UNITED STATES PATENT OFFICE.

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MANUFACTURE OF IRON.

SPECIFICATION forming part of Letters Patent No. 243,365, dated June 28, 1881.

Application filed January 13, 1881. (No model.)

To all whom it may concern:

Be it known that I, CHARLES MEREDITH DU PUY, a citizen of the United States, residing at Philadelphia, in the State of Pennsylvania, but temporarily of London, England, have invented a certain new and useful Improvement in the Manufacture of Iron; and I do hereby declare that the following is a full, clear, and exact description of the invention, which will enable others skilled in the art to which it appertains to make and use the same.

This invention relates to improvements on the process set forth in specification No. 194,340, dated August 21, 1877.

Iron ores, when sufficiently heated, may be reduced to a metallic state when brought into contact with carbonaceous matter, by reason of the superior affinity which the combined oxygen of the ores has for carbon. In this condition the oxygen leaves the ore and passes off chiefly as carbonic oxide. When, in addition to this, the earthy substances of the ore are combined with suitable alkali or acid materials, (according to the peculiar constituents of the ore,) a greater affinity may be made between these various substances than they have for the iron. In this way a liquid glass may be created from these earthy substances, thereby more effectually preserving the metal from oxidation and consequent waste. As the oxygen of the ore is nearly one-third of the entire bulk and weight of the whole, and is evenly blended throughout the mass, it follows that as it passes off as carbonic oxide there are left infinitesimally-subdivided spongy spaces or cells between the delicate particles of metal. Something must fill the vacuum caused by the exit of this oxygen. Usually the furnace-gases fill these spaces, and where this is the case (as all furnace-gases are more or less oxidizing) the delicately-subdivided walls or granules are reoxidized to such an extent as to bring the yield of iron down so low as to defeat the commercial economy of the direct process.

In the course of various experiments I have found that the glassy slag may be utilized by making it of such consistency as will retain it in the masses of metal, causing it to glaze and seal these metallic granules by filling the spaces or cells vacated by the oxygen, and thus the reoxidation of the metal by the furnace-gases will be prevented. The combination of these substances may, at the same time, be such as will take up the impurities contained in the iron and leave it in a comparatively pure state. This discovery I consider of great value, as from a given amount of ore a larger and purer yield of iron may thus be obtained than by any other direct process known to me. The earthy mixtures should, at the same time, be made of such consistency as to hold the entire ore mixture together in such mold shapes as will enable the heat to penetrate the masses until the iron comes to nature in the furnace. This discovery is very important, as under many conditions it saves the necessity and the cost of the sheet-iron canisters or envelopes described in my specification No. 194,340.

I have further discovered that these combinations may be effectually applied, not only to the working of iron ores, but also to droppings from puddling-furnaces, scale from the rolling-mills, and to the waste slag or cinder from blooming-hammers. My method is to coarsely pulverize and intimately commingle ore, tap-cinder, droppings from puddling-furnaces, scale from iron, hammer-slag, or similar materials, and mix either, any, or all of them with pulverized carbonaceous matter. I have found the slack or fine waste coal from bituminous or anthracite or the fine waste dust from wood charcoal satisfactory carbon for this purpose; but other carbonaceous matter may also be used effectively. I have found fifteen to twenty per cent. (by weight of the iron-making material) of bituminous or anthracite carbon to be sufficient for deoxidation; but as charcoal carbon is more volatile I use of it as high as twenty-five per cent. With the pulverized carbon and the iron-bearing materials I mix lime, clay, and sometimes salt, or manganese, or both, in such proportions as will permit of the combined mixture being molded into suitable forms, and, when subjected to the furnace heat, will form the glassy non-flowing slag before described, it being clearly understood that the proportions of these substances must be varied to suit the analysis of the ore or material to be worked. Some ores may be highly calcareous, in which case the lime would be in part or wholly left out. Ores highly aluminous would not require much if any clay. In all cases the ingredients must be varied with the character of the metal-making material. In using "droppings" carrying approximately forty to fifty-five per cent. of iron, and silica to the extent of ten to fifteen per cent., I find that five to ten per cent. of the whole weight of the droppings of good aluminous clay and about one-half this proportion of lime, and also ten to fifteen per cent. of scale, will bring the mass to malleable iron ready for forging in two hours. A small percentage of scale is sometimes effectively used with ores, and salt is sometimes useful in separating impurities.

