# THE PUDDLING PROCESS, PAST AND PRESENT.

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It may seem necessary to offer an apology for presenting for consideration a process which is conspicuous by its absence in the literature of the Institute, and which may be thought by some to belong to the past in metallurgy, and to have been already superseded. But the large capital invested in puddling calls for a careful consideration of the question whether the time has certainly arrived when the puddling furnace must be replaced by the converter and open-hearth furnace. May there not still be a place for puddled iron alongside of molten iron and steel, and is not the improvement of the puddling process itself worthy the attention of engineers equally with the Bessemer and open-hearth processes?

The changes involved in the conversion of pig iron into wrought iron are well understood and need only be briefly alluded to. The patent of Henry Cort bears the date of 1784. Since that time the improvements in the process have mainly consisted in the replacement of sand by iron bottoms by Samuel Baldwyn Rogers in 1818, and the still more recent substitution of iron oxide for the refractory materials used for the sides and bridge of the hearth, which distinguishes the wet or boiling process from the dry or puddling process. Chemically, the process consists in the removal of the metalloids from the pig iron, a result effected mainly by the iron oxide. Silicon is first oxidized, then the phosphorus, and finally the carbon. The silicic and phosphoric acids produced pass into the cinder and the carbonic oxide burns as it escapes from the bath of metal.

It ie interesting in this connection to note the effect of temperature on the removal of the phosphorus from the iron. As is well known, no phosphorus is eliminated under the oxidizing influences prevailing in the Bessemer converter, while from 70 to 80 per cent. is removed in puddling. But we find, if in working cold short irons the temperature of the furnace is much increased towards the end of the process, that a considerable amount of the phosphoric acid is deoxidized and phosphorus again combines with the iron. This reverse process is aided by a siliceous cinder arising either from the use of a very siliceous pig iron, or of an over-siliceous ore for fix. The fact which has been known for some time that only a basic cinder can retain phosphoric acid has given rise to the "basic lining" which now attracts so much attention in the Bessemer process. For the conditions affecting the removal of phosphorus from pig iron I would refer to the careful and complete experiments of I. Lowthian Bell, in England.

Notwithstanding the recent progress in the metallurge of iron the puddling process is essentially what it was three-quarters of a century ago—laborious, crude and unsatisfactory. The attempts at improvement in the process may be classified under two heads: 1. economy of labor; and 2. economy of fuel.

Increase of yield and improvement of quality are so intimately connected with both of these two classes that it is not easy to consider one apart from the other.

### 1. Economy of Labor.

For the successful accomplishment of the operation of puddling it is necessary to bring the molten metal into contact with the solid oxides by agitation effected either by human or mechanical agency upon a stationary hearth, or by giving motion to the whole body of the furnace. One of the first attempts for lessening the labor of the puddler is recorded in a drawing at Dowlais which has been traced back to the year 1834. It is a reverberatory furnace with a revolving hearth, driven with a vertical shaft by bevel gearing. Whether this machine was ever used I do not know, but it is of interest as showing that most of subsequent improvements are not new in principle. Coming to more recent times, we have the Richardson process of blowing air into the molten bath through a tubular rabble. The advantages claimed for this method are that it hastens the boil, reduces the labors, and produces a tough metal of uniform and high quality. After the iron has come to a boil the rabble is withdrawn and the working continued in the ordinary manner. I believe this process has never been used in this country and but sparingly in England.

Morgan's puddling machine consists of a reverberatory furnace of the usual form, which has an opening in the roof through which a vertical shaft is lowered with a horizontal arm. The shaft is set in motion by suitable machinery, and the arm revolves in the furnace, doing away with the labor of the puddler and helper until the heat is ready for balling, when the shaft and arm are withdrawn, the opening in the roof closed, and the balling proceeded with in the usual manner. The wear and tear connected with this method must be enormous, and the results, I should think, not very satisfactory.

Griffith's and Whitham's devices are similar in idea, but different in mechanical details. Their object is to give an oscillating movement to a rabble of the ordinary shape by means of machinery, the puddler or helper merely guiding the rabble. The balling is accomplished in all cases by hand labor. None of the above-mentioned improvements do away with the skilled workman, but merely lessen the laborious work of the early stages of the heat, which requires brute force rather than experience.

In a work by Kohn upon the *Manufacture of Iron and Steel* will be found more detailed statements concerning these processes. That any of them has proved satisfaetory I question. One of the imperfections common to them all is the difficulty of keeping the raw iron from gathering in the crevices of the fix and settling on the bottom and in the corners of the furnace into which the rabble does not enter, leaving the furnace at the conclusion of the heat in a very dirty condition. We all know the importance of a thorough working of iron in the jambs of a furnace, as it is there that the metal begins to gather when coming to nature, requiring careful working for good results. Another serious objection which may be advanced against these processes is, that they require the same skilled workmen to operate them as are needed for the old style of hand puddling. No increase in the number of heats is obtained, for the men, instead of encouraging experiments, look upon them with great distrust as inimical to their best interest, and when a workman and his tools do not agree good results cannot be expected.

