From the Author

ON

THE PAST AND PRESENT

OF

IRON SMELTING.

BY

ST. JOHN VINCENT DAY, C.E., F.R.S.E.,

FELLOW OF THE ROYAL SCOTTISH SOCIETY OF ARTS, MEMBER OF THE INSTITUTION OF MECHANICAL ENGINEERS, MEMBER OF THE INSTITUTION OF ENGINEERS IN SCOTLAND, MEMBER OF THE IRON AND STEEL INSTITUTE, HON. LIBRARIAN PHILOSOPHICAL SOCIETY OF GLASGOW.

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ON THE

PAST AND PRESENT OF IRON SMELTING.

Part I.

(*a.*) *Preliminary Remarks.*

As to the importance of the position which pig iron occupies in the list of our manufactures, it were idle to urge anything in explanation to a society located in Glasgow. When we consider that in 1871 no less than 16,859,063 tons of iron ores were smelted in Great Britain alone, from which was produced 6,627,179 tons of pig iron, representing a money value at the works of £16,667,947,* and which for the corresponding period we have just passed through, must by reason of an unprecedented demand for the material itself, and at unprecedented prices, be greatly increased; it will, I venture to hope, be readily admitted that our time may be profitably spent in considering the steps by which a manufacture, in former years carried on very much in the dark, has at length been reduced by the conjoint labour of many to *almost* a scientific exactitude. To say that iron smelting has yet been completely reduced to a science would be nothing other than pretence; nevertheless, that with a given furnace, ore, fuel, flux, and blast, we can estimate within tolerably narrow limits the quality and quantity of the product. Yet there are numerous points in the true understanding of what takes place in the blast furnace which are still enshrined in the region of uncertainty.

Within the last forty years, it may be said that iron smelting has been becoming by slow degrees to be scientifically understood, since Mushet and Clark in our own country, as well as several French and German physicists, have devoted their energies to the solution of various inquiries wherewith the subject is entangled; but since 1846, when the first furnace was built at the Walker Works, by

* Mineral Statistics, 1871.

Mr. I. Lowthian Bell, for smelting the Cleveland iron-stone,* and several more iron-making districts, with furnaces of colossal dimensions, have sprung up, the most important investigations, so far at least as our own country is concerned, have been carried out, the general results of which have led to improvements in practice, whereby the fuel required for smelting has been reduced by about 30 per cent.—this being directly due to operating with a larger bulk and higher column of materials at a time; utilizing the waste gases for heating the blast and generating steam for the blowing engines; and to a greatly elevated blast temperature.

No argument can be necessary to shew why it is important, in dealing with the subject of this investigation, to attack it at the very foundation; for that must be self-evident to any one whom it may concern to understand it, and as certain special reasons which, I trust, will clearly appear in the sequel, seem to render it desirable to consider briefly some information which comes to us from remote past ages, it may not, I hope, be considered tedious nor out of place if, at the commencement of this record, I dwell somewhat briefly on a few features in the history of the subject.

Any attempt at elucidating the course through which the modern gigantic operations of iron-smelting have been reached involves at once the history of the manufacture of cast iron—and it is not too much to say that recent investigations into that subject, if they prove anything at all, prove, amongst other things, that the true history of cast-iron still remains an unwritten chapter. However interesting, as well as useful it might prove, to probe the ultimate depths of that history, yet it is not proposed as a feature of this paper to attempt what must at present be so unfathomable a task.

Before entering into the deeper points to which the subject before us will probably be found to reach, I may remark that, whereas by some researches,† made a few years since, I was enabled to prove, from a variety of consentaneous evidence, that *malleable* iron was well known and used at least as far back as 4,000 years ago, and almost certainly much earlier still, I was thereby, and of necessity, led to doubt whether the usually accepted assertion as to cast iron having been invented within the last three or four hundred years only, rested on an entirely stable and reliable basis. The sequel will shew the results of the doubt so raised in my own mind.

* *Chemical Phenomena of Iron Smelting*, Preface.

† Vide *Proc. Phil. Soc.*, Glasgow, Vol. vii., p. 476.

(*b.*) *The Origin of the Blast Furnace.*

Not unlike many other discoveries made at periods remote from the present age, and which have had in varied degrees incalculable influence upon the condition and destinies of mankind, does it at a first view appear out of keeping with an almost constant order, that the place and date, no less than the names, of the first makers of cast iron are not absolutely known.