I have discovered that twenty to thirty per cent. of scale is used with advantage to give fiber to the iron as well as to better preserve intact the shape of the molded mixture when subjected to the reducing heat of the furnace, and when classes of ores or other metal-making materials are used which have not sufficient tenacity without it. A further advantage of the aluminous calcareous and saline mixtures is found (by an analysis of the product) to be in passing off the phosphorus, sulphur, and other impurities in the cinder by volatilization, or otherwise, when the reduced metal is compressed under the hammer, squeezer, or rolls, as the affinity for most of the impurities, particularly the phosphorus, is greater for the glassy slag than for the iron at the temperature at which it comes to nature. The metal is thus not only deoxidized, but also dephosphorized, desulphurized, and desiliconized.

The various substances used in my process may be coarsely pulverized and intimately mixed in a moistened state by means of a pug or other suitable mill, the substances being then molded, preferably under considerable pressure, into suitable shapes or forms, as hereinafter set forth. The compression should be such as to largely express the moisture and solidify the masses, so that they may be at once charged into a reducing-furnace, and in the course of two hours, under a suitable heat, may be rolled together into balls of suitable size and withdrawn and forged or rolled into blooms or bars of malleable iron.

A further discovery practically proved is that the shape of the molded mass must be such as to allow the heat to rapidly penetrate it, not requiring it to penetrate more than about from one to two inches from the outer surfaces. While, with care and sufficient time, a mass having four or more inches from the outer to the inner surface may be reduced, yet it is at the cost of such increased time and fuel as to defeat the commercial economy of the process.

It is essential that the furnace operation should be finished as rapidly as possible and with the least amount of waste of metal, so as to guarantee a remunerative output for the investment of plant, fuel, and labor, and this output is largely dependent upon the shape of the molded masses. A series of furnace operations with various molded shapes has proved the best form to be tubular cylindrical masses, which I prefer to set on end throughout the furnace, spaced sufficiently apart for a free circulation of heat. These tubular masses should have holes or openings from their outer to their inner walls, so as to secure a free circulation of heat both without and within them. The tubular masses are advantageously formed by machinery similar to that employed in the manufacture of ordinary drain-pipes.

I have tried various molded shapes. They may be made cubes, hexagons, octagons, or rectangular; but none of these give the same extent of surface for the action of the heat as the tubular form herein described, and hence will not produce an equal output of metal in the same given time. I do not limit my invention in these molded shapes to the forms above described; but any hollow shape will answer that possesses the ability to resist breakage by handling, that will firmly stand on end in the furnace, and that will present the greatest superficial surface for the action of heat. The size of these tubular masses is also governed by the facility of handling them into the furnace. I find sixteen to eighteen inches high, an outside diameter of seven to eight inches, and cored two to two and one-half inches to be convenient dimensions for readily sliding into the furnace on a "peel." If higher, they are not quite so easily charged, unless made thicker, and then they are not so rapidly penetrated with heat and reduced, and so extend the length and cost of the furnace operation.

Molding into shapes of the dimensions above given enables me to give large area of surfaces for heat absorption and generation. The effect of this is the moment the highly-heated furnace is charged with the molded material properly placed the gases generated by the action of the heat upon them are quickly inflamed from all the surfaces. These gases envelop the outer surfaces of the molded mixtures and protect them from furnace oxidation, so that the heat may be rapidly increased from the outset of the operation without decreasing yield, and thus bring the system to a practical working economy by reducing the furnace operation to approximately two hours' duration.

Heretofore it has usually taken from three to six hours to reduce metallic ore by analogous processes, which means commercial unprofitable cost of fuel and labor. By my process I consume only two hours, and I effect this economy by pushing the heat high at the start for, say, an hour and a quarter. Then I slack it, because the masses are saturated with heat and the gases begin to act, the oxygen from the ore combining with the carbon and passing off as carbonic oxide. High heat is then not required to complete the reduction.

I am aware that previous to my invention ores have been mingled with carbon and other substances, and subjected to the action of heat in reverberatory furnaces for the purpose of reducing them from their oxides, as well as to free them from earthy impurities. Sometimes the mixtures have been molded into the form of bricks and charged into the furnace, but in such large masses and so arranged as to prevent rapid reduction, and thus to defeat the commercial economy and value of this process.