About 1867 a change in the direction of improvement took place, and it was reserved for an American, Samuel Danks, to have the boldness to propose an entire revolution in the puddling process. The Danks furnace was the first rotary furnace to be put into successful operation, although its success was not assured until many improvements and alterations were made upon the original designs.

In England this same idea was elaborated, and several machines were brought out differing in details. The one of most novel construction was the Godfrey-Howson furnace, which had but one opening into which the heat enters and the products of combustion escape, a blowpipe on a large scale being substituted for the ordinary fireplace. Later, in this country, we find a rotary furnace designed by the Edgemoor Iron Company, of Wilmington, Del., worthy of mention from the fact that this company is at present equipping their works with these furnaces, which would seem to indicate great confidence upon the part of the proprietors in the success of the rotary process.

## 2. Economy of Fuel.

In the utilization of coal for puddling two methods are employed. The one in almost universal use, where coal is directly burned on the grate of the furnace, is irrational and wasteful. The other method, consisting in the conversion of the coal into combustible gases, which are burned on the hearth of the furnace, though more economical and rational, is but seldom used.

The attempts which have been made to improve the old system may be divided into two classes: First, those having for their object the prevention of smoke by feeding the coal below the surface of the fire, which is always kept bright. The mechanical devices for accomplishing this object are found in the Frisbie & Sweet furnaces. The system has not come into general use. An objection in the case of coal forming clinkers is, that the clinkers are forced to the top of the fire. Second, those having for their object the utilization of the volatile matters of the coal by a partial coking of the coal before it reaches the fire. This is effected by the employment of a separate magazine in connection with the fireplace. The gases from the coal are caused to pass over the fire and are there burned. Of this variety of furnace may be mentioned the Wilson furnace, and of more recent date the Price furnace, which has given very good results.

When we consider, however, the cost of introducing these improved furnaces, and the trouble and annoyance of teaching workmen to use them, it is evident that we might just as well go a step further and introduce the gas system in its entirety. The great advantages to be gained in the use of gas in puddling are well known. We may distinguish here two systems, the continuous-acting furnace, of which Swindell's furnace is an example, and the well-known Siemens regenerative furnace.

Of the use of water-gas in the place of the ordinary generator-gas it is too soon to speak, but reference may be made in passing to the astonishing results said to have been obtained at Washington by the

Gill process, with gas containing as high as 75 per cent. of combustible gases, which we take *cum grano salis.*

What, let us now ask, is the present state of the puddling process, and what relation does its welded product sustain to the fused product of the Bessemer converter and the Siemens furnace? Will steel supplant iron?

In a paper on the Separation of Phosphorus from Pig Iron, read before the Iron and Steel Institute of Great Britain in 1878, by I. Lowthian Bell, occurs the following:

"The elimination of this metalloid from pig iron is, doubtless, a subject of great interest and importance to British smelters, having regard to the fact that nearly five-sixths of the metal obtained from their native ores contains so much of this impurity as to unfit it for the manufacture of steel, that form of iron which bids fair to supersede, in a great measure, the product of the puddling furnace."

If phosphorus cannot be removed, the question is easily settled; the production of steel is a limited one; and in the future, as at present, it will be made from the highest grades of our pig irons, and be used for certain special purposes, such as rails, etc., for which it has shown its great superiority over iron.

But, no doubt, many will at once say: phosphorus can be removed, the Thomas & Gilchrist process, with its basic lining, has overcome this difficulty. That phosphorus has been removed experimentally there can be no question; that it has been expelled successfully, from a commercial point of view, is open to doubt. Of the three processes established for its elimination, the Bell, the Krupp, and the Thomas & Gilchrist processes, the second has, from an economical standpoint, produced the best results.

There are some points in regard to all of them which, in the published results of experiments, have not been very fully touched upon, though they are of great importance. Is the increased cost of working greater than the difference in price between inferior brands of pig iron and those suitable for steel-making? This is, of course, a secondary consideration if the demand for such pig exceeds the supply, but it will be of vital importance if the reverse is the case. Is the removal of phosphorus uniform or does it vary, giving us results differing from day to day? What is the percentage of bad blooms made by these processes as compared with the usual method of working? How uniform is the quality of the final product as furnished to the consumer? It will, perhaps, be said that sufficient experience has not yet been obtained to answer these questions, but until they are disposed of we must be very cautious in accepting the announcement made by inventors or operators to the effect that success has been achieved. Granted that a method of dephosphorization may be established upon a commercially successful basis (and present indications seem to point to such a conclusion), what will be the resulting product, and how well will it be fitted for its intended uses?