When, however, we reflect upon that which we really do know, as being reliably ascertained concerning early methods of making iron and steel, weigh carefully the precise nature of the conditions involved under those methods, and seek out the results inevitably accruing through them, as explained by the guiding light of modern chemistry, it would appear that the blast furnace as a distinct apparatus could scarcely at any time have consisted in a definite or sudden departure from an existing order of things; by saying which, I mean to explain, that in all probability, there never was in the development of iron smelting an *immediate complete change* made from the method of reducing ore at once to malleable metal (the direct method) to that of first making pig or sow metal (or the indirect method of the blast furnace as we practise it to-day); rather, on the contrary, the evidence which has been collected goes to shew that the blast furnace was ultimately reached as a definite and distinct apparatus for reducing iron ore quickly, and producing an easily fusible compound of iron, partly by its accidental production occasionally when reducing easily fusible ores in the air or blast bloomeries, or other formerly used types of *low* furnaces, in which the product sought to be obtained was malleable iron or steel This probability, indeed, appears to rest on conclusive grounds; and the tendency of the evidence is further to shew that the blast furnace, as an apparatus having as a distinct object the production of cast iron, was at last arrived at through very gradual accessions to the height of the ancient types of low furnaces.

Where we are to look for the earliest traces of the practice of reducing iron to the form of a carburet or as cast iron, I cannot suppose that at the present time any one would venture to assert; but as the employment of steel in fashioning the stones used in the monuments of Proto-Egypt, India, Greece, and elsewhere, has been shewn, that almost seems to imply the acquaintance of those ancient nations with the *fusion* of iron, and leads us to expect that to the East and not the West must we look for the beginnings of the art.

In so far as our own country has yet given testimony, the oldest blast furnaces yet recorded are those of which the ruins formerly existed, and may, for aught I know, still exist, in the Forest of Dean, and the age of which Mr. Mushet has computed as belonging to the commencement of the seventeenth century.*

* In his "Papers on Iron and Steel," Mr. Mushet supplies us with the following instructive remarks:—"I have examined the sites of many old charcoal blast furnaces, with a view of determining their age, by the quantity of slags with which they were surrounded. Here, however, another difficulty has been, in every case but one, interposed. The manufacture of black bottles has, I think, been traced as far back as the fifteenth century. At what time the manufacture was introduced into this country, I am uncertain; but it is not improbable that in early times, as in the last century, the slags or cinders of the charcoal blast furnace have entered into the composition of black bottles, and created a consumption of that sort of waste which otherwise would have remained in the vicinity of the furnaces. The superior quality of the Bristol black bottles has been attributed to the immemorial use of a portion of the slags of the charcoal furnaces from the neighbourhood of Dean Forest. The consequence of this long-standing practice has been to carry from the furnaces not only the old slags, but those currently made. In one instance only have I found from this source data for calculation. Before the civil commotions of the seventeenth century, the Kings of England were possessed of two blast furnaces in the Forest of Dean, when the cord-wood of the Forest and the king's share of the mines were used for the purpose of iron-making. Soon after the commencement of the struggle between Charles the First and his Parliament, these furnaces ceased working, and at no period since have they been in blast. About fourteen years ago, I first saw the ruins of one of these furnaces situated below York Lodge, and surrounded by a large heap of the slag or scoria that is produced in making pig iron. As the situation of this furnace was remote from roads, and must at one time have been deemed nearly inaccessible, it had all the appearance, at the time of my survey, of having remained in the same state for nearly two centuries. There existed no trace of any sort of machinery, which rendered it highly probable that no part of the slags had been ground (the usual practice) and carried off, but that the entire produce of the furnace in slags remained undisturbed.

"The quantity I computed at from 8,000 to 10,000 tons; a quantity which, however great it may appear for the minor operations of an early period, would yet in our times be produced from a coke furnace in less than two years. If it is assumed that the furnace made annually 200 tons of pig iron; and further, assuming the result which has been obtained with ores richer than the Roman cinders, and ores used at that time in Dean Forest, *that the quantity of slag run from the furnace was equal to one-half of the quantity of iron made* (in modern times the quantity of cinder from the coke furnace is double the weight of the iron), we shall have 100 tons annually for a period of from 80 to 100 years. If the abandonment of this furnace took place about the year 1640, the commencement of its smeltings must be assigned to a period between the years 1540 and 1560." Mushet, from this computation, assigns the mean period or 1550 as the most probable period for the commencement of smelting operations with this furnace. In a note, however, at the end of the paper from which the previous