It is old to mold mixtures of ferruginous and carbonaceous matter in tubular shapes. It is old to put such mixtures into cans, and perforate the cans at their tops when set upright and through their sides when laid horizontally in the furnace, in order to effect a better circulation of the gases of combustion to increase the heat; but, as hereinbefore repeatedly stated, no one prior to my discovery has developed the necessity of reducing such cylinders in a very short period by the initial application of high white heat in order to obtain commercial success.

Ore mixtures have been spread and stirred on the hearths of one or more communicating heated reverberatory furnaces. They have been revolved in heated cylindrical furnaces. In all these different ways the prime object has been to secure a direct and rapid reduction and separation from impurities, so as to withdraw and shingle balls of malleable iron more quickly and with less cost than by its production from pig-iron. While the large molded masses failed to secure economical working, owing to the long period of time required for reduction, the fuel consumed, and the waste of iron from oxidation, the stirring and rotating method has also been objectionable, for the reason that the frequent exposure of partly-deoxidized granules of spongy ore to the surface action of oxidizing furnace-gases causes reoxidation, and consequently large waste of iron to cinder.

I have discovered that the necessity exists of keeping the metal-making material in a perfectly quiescent state during the process of reduction, and on this point I lay great stress, as also on the necessity of so combining the mixtures as to form the liquid non-flowing glass which enters the cavities or cells vacated by the oxygen, and so protects the metal from the oxidizing effects of the flame until the masses are withdrawn and hammered, squeezed, or rolled, when the glass or cinder is rapidly and easily expressed, leaving the metal in a remarkably pure and homogeneous mass, from which it can be immediately rolled. When the mixtures are properly combined the molded material may be subjected to a sufficient heat to secure rapid reduction without disintegration in the furnace during the whole operation.

No one previous to my invention has, to my knowledge, been able to make malleable iron by one direct reduction of the ores of iron and the materials herein named, and to effect such a commercial success in its attainment, as by my process of preparing the iron-producing materials, combined with such proper mixtures as admits of their being rapidly and cheaply compressed in molds of such shapes as will hold the materials compactly together under the action of a reducing heat, and at the same time allow it to penetrate rapidly, not requiring it to travel substantially more than from one to two inches from the inner and outer surfaces, for the purpose of effectively reducing the metal, and yet sealing the particles of newly-made iron against reoxidation, while at the same time the gangue is being utilized (by the combination of the various ingredients) in forming the glassy slag and taking up the impurities which would otherwise enter the iron. A further peculiarity and advantage in charging these small masses of metal-bearing material into the reverberatory or reducing furnace of such described shapes as are readily permeable by heat is that the rapid combustion of the gases formed by the combination of the oxygen of the ore with the carbonaceous matter which is so intimately blended in the mixture serves as a means of quickly creating throughout the entire hearth of the furnace a continuous and powerful but mild heat, the reflection of which from the furnace-roof, added to the heat generated from the furnace-grates or gas-producer, not only causes a very rapid reduction of the metal-making substances to nature, but also effects a great economy of fuel.

It will thus be seen that not only a proper combination of the elementary substances with the ore mixture is necessary, but also their form and the manner of placing these materials in the furnace, as well as the after management of the furnace. All these points are essential to a complete commercial success. It is because these successive links have heretofore remained undiscovered that the working of all previous direct processes has been unprofitable. The quickest reduction, it is well known, is accomplished with pulverized materials, and to this end ore mixtures have been sought to be reduced and balled on the hearths of reverberatory furnaces. Owing, however, to the non-conducting character of all such mixtures an energetic stirring and highly-oxidizing heat is necessary. At such heat the carbon, mingled with the ore to deoxidize it, is largely consumed by the furnace flame without performing its office of reduction; hence the ore is largely wasted to a useless slag, causing a small yield of metal and practically defeating commercial economy.

From time to time lumps or bricks of various pulverized and compressed ore mixtures have been tested in variously-arranged furnaces to overcome the waste found by working it in a loose powder. These have likewise failed, because either the combination of the mixtures, their shape, the manner of placing them in the furnace, or management of the furnace heats, or all of them together, have been defective.

I lay no claim to nice proportions of carbon or fluxes. A chemical analysis will determine both. The last must be simple and cheap, and are therefore of limited range. I deem proper, however, to recapitulate briefly the essential requisites to secure the commercial success of my process.