In advocating the use of high qualities of steel, and enumerating the advantages to be gained by employing it, the fact is frequently lost sight of that this superior metal is made from the highest grades of pig, obtained with the greatest care from the purest ores, and that the succeeding processes are worked out with the aid of the most improved plant. The metal is followed through all details of manipulation with the most thorough inspection and rigid chemical and mechanical tests. Material thus obtained is compared with wrought iron made from anything and everything. No chemist mixes the charge or analyzes the product, but a puddler is left to guard the interests at the most vital stage of the process. It is his aim to produce the greatest weight, with the least labor, in as short a time as possible, and with such work no one can blame him. It is not astonishing that under such conditions iron is so much inferior in its physical qualities to steel. Even taking the same grade of pig metal for the manufacture of wrought iron as is now used for steel, the mild grades of the latter suitable for structural purposes will, no doubt, give higher results by mechanical tests, but the difference between the two will not be as great as many are apt to think.

On the other hand, if in the future, by means of dephosphorizing processes, we shall use all sorts of pig iron for steel, shall we not introduce a dangerous element of uncertainty into its manufacture which we do not have to deal with at present? When it is considered how very slight a change in the percentage of some foreign substance may produce a considerable variation in the quality of steel, uniformity in a metal derived from such impure raw materials must be difficult to attain. The homogeneous nature of steel, as compared with the many-pieced structure of iron, is claimed as one of its advantages. Homogeneity in steel may be a cause of weakness, and the lack of homogeneity in iron a source of strength. A steel bloom, to all external appearance perfect, may be within entirely bad, either from piping in the moulds, or from other causes of a similar nature. Chemical analysis will not show this defect, and a bar produced from the same, although sound as far as can be seen, may fail in service suddenly and without warning. On the other hand, the possibility of a wholly bad iron bar diminishes just in proportion as the number of pieces in the pile from which it is made increases.

For a material for structural purposes the term uniformity should take the place of homogeneity. A material exposed to abrasion, such as a rail receives, requires the latter quality, but one subjected to strains of compression and extension, tension and bending, wants uniformity more than any other property. If one bad member is contained in a structure the strength and homogeneity of the whole is of no avail. For many purposes in construction steel may be used to very good advantage, notably for members liable to wear and parts running in bearings. But whenever it is applied in parts of varying outline, where sudden changes in form take place, planes of weakness are developed at all those points at which anything like a corner occurs, unless large fillets are used and great care is taken. It must not be forgotten that the structures hitherto erected of steel, have been, as it were, experimental, and have therefore been put up with the closest inspection and caution. If it should be generally adopted, this same care could not be exercised unless an entire revolution in existing modes of manufacture takes place. The rough handling which iron for structural use receives in manipulation would be fatal to steel. Existing plant and methods of working must be abolished, and workmen be educated in the proper handling of the new products.

Looking upon the above objections as a few of the more important ones yet to be met before a more general use of steel can take place, it will be apparent that its substitution for wrought iron will be very slow and gradual. The puddler and his furnace yet have many years before them. No one could regret it more than the writer. No other process in iron metallurgy requires so much work per ton of metal produced. It seems absurd to think that the labor of two men for ten hours is necessary tr produce a ton of wrought iron, and that for one ton of pig iron used one ton of coal is consumed! It is not worth while to consider those methods which aim merely to lighten but do not do away with the labor of the puddler. They may have some advantages, but they will never come into general use. What is needed is a method which is governed by intelligence, but which requires only ordinary labor for its working. The rotary furnace process is the only one which at present aims at this result, but its complete success is open to doubt. The wear and tear of the complicated mechanism and revolving surfaces is a source of expense, and the lining is composed of a material not well calculated to resist heat. The quality of the iron, however, is good, and counterbalances many of the attending disadvantages, although it will not, as was at one time hoped, answer for making bars without weld. It must be cut and piled as ordinary iron, or the work upon it will not suffice for good results.

We are now in the midst of an epoch of uncertainty; a few years more and the success or failure of steel to supplant wrought iron will be established beyond a doubt. Its success depends upon the results which shall be obtained from the working of all grades of pig iron; and its failure is certain if uniform quality cannot be produced. For the present, therefore, the system of puddling must continue as of old; but every ironmaster, not only of this but of other countries, will most gladly welcome the process, whether it be of steel or of iron, which shall do away with the weary toil of so many thousands, and usher in a brighter and a better era than could ever be accomplished by the puddling process as invented by Henry Cort.

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**Relation of Spectral Rays to the Constitution of Nebulæ.**—Ch. Fievey has made the spectral rays of hydrogen and of nitrogen the subject of a special careful investigation. By attaching to the spectroscope a contrivance which enables him to regulate at will the quantity of light received, he observed that the spectrum of hydrogen was modified and simplified in proportion as the brilliancy diminished. The H line first disappeared, then C, and finally only F was left. It is well to remember that the F line is the only one of the hydrogen lines which has been observed, in a large number of nebulæ that have been examined by the spectroscope. The spectrum of nitrogen gave results similar to that of hydrogen. It is, therefore, not strange that we should meet, in nebulous spectra, only the rays which are most persistent in diminished light. Such rays may suffice to establish the presence of the body to which they belong, and the disappearance of the others may be explained by their extinction in traversing the intervening spaces.—*Bull. de l'Acad. Belg.* C.