It is desirable, ere proceeding too far in the paths of research which for the present occupy our attention, in order to avoid any

extract is taken, he says, "the calculation of age, which proceeded on the assumption of a certain weight of cinder being obtained in the production of a given weight of iron, and which with so rich ore may be correct; yet, on further consideration of the subject, and taking into account the calcareous nature of the iron ores of Dean Forest requiring a considerable portion of argillaceous schist to neutralize the lime, it is more than probable that the furnace would necessarily, from this circumstance, and from the inferior produce of the ores, produce fully as much cinder as pig iron, and that in place of only being one-half the weight, it would probably be of equal weight with the iron. Taking the calculation in this way, we should not reach an older period than the commencement of the 17th century for the introduction of the blast furnace into Dean Forest.' . . . The local history of Tintern Abbey assigns a later period (the early years of James the First) for the erection of that furnace. The opportunity afforded of examining both the slags and the iron produced in that early period abundantly proves that the furnace in Dean Forest above mentioned was one of the earliest efforts in the art of making pig iron. Small masses or shots of iron are found enveloped in the slags, specimens of iron in a malleable state, though rarely, more frequently rough nodules of large grained steel, resembling blistered steel, and others of a more dense fracture, but of a similar quality. The more fusible reguli of white, mottled and grey iron are found in great abundance, all of them possessing forms and appearances of fusion more or less perfect, according to the quantities of carbon with which they are united; and it is but justice to the memory of the fathers of this art to add, that the specimens of grey cast iron are more abundant than those of the other sorts.

"This furnace seems to have been erected upon the spoils of former ages of iron-making; and probably the situation was in the first instance determined by the numerous bloomeries that existed in the neighbourhood—the scoria of which has in after ages been worked to so much advantage in the blast furnace; and though, as a blast furnace, possessed of no great antiquity, yet, as the site of the ancient bloomery, entitled to be considered as the remains of an extensive manufactory of iron in ages more remote.

"Upon the whole, several circumstances incline me to the opinion, that the blast furnace must have been known in some of the then iron-making districts of England before it was introduced into Dean Forest. The oldest casting I have met with in Dean Forest is dated 1620.

"The great infusibility and difficulty attending the management of calcareous ores, such as those belonging to Dean Forest, is another circumstance that inclines me to think that the art of making pig iron did not originate in that quarter, and probably did not succeed entirely till the practice of increasing their fusibility by the addition of the bloomery cinder became known and established. These conjectures are confirmed by reference to a paper in my possession, professing to be an account of all the blast furnaces in England previous to the manufacture of pig iron from pit-coal—probably about the year 1720 or 1730; in which, however, the blast furnace of Tintern Abbey is omitted, and possibly others. At that period there were in all England 59 furnaces, necessity for raising the question hereafter, once and for all to point out, that, it is not a consequence, because we are unable to assign an earlier positive date for the blast furnace than that above given, that cast iron was unknown before that period; indeed, from what we do glean from the historical records, they assure us that it was in considerable use at a much more remote age. And whereas this knowledge might lead some persons to conclude that as the blast furnace constitutes the first step taken in the manufacture of cast iron to-day, it was necessarily the first step taken in ages long past; still, a candid consideration of certain features of history, coupled with a consideration of what chemistry now teaches, are more than sufficient to convince us that the high or blast furnace is not indispensable to the production of that carburet, however much it is essential, under our current knowledge at the present period, in order to comply with modern demands for the metal at paying prices.

To but briefly, indeed, indicate how much more ancient cast iron may really be than, so far as I have ascertained, has been noticed during the last quarter of a century,—a period unprecedented in the issue from the press of a metallurgical literature of extreme value,—I may mention a process of making steel used by the

making annually 17,350 tons, or little more than 5 tons of pig iron a week for each furnace.

"Should it appear that there have been since the invention of blast furnaces iron-making districts in England in which a greater number of furnaces have been established than in Dean Forest, then to that quarter I should be inclined to look for information on the history, rise, and progress of the blast furnace.

Brecon,	2	Gloucester,	6	Salop,	6
Glamorgan,	2	Hereford,	3	Stafford,	2
Carmarthen,	1	Hampshire,	1	Worcester,	2
Cheshire,	3	Kent,	4	Sussex,	10
Denbigh,	2	Monmouth,	2	Warwick,	2
Derby,	4	Nottingham,	1	York,	6

"It would appear from this account, that the counties of Sussex and Kent alone contained, in the early part of the eighteenth century, 14 blast furnaces; and as it is probable that the woodlands in the vicinity of the metropolis would sooner disappear than in the more distant counties, it is equally probable that a century before the number of blast furnaces might have been considerably greater in that district. The only other iron-making district that will at the time now spoken of bear a comparison with Sussex and Kent, is that of Dean Forest, in which I include the Furnace of Tintern Abbey, in Monmouthshire, not included in the list; Gloucestershire 6, and Herefordshire 3,—making in all 10 blast furnaces."