First. The ore mixture must be so compounded as when molded in the desired shapes shall become firm and solid, so as to withstand the shock of rough handling without disintegration until placed in the furnace.

Second. Its combination must be such to withstand disintegration when charged cold into a highly-heated furnace, and preserve the original shape until the ore is reduced to metal and ready for balling. Unless these shapes are preserved they will not be rapidly penetrated by heat. If they disintegrate and become spread over the hearth, much of the metal will waste and the charge will be slowly worked off, thereby largely increasing the commercial cost.

Third. The surfaces of the molded shapes for heat absorption should be as large as possible. The non-conducting character of such mixtures causes heat to penetrate very slowly more than two to three and one-half inches beyond the surface. It is for this reason I mold the mixture in tube shape, arranged for an inner circulation by openings at the base from their outer to their inner walls, and have them fifteen to eighteen inches high placed within a couple of inches of one another all over the hearth of the furnace. This method of molding and placing them enables the operator to turn out six hundred to seven hundred pounds of iron from ore in an ordinary puddling-furnace every two hours, with very little labor.

Fourth. The mixture must form a non-flowing slag or glass which will be substantially retained where it is created, filling in and sealing the space between the filaments of iron that have been vacated by the oxygen that had been associated. This is a highly important discovery to secure a large yield of iron.

Fifth. The combined ingredients, while performing all the above offices, at the same time will eliminate phosphorus, arsenic, and sulphur. The close affinity of these impurities for iron will be broken by the furnace heat, and they will form new affinities. They will be partly volatilized and pass off in fumes, and partly pass into the newly-formed glass to be expelled by forging.

Sixth. The manner of combining the mixture, placing it in the furnace, and working the furnace heats brings the ore to metal without physical labor. In fact any disturbance of the molded masses during the chemical change is positively injurious, because it exposes particles of metal to reoxidation by the furnace heat. Otherwise they are sealed and protected by the enveloping glassy slag. Hence the commercial economy in labor for a given product of iron is very marked over the old method of manufacturing, by first making pig and then puddling it by excessive labor to wrought iron.

Seventh. The extreme purity of the product by this method of manufacture, being well freed from phosphorus and sulphur, admirably fits it for the manufacture of "open-hearth" and "pot" steel at low commercial cost.

All the above points are accomplished by close attention to this continuous system of working.

From the combining of the materials until the ball is withdrawn from the furnace the whole system is different in its essential features from other direct processes, and these successive steps, as explained, are essential to commercial economy. If any one of them is omitted, the results may not be quite so satisfactory.

Having thus described my invention, I claim—

1. The improvement in the manufacture of iron hereinbefore described, consisting in molding the pulverized iron-making carbonaceous, binding, and fluxing substances into longitudinally-hollow and transversely-perforated cylinders, whereby the greatest surface for the action and circulation of heat is obtained, substantially as and for the purposes specified.

2. The improvement in the manufacture of iron which consists in subjecting molded masses of iron-producing carbonaceous and fluxing materials to the action of a quick but not a cutting heat until liquid glassy slag or cinder be completely formed in the said masses, and then checking the heat, for the purpose of allowing the metal to gradually come to nature largely by the heat-producing character of the substances composing the said masses, metal being thus produced without manipulation or physical labor from the beginning of the furnace operation, as set forth.

3. The improvement in the manufacture of malleable iron, as hereinbefore described, consisting in deoxidizing, dephosphorizing, desulphurizing, and desiliconizing iron-bearing substances and ores, by intimately commingling with them, in a pulverized moist condition, the ingredients, as described, and compressing the mixture into longitudinally-hollow and transversely-perforated shapes, as set forth, and subsequently reducing such shapes in a furnace by the initial application of a high white heat, and then hammering or squeezing and rolling the metal into malleable shapes or bars, as set forth.

4. The method of manufacturing malleable or wrought iron which consists in charging a reverberatory or reducing furnace with metal-bearing carbonaceous mixtures molded into perforated tubular or other hollow shapes adapted to set upright in the furnace, and subjecting them, in such position, to the heat of the furnace, whereby the oxygen of the ore is developed, and, combining with the carbon of the mixture, quickly produces throughout the entire hearth a continuous and powerful but mild heat, which radiates from and circulates among the molds, and is reflected from the roof of the furnace, thereby causing a very rapid reduction of the metal-making substances to nature, and also economizing fuel, substantially as described.

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Witnesses:

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