wood charcoal, yielded a very superior quality of the metal to any of the former. In point of quality and fracture, it was deemed no way inferior to many of the best Swedish marks. Still, however, it must not be denied, that this iron formed comparatively but an inferior quality of steel. In this state I left this process for making bar iron, and have not yet found time nor sufficient opportunity to resume it. Of late years I understand a process, somewhat similar, has been established near Whitehaven, in the neighbourhood of the Cumberland iron-mines, but abandoned, not because the quality of iron was inferior, but I believe from a want of economy in the process itself.

A thousand unforeseen difficulties occur in striking out a
new

new line of manufacture, before a good quality of product is obtained. These are seldom diminished, but often increased, in transferring it from the scale of experiment to that of manufacture.

In the present process followed out at the bar-iron forges in this country, the greatest drawback upon the profits and correctness of the business is the immense loss of metal. This is called waste, and it is generally believed that the more the waste the better the quality of the resulting iron. This circumstance I conceive is owing to the following facts—the combustibility of the metal, the high temperature requisite, and the tedious length of the process. The puddling process invented by Cortes avowed a degree of simplicity, which promised to lessen the waste by diminishing the variety of operations, and the length of the exposure. Experience however has proved, that, in general, what was gained in weight was more than lost by the inferior quality of the iron produced.

With a view to produce a quality of iron from coak pig equal or superior to what is obtained in the best processes now in use, it occurred to me that an operation which would unite the properties of the finery fire and of the puddling furnace would be productive of a good quality of iron, and with little comparative loss. With this view a small furnace was contrived, somewhat similar in shape to an iron-founder's air furnace. The depth of the grates below what is called the bridge of the furnace was more in proportion. A shallow cavity was formed in the middle of the furnace with sand, about two inches deep, fifteen inches long, and eight broad. The furnace was heated to a bright white heat with raw pit-coal: a small door was then opened, and nearly 84 lbs. of fragments of white crude iron introduced. The grates of the furnace were then charged with coaks, and a semifusing heat brought on, and continued for ten hours after. During this operation the metal continued to boil, and discharge a blue vapour, frequently accompanied with hissing explosions. At last, when the metal exhibited no further signs of ebullition, nor of fusion, the fire was allowed to die away. When cold, I found the whole, without stirring or agitation, resolved into a mass of malleable iron, which, even in this state, was broken with great difficulty. The lump, or plate, was divided into three pieces, one of which was drawn into a stout bar, and weighed 18 lbs. The quality of this iron was excellent for every purpose, steel-making excepted. In this process it disjoined, and formed laminæ; which rendered it unfit for any steel purpose. This experiment was frequently

quently repeated with similar results : but, from several circumstances not here necessary to be mentioned, I never ascertained the exact loss sustained in the operations. I am confident, however, that it would not amount to more than half what is experienced in the common processes.

I offer this slight sketch, as I did the former, merely as an outline of an operation, the perfection of which might be attended with great advantages, but which would previously require a considerable portion of time, and many experiments, to establish.

XL. *An Essay on Longevity.* By Sir JOHN SINCLAIR, Bart.

[Continued from p. 172.]

APPENDIX.

No. 1.

THE preceding observations are only intended as a basis, for the purpose of obtaining the additional facts and observations which are necessary to elucidate so important an inquiry. It is particularly requested, therefore, that the following questions may be answered with as much minuteness and accuracy as circumstances will admit of.

Questions for the consideration of those intelligent persons by whom this Paper may be perused :—

1. What is the effect of the climate in which you reside, on the health and longevity of the human race ?
2. What form is reckoned most conducive to health and longevity ?
3. 's it found, that being descended from young and from healthy parents, is essential for good health and old age ?
4. Is it found, that health and old age depend much on the disposition or temper of the individual ?
5. Is there any perceptible difference in consequence of situation of life ?
6. What professions are reckoned favourable to longevity or otherwise ?
7. Is exercise or moderate labour found necessary for preserving health and long life ?
8. Have the long-lived in general been in the marriage-state ?
9. Have the greatest proportion of the long-lived consisted of males or females ?

10. Have