Greeks, and recorded in the writings of no less an authority than Aristotle, and to which I have, on a previous occasion, directed attention.* Where it is stated:—

"Wrought iron itself may be *cast* so as to be *made liquid, and to harden again.*"

Somewhat obscure as the Aristotleian account of Greek steel manufacture unquestionably is, nevertheless, when the terms of the fragment are analyzed, and it is placed in juxta-position with other accounts of steel-making appertaining to times long subsequent, it is even sufficient to assure us that such iron, although it may not have been specially employed in the art of making castings, but produced for the purpose of converting bars of wrought iron into steel, by a process of cementation in a bath of metal surcharged with carbon, was known to and practised by the Greeks at least as early as 400 years before our era.

Indeed, we may venture further still—for recent discoveries in India, and the impossibility of explaining Egyptian sculpture in granite, porphyry, diorite, &c., without the use of steel tools, hold out much to hope for towards the increasing of our acquaintance with the metallurgy of the ancient eastern world, by further special researches into the storehouses of information yet waiting there to be opened up. For, after the discovery of the Kutub Minar Lâht,† near Delhi, as well as the huge iron beams in the Temple of Kanaruc,‡ and the coming to light of numerous other testimonies, proving beyond doubt the extremely high acquaintance with manufacturing art, which some persons at least possessed in the East in ages long past, the cautious observer is compelled to pause ere risking to pronounce, whether, as it even yet is generally asserted, Western civilization has in all respects exceeded all previous civilization, or questioning, whether we have attained in some respects the position in certain of the manufactures most important to man at one time reached in the old world; for, whilst the rate of production has increased as a necessary sequence of the growth of population, and novel as well as wider fields of application, yet it is notorious that in many instances high quality is not maintained. There is much to be met with in the remains of the Proto-Egyptian, Assyrian, Greek, and Chinese nations to assure us that we have not—while to Central Asia, Asia Minor, and Persia we must look hopefully for further light in this respect.

* Vide *Proc. Phil. Soc., Glasgow*, vol. viii., p. 244.

† *Trans. Asiatic Soc.*, Bengal, 1864.

‡ *Illust. Ancient Architecture of Hindustan*, p. 28, Pl. iii., 1848.

With this much of digression from the immediate subject in hand, purposely introduced too as a forewarning signal to us that at this time we have no sufficient facts to warrant us in assigning any approximate period even for the origin of the indirect method of reducing iron ores (the prevalent system of this age), we may with advantage return to the question of producing cast iron *without the* blast furnace; in order to satisfy ourselves that, whilst all the very old examples of iron which we do find are malleable, and appear from more than one point of view to have been produced from ores reduced *without fusion;* and when inquiring still further into the most ancient practice of reduction, no country so far affords conclusive evidence of cast iron having been an established manufactured product—in the sense we find malleable iron to have been therein—yet the collateral evidence as to an extremely early method of making steel, in the production of which cast iron was a *sine qua non,* convinces us of the necessity for exercising extreme caution ere drawing a conclusion.

The next early intelligible account that we have of steel-making throws equal light over cast iron making, and this is to be found in a work entitled *"De la Pirotechnia,"* published at Venice in 1540, by Vanoccio Biringuccio; and in the somewhat later, but better known writings of Agricola—"*De re Metallica*"—published about 1561. Both these authors describe a process of converting bars of malleable iron into steel by keeping the bars immersed for a considerable time *in molten cast iron.*

The process as described by the earlier author has been translated by Mr. Panizzi,* of the British Museum; and I here quote an extract from that translation, shewing how the cast iron was produced.

"Steel is nothing but iron well purified by means of art, and through *much liquefaction* by fire brought to a more perfect admixture and quality than it had before. By the attraction of some suitable substances in the things which are added to it, its natural aridity is mollified by somewhat of moisture, and it is made whiter and denser, so that it seems to be almost removed from its original nature; and at last, when its pores are well dilated and mollified with much fire, and when the heat is driven out of them by the extreme coldness of the water, they contract, and so the iron is converted into a hard substance, which from its hardness becomes brittle. This may be done with every kind of iron, and so steel

* *Metallurgy, Iron and Steel.* By John Percy, M.D., F.R.S., London, 1864 Murray, p. 807, *et seq.*

may be made of all kinds of iron. It is true, indeed, that it is made better from one kind than from another, and with one sort of charcoal than another, and it is also made better according to the skill of the masters. The best iron to make it good is, however, that which, being by its nature free from the corruption of any other metal, is more easy to melt, and which is to a certain extent harder than other kinds. With this iron is put some pounded marble or other fusible stones, in order to melt them together. By these it is purged, and they have, as it were, the power of taking away its ferruginosity, of constricting its porosity, and of making it dense and free from cleavage. Now, to conclude, when the masters wish to do this work, they take of that iron passed through the furnace or otherwise as much as they wish to convert into steel, and they break it into little bits; then they prepare before the aperture of the forge a circular receptacle, about a foot or more in diameter, made of one-third clay and two-thirds small coal (carbonigia), well beaten together with a hammer, well mixed, and moistened with so much water as will make them keep together when squeezed in the hand; and when this receptacle is thus made, in the same way as they make a hearth (ceneraccio), but deeper, the aperture is prepared in the midst, which should have a little of the nose turned down, so that the wind may strike in the midst of the receptacle. Then, when all the space is filled with charcoal, they, moreover, make round about it a circle of stones or soft rock to keep in the broken iron and the additional charcoal which they put upon it, and so they fill it up and make a heap of charcoal over it. Then, when they see that the whole is on fire, and well kindled, especially the receptacle, the masters begin to set the bellows to work, and to put on some of that crushed iron mingled with saline marble and with pounded slag, or with other fusible and not earthy stones; and so *melting* this composition by little and little, they fill up the receptacle so far as they think fit; and having first formed with the hammer three or four lumps of the same iron, each weighing 30 or 40 lbs., they put them hot into that *bath of melted iron,* which bath is called by the masters of this art the art of iron; and they keep them thus in the midst of this melted matter with a great fire about four or six hours, often turning them about with a rod as cooks do victuals, and so they keep them there, turning them again and again, in order that all that solid iron may receive through its porosity those subtle substances which are found to be within that *melted* iron, by virtue of which the gross substances which are in the lumps are consumed and dilated, and the lumps become softened, and like a paste. When they are seen thus by the experienced masters, they judge that that subtle virtue of which we have spoken has thoroughly penetrated; and taking out one of the lumps which appears best from their experience in testing, and bringing it under the hammer, they beat it out, and then throwing it suddenly as hot as they can into the water, they temper it, and being tempered, they break it, and look to see if the whole of it has in every particle so changed its nature as to have no small layer of iron within it; and finding that it has arrived at that point of perfection which they desire, they take out the lumps with a large pair of pincers, or by the ends left on them, and cut them into small pieces of seven or eight each, and they return them to the same bath to get hot again, adding to it some pounded marble and *iron for melting* to refresh the bath and increase it, and also to restore to it what the fire may have consumed, and also that that which [is to become steel may, by being immersed in that bath, be the better refined; and so at last, when these are well heated, they go and take them out piece by piece with a pair of pincers, and they carry them to the hammer to be beaten out, and they make rods of them as you see. And when this is done, being very hot, and almost of a white colour from the heat, they cast them all at once into a stream of water as cold as possibly can be had, of which a reservoir has been made, in order that the rods may be suddenly cooled, and by this means get the hardness which the common people call temper, and thus it is changed into a material which hardly resembles that which it was before it was tempered. For then it was only like a lump of lead or wax, and by tempering it, it is made so very hard as almost to surpass all other hard things; and it is also made very white, much more so than is the nature of its iron, even almost like silver, and that which has its grain white, and most minute and fixed, is of the best sort. Among those kinds which I know of, that of Flanders, and in Italy that of Valcamonica, in the territory of Brescia, are very much praised; and out of Christendom, that of Damascus, that of Caramenia and Lazzimino (?), as well as that of the Agiambi (?)."

The same process is described by Agricola; but it is worthy of remark, as stated on the authority of the elder Mushet, that "nowhere does he describe a process by which cast iron was obtained and applied to *foundry* purposes." *

In India, near Trincomalee, steel (wootz) is still made in the same manner, its manufacture being confined to a few families in that

* *Papers on Iron and Steel*, London, 1840, p. 380.

neighbourhood, and altogether unknown to the common steelmakers of Salem, a distance of only 70 miles. The cast iron used in this case is obtained from "a small blast furnace, about 8 feet high, and tapering from 18 inches diameter at the bottom to 9 inches at the top. The iron flows out of a grey quality, but without perfect separation, as the cinders produced contain a good deal of iron.

With regard, then, to the production of cast iron in the most ancient *low* furnaces, that was practicable with ores not difficult to fuse when in presence of large quantities of flux and a great excess of charcoal—the former of which would preserve the metal from oxidation, whilst it was allowed to remain a sufficient time in contact, to take up a maximum quantity of carbon from the latter; but as the temperature in such furnaces was low, the slag of necessity contained a large proportion of the iron, and, except with the most easily fusible ores, the process was very slow; indeed, with the more difficult fusible ores, almost impossible. With this certainty before us, however, of the possibility of producing cast iron even in the oldest known types of furnaces, coupled also with the well-ascertained fact of the use of iron and steel by Greeks, Indians, ancient Egyptians, and Assyrians,† it is impossible to say how far back we may carry the date of the discovery of cast iron. But it is not, as I have already pointed out, to be inferred that the blast furnace has any claim at all to antiquity; on the contrary, I have collected together the foregoing evidence with the one object, amongst others, of avoiding any misapprehension on that point.

Percy,‡ remarking on a quotation from Lower's *Contributions to Literature, &c.*, says,—

"The date of the discovery of cast iron has not, so far as I am aware, been precisely ascertained, though it is a point of great archæological interest. Lower has published the following remarkable statement, which would lead to the conclusion that cast iron was made and applied in England 500 years ago. A curious specimen of the iron manufacture of the fourteenth century, and, as far as my own observation extends, the oldest existing article produced by our foundries, occurs in Burwash church (Sussex). It is a cast iron slab, with an ornamental cross, and an inscription in relief. In the opinion of several eminent antiquaries, it may be

* *Papers on Iron and Steel*, London, 1840, p. 673.

† *Proceedings Phil. Soc.*, Glasgow, vol. vi., 1871; also *Trans. Devon. Assocn.*, 1868.

‡ Percy's *Metal; Iron and Steel*, p. 878.

regarded as unique for the style and period. The inscription is much injured by long exposure to the attrition of human feet. The letters are Longobardic, and the legend appears, on a careful examination, to be,—

'ORATE P. ANNEMA JHONE COLINE, (or Colins).

'Pray for the soul of Joan Collins.'

Of the identity of the individual thus commemorated I have been unable to glean any particulars. In all probability she was a member of the ancient Sussex family of Collins, subsequently seated at Locknersh, in the adjacent parish of Brightling, where, in company with many of the neighbouring gentry, they carried on the manufacture of iron at a place still known as Locknersh Furnace."

M. Verlit says that cast iron was known in Holland in the thirteenth century, and that stoves were made from it at Elass, in 1400, A.D.;* and, according to Lower, the first cannon of cast iron were manufactured at Buxteed, in Sussex, by Ralphe Hogge, in 1543. It is recorded, however, by others that the first iron guns cast in England were made in London, in 1547, by Owen; and in 1595 the art of iron casting was so well understood that John Johnson and his son Thomas had by that time "made forty-two cast pieces of great ordnance of iron for the Earl of Cumberland, weighing 6,000 pounds, or three tons a-piece." Agricola, too, who died in 1494 A.D., seems to have been acquainted with cast iron; for he writes,—"Iron melted from ironstone is easily fusible, and can be *tapped off;*" so that although he does not appear to say anything as to the method by which such cast iron was produced, it nevertheless is evident, when we consider the large extent to which cast iron was probably then employed for guns, and doubtless other purposes, that the blast furnace was at that time in existence, though on a very small scale, grown out of the Catalan, and through the Blaseofen, or Osmund,† to the German Stückofen, in which cast or malleable iron

* Mushet's *Papers on Iron and Steel*, p. 391.

† Percy says (*Iron and Steel*, p. 320),—"Between the Luppenfeuer, or Catalan furnace, and the Stückofen, German metallurgists place a furnace of intermediate height, which they designate Blaseofen and Bauernofen. This furnace was formerly employed in Norway, Sweden, and other parts of Europe; and although a century may have elapsed since it became extinct in the first two countries mentioned, yet to this day it continues in operation in Finland." "Osmund" is the Swedish word for the bloom produced in this particular kind of furnace, of which the annexed woodcuts (Figs. 1 and 2) are a plan and vertical section, respectively, shewing the outside as consisting of a timber casing,

was produced as required, by varying the proportions of the materials constituting the charge.

"Osmund" Furnace.

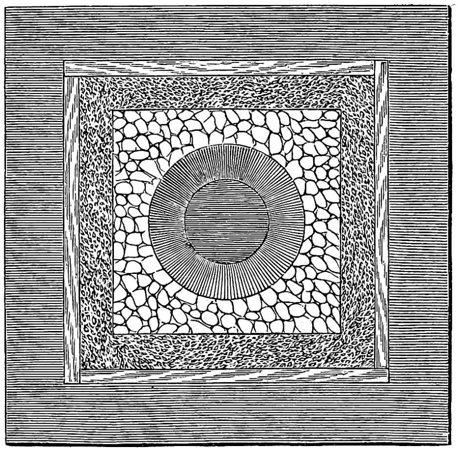

Fig. 1.—Plan.

As the Stückofen would appear to be the last stage of transition from the *low* to the *high* furnace, into which it ultimately became

"Osmund" Furnace.

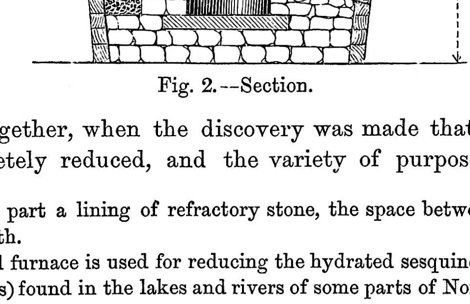

Fig. 2.--Section.

merged altogether, when the discovery was made that the ore was more completely reduced, and the variety of purposes to which

and the inner part a lining of refractory stone, the space between them being filled with earth.

The Osmund furnace is used for reducing the hydrated sesquinoxide ores (lake or bog iron ores) found in the lakes and rivers of some parts of Northern Europe, and in Finland is stated at the present day to be working side by side with the modern blast furnace.

the pig or sow metal could be applied increased the demand for cast iron to such an extent as to induce the indirect method of reduction to be carried out on a large scale, it will be unnecessary in this paper, which deals with cast iron and the blast furnace as its principal subjects, to refer further to the pre-existing *low* furnaces.

Regarding the Stückofen, then, or high bloomery furnace, it has been correctly described by writers on metallurgy as a Catalan or low furnace, extended upwards in the form of either a circular or quadrangular shaft. In Germany this furnace is also known as Wulfsofen, the reduced metallic mass resulting from the operations being designated "Stück" or "Wulf:" hence the Stück or Wulf oven—Salamander* furnace—for the following particulars of which I am indebted to Professor Osborne's treatise,† and who, in a paragraph preceding the extract, significantly terms this the "transition furnace," which might be used for the production of cast iron or malleable iron at will, by varying the constituents of the charge and the intensity of the blast.

Osborne says,—

"This kind of furnace is at present very little in use. A few are still in operation in Hungary and Spain. At one time they were very common in Europe. The iron produced in the Stück oven has always been of a superior kind favourable for the manufacture of steel; but the manipulation which this oven requires is so expensive that it has been superseded. Fig. 3 shews a cross section of a Stück oven; its inside has the form of a double crucible. This furnace is generally from 10 to 16 feet high, 24 inches wide at bottom and top, and measures at its widest part about 5 feet.

The "Stückofen."

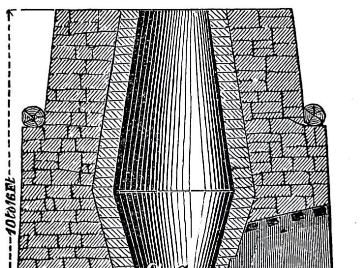

Fig. 3.—Section.

* "Salamander is the term now given to the mass of half-pure iron, which results when the molten mass of a furnace chills before it can be regularly tapped off into pigs. It is difficult to melt, and is sometimes largely malleable iron. The present may have originated from the earlier use of the word as applied to this furnace.

† *The Metallurgy of Iron and Steel,* Theoretical and Practical, in all its branches,

There are generally two tuyeres* [twē-er, allied to tuyaw, a pipe], *a a*, and at least two bellows and nozzles, both on the same side. The breast, *b*, is open, but during the smelting operation it is shut by bricks; this opening is generally 2 feet square. The furnace must be heated before the breast is closed; after which charcoal and ore are thrown in. The blast is then turned into the furnace. As soon as the ore passes the tuyere, iron is deposited at the bottom of the hearth; when the cinder rises to the tuyere, a portion is suffered to escape through a hole in the dam, *b*. The tuyeres are generally kept low upon the surface of the melted iron, which thus becomes whitened. As the iron rises the tuyeres are raised. In about 24 hours one ton of iron is deposited at the bottom of the furnace. This may be ascertained by the ore put in the furnace. If a quantity of ore is charged sufficient to make the necessary amount of iron for one cast, a few dead or coal charges may then be thrown in. The blast is then stopped, the breast wall removed, and the iron, which is in a solid mass, in the form of a salamander or "*stück-wulf*," as the Germans call it, is lifted loose from the bottom by crowbars, taken by a pair of strong tongs, which are fastened on chains suspended on a swing-crane, and then removed to an anvil, where it is flattened by a tilt hammer into 4-inch thick slabs, cut into blooms, and finally stretched into bar iron by small hammers. Meanwhile the furnace is charged anew with ore and coal, and the same process is renewed.

"By this method good iron as well as steel may be furnished. In fact, the salamander consists of a mixture of iron and steel—of the latter, skilful workmen may save a considerable amount. The blooms are a mixture of fibrous iron, steel, and cast iron. The latter flows into the bottom of the forge fire, in which the blooms are re-heated, and is then converted into bar iron by the same method adopted to convert common pig iron. If the steel is not sufficiently separated, it is worked along with the iron. This would be a very desirable process, on account of the good quality of iron which it furnishes, if the loss of ore and waste of fuel it occasions were compensated by the price of bar iron. Poor ores, coke, or anthracite coal, cannot be employed in this process. Charcoal made from hardwood, and the rich magnetic, specular, and sparry ores are almost exclusively used."

It is obvious that the conditions necessary to the production of

edited by H. S. Osborne, LL.D., Professor of Mining and Metallurgy in Lafayette College, Easton, Pennsylvania. Trübner & Co., London, 1869.

* One tuyere, however, is frequently used.—S. J. V. D.

cast iron—viz., a column of materials which gradually become increased in temperature during their descent, exposed to reducing gases, and latterly, prolonged contact in the reduced state to carbonizing matter, obtained in this furnace; and the result frequently was that, when intending to produce malleable iron at once, the lump was so much carbonized, owing to excess of carbonizing materials, that it had to be submitted to a decarbonizing process before it could be hammered. Experience in working the Stückofen proved it to be extremely wasteful of fuel; and about 1840 it was to a great extent abandoned in Carniola, Carnithia, and Styria, although still worked in Germany and Hungary to a limited extent (KARSTEN). In some cases a throat was added to the furnace, of a gradually widening form: this gave facility in charging. The tuyere was placed about a foot above the hearth bottom; but as the furnace continued in operation this distance became increased, by reason of the disintegration or wear of the hearth (silicious conglomerate), which we learn influenced the yield and quality of the iron as well as the quantity of charcoal consumed. Besides being made of the form shewn at fig. 3, the Stückofen sometimes increased with a regular taper throughout the entire height of the shaft, being broadest at the bottom, and both rectangular as well as circular in horizontal section. The tuyeres were sometimes made of clay, at others of copper, situated at different parts of the furnace; and when in the breast, the bellows had to be removed before the lump of reduced iron could be withdrawn. As the demand for cast iron increased, the Stückofen was gradually replaced by the Blauofen,* in which cast iron was produced alone; but it still retained its place for the direct production of malleable iron—and indeed malleable iron was also produced in the Blauofen, which at first, it would appear, was simply a tall Stückofen, eventually becoming increased in height to from 20 to 25 feet, in which case it was capable of producing cast iron only. In working these furnaces for the production of malleable iron, the slag was allowed a constant escape, so that the lump of metal in the hearth might be exposed to the action of the blast, which prevented it from becoming carbonized to excess; at other times the slag was allowed to accumulate, thus protecting the metal from the decarbonizing action of the blast, after it had become carbonized in passing through the lower part of the furnace, and therefore producing

* By some authors termed "blue furnace." Fr. "Fournean blue," "blue oven."

carbonized or cast iron. The Blauofen, as in common use on the continent, is represented in vertical section at fig. 4, wherein *a* is the breast, *b* the tuyere. This furnace may be kept in blast for three to six months, or even longer, when the hearth widens and interferes with successful operations. In working with this furnace, the practice is to heat it by a fire, after which the breast previously open is closed; it is then filled to the top with coal and iron ore, which are renewed as the charge sinks. The tuyeres are about 14 inches above the hearth, which slopes towards the breast. This furnace requires rich ores and a plentiful supply of charcoal, and produces good pig iron, as well as a metal specially suitable for steel, sometimes called "steel metal,"* and said to be that from which German steel (shear steel) is made. The management of the Blauofen is simple—generally and where sparry carbonates are plentiful—and the furnace is cheaply constructed.

The "Blauofen."

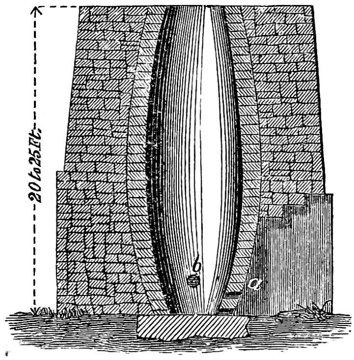

Fig. 4. Section.

From the preceding remarks we have become familiar with the earliest known form of the blast furnace, which originating in the Stückofen, or high bloomery, of some 95 cubic feet capacity, passed into the Blauofen of some 500 to 600 cubic feet; and without following its progressive development minutely through the furnaces in the Hartz, Silesia, Prussia, Sweden, Great Britain, and America—all of which has been already done, and so excellently in the *Treatises* of Percy, Osborne, and others—we may at once come down to our own age, and now find furnaces in the Cleveland district of the enormous capacity of 20,000 to 30,000 cubic feet, or about 280 times that of an early Blauofen.

* Osborne's *Metallurgy*, p. 